SUPTM 2026: 3rd Conference on Future Challenges in Sustainable Urban Planning & Territorial Management

Universidad Politécnica de Cartagena
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Proceedings

Digital connectivity and physical mobility for new accessibility to urban services

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Abstract: Ensuring equal access to goods and services is crucial for sustainable development, with accessibility recognized as a fundamental human right. Traditionally linked to physical mobility and spatial proximity, accessibility has evolved with digital technologies. This has led to the concept of Triple Access Planning (TAP), which integrates physical mobility, spatial proximity and digital connectivity to address current transitions (ecological, digital, demographic). This study assesses how the digital transition redefines the accessibility of local communities to essential services, analyzing the relationships between physical accessibility and digital connectivity, taking the Autonomous Region of Sardinia as a case study.

Keywords: physical accessibility; digital connectivity; peripheral areas.

1. Introduction

Accessibility is a fundamental human right, essential to ensure that everyone can use the environment and services, eliminating all types of barriers (physical, digital, sensorial, cognitive). It measures the ease of interaction with specific activities [1]. Traditionally linked to the organization of territory and transport [2; 3; 4], accessibility has been revolutionized by the digitalization of services [5] thanks to the advancement of the web and ICT, informing the concept of Triple Access Planning (TAP) [6], which integrates physical mobility, spatial proximity and digital connectivity. The aim is to address current challenges (ecological, digital, demographic) by enhancing both proximity for active mobility and technological opportunities to reduce the need for physical travel. Several indexes have been proposed in Italy to assess physical accessibility and digital connectivity. ISTAT provides indices on physical accessibility to essential services and transport infrastructures [7; 8], while AGCOM offers indices on digital connectivity, such as the number of families without a wired network and those served by connections at different speeds (from 0 − 2 to 500 − 1000 Mbps) [9].

Accessibility to the digital network is considered a precondition for an inclusive online environment, in line with European and national regulations, the National Recovery and Resilience Plan for Italy and the National Strategy for Internal Areas (SNAI), which proposes policies to face the multiple divide of marginal areas, recognised with reference to several indicators, such as the distance (travel time) from essential services and the level of Digital Divide [10,11].

This study evaluates how digital connectivity is redefining the accessibility of local communities to urban services. The proposed method analyzes the relationships between physical accessibility and digital connectivity through the systematization of the main collected indices and the application of linear regression, developing a correlation matrix to support future sustainable development policies, adopting the Sardinia Region as a case study.

Citation: Mara Ladu, Ginevra Balletto and Laura Corona. Digital connectivity and physical mobility for new accessibility to urban services. *SUPTM 2026 conference proceedings* sciforum-128316. https://doi.org/10.31428/10317/24356

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2. Method

The present study aims to assess whether and how the digital transition is contributing, together with physical mobility, to redefine the accessibility of local communities to essential services, understood as a fundamental parameter to define the level of peripherality of urban centers. The method consists of three main phases: 1) collection and systematization of the most representative indices of physical accessibility to essential services and digital connectivity; 2) their categorization into classes; 3) application of the linear regression technique and development of a correlation matrix.

Phase 1 collects the main indices of physical accessibility to essential services and of digital connectivity. The first is calculated as the average travel time to reach a municipal center equipped with education (high schools or technical/professional institutes), healthcare (DEA hospital of level I) and mobility (Platinum/Gold/Silver railway station). Furthermore, it measures the degree of peripherality of an area, contributing to the Composite Index of Municipal Fragility, where higher values indicate greater territorial fragility [11, 12]. For digital connectivity, the study is based on the AGCOM indices that are normalized on the number of families to indicate the percentages served by different connection speeds (from 0-2 Mbps to 500-1000 Mbps), essential for intensive uses [9].

The categorization of the indices into five classes (Phase 2) is functional to assess their relationship and how connectivity influences overall access to services in the digital age (Table 1). Physical accessibility is classified based on travel time to reach a service hub and ranges from class 1 (0-29 minutes) to class 5 (over 120 minutes), while digital connectivity is based on the connection speed of families and ranges from class 1 (500-1000 Mbps) to class 5 (0-2 Mbps).

Table 1. Categorization into classes of physical accessibility and digital connectivity indices at municipal level.

Physical Accessibility Index	Range	Class
Accessibility index for essential services [minutes] (ISTAT, 2021)	0 – 29	1
	30 – 59	2
	60 – 89	3
	90 – 119	4
	>120	5
Digital Connectivity Index	**Range**	**Class**
Number of families served by fixed network with different speeds: 0 – 2/ 2 – 30/ 30 – 100/ 100 – 500/ 500 – 1000 [Mbps] (AGCOM, 2018)	500 – 1000	1
	100 – 500	2
	30 – 100	3
	2 – 30	4
	0 – 2	5

The statistical technique of linear regression (Phase 3) is functional to understand the relationship between the variables (physical accessibility and digital connectivity). A positive correlation is when both variables increase at the same time. The subsequent correlation matrix shows the joint distribution of physical accessibility and digital connectivity in the case study.

3. Case study: Sardinia region

The Sardinia region, the second largest Mediterranean island and the third in Italy, has a settlement structure that is strongly dependent on major urban centers: 84% of the 377 municipalities have fewer than 5,000 inhabitants. The smaller municipalities, mainly in the internal areas, have a constant decline in population (from 52.3% in 2011 to 36.6% in 2023) and an average age of 47 years, with 25% of inhabitants over 65 years [10]. The remaining 63.4% live in the main urbanized areas [13]. This geographical distribution heavily affects infrastructure and transport services [14; 15]: the region has significant gaps in infrastructure and in the supply of transport services to ensure extra and intra

continuity, which further accentuate the disparities due to the insular condition [8]. As regards accessibility to essential services, urban centers and coastal areas are better served (0-30 minutes), while in central-eastern inland areas times can exceed 120 minutes (Fig. 1a). The digital divide is also significant. In 2018, approximately 50% of Sardinian families had broadband >30 Mbps [16]. Despite high mobile data traffic (12.8 GB/month in 2021, +17.4% compared to the national average), the "digital grey divide" persists, particularly in inner areas and among the elderly population, highlighting a correlation between geographic/demographic marginality and digital divide [17]. The 2018 AGCOM indices and the maps provided by the Department for Digital Transformation (2025) show regional connectivity, including the connectivity of schools and health facilities [18] (Fig. 1b, c).

4. Results and conclusions

The proposed methodology was applied to the case study of the Sardinia region to evaluate the relationship between levels of physical accessibility and digital connectivity in accessing essential services. The following indices were collected: Physical accessibility to essential services [12]; Number of families without stable wired internet connection [9]; Number of families with different connection speeds (0-2 Mbps, 2-30 Mbps, 30-100 Mbps, 100-500 Mbps, 500-1000 Mbps) [9]. The normalization of the digital connectivity indices with respect to the number of households highlighted that the tourist coastal areas show a higher percentage of households without a wired connection, probably due to the prevalent use of mobile connections by tourists and city users. The main urban centers, on the other hand, have a low percentage of excluded households, indicating the presence of better network infrastructure. The physical accessibility and digital connectivity indices were categorized into five classes to apply the linear regression technique and develop the correlation matrix (Fig. 1d).

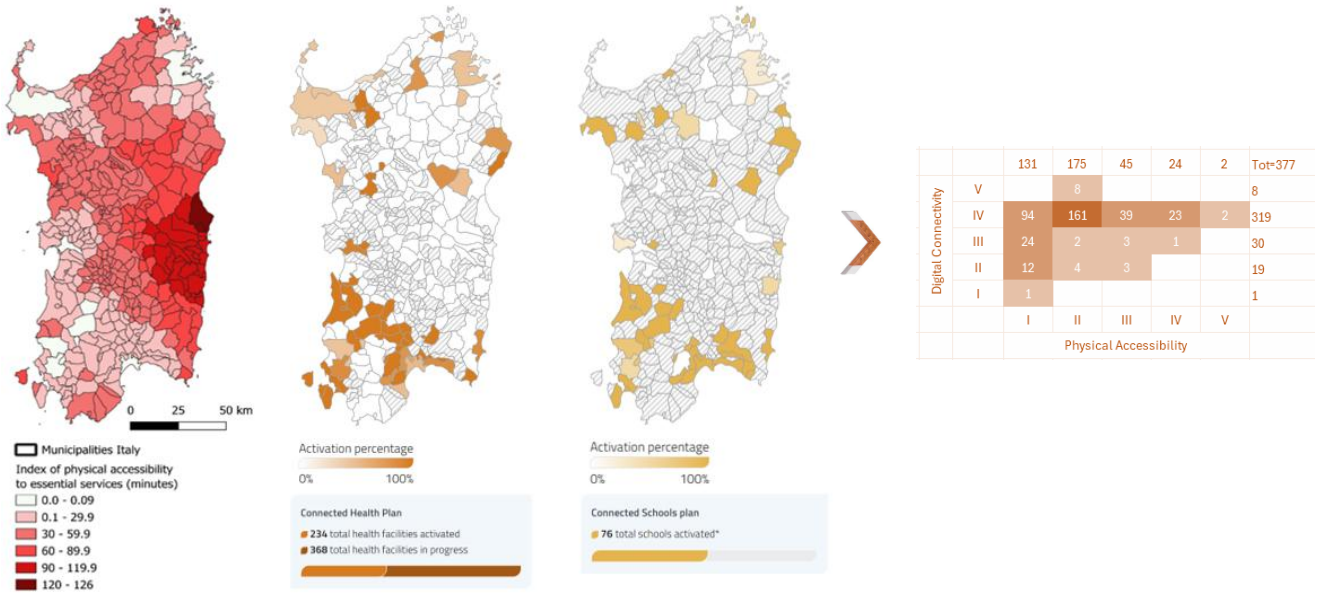

Figure 1. Index of physical accessibility to essential services (a, b, c and d, Data source: [12, 18]) and the results of correlation matrix between physical accessibility and digital connectivity in Sardinian municipalities. Authors' elaboration.

The results reveal a positive correlation between the two variables analyzed on a municipal scale: as physical accessibility increases, digital connectivity also increases. The matrix allows us to appreciate how the combination between level IV of digital connectivity (connection speed of 100 − 500 Mbps) and level II of physical accessibility (30 − 60 min.) is the one within which most of the municipalities fall (161). Furthermore,

municipalities with poor physical accessibility (classes IV and V), often attributable to orographic or infrastructural factors, do not have a level of digital connectivity that can overcome this limitation, further accentuating phenomena of marginalization and vulnerability. The best digital connectivity (class I: 100 − 500 Mbps; class II: 500 − 1000 Mbps) is found in municipalities with high levels of physical accessibility, coinciding with the urban centers of the Island that represent hubs of essential services.

In conclusion, the study highlights the need to jointly consider physical accessibility and digital connectivity to assess accessibility to essential services, a key factor in determining the levels of local and regional peripherality and fragility. The results suggest that the adoption of an integrated approach to urban planning, which considers physical accessibility and digital connectivity as correlated and not independent variables, favors territorial cohesion. The methodology is useful to guide future public policies at national and regional level, as it is replicable in other similar contexts.

Funding: This research was funded by the Ecosystem of Innovation for Next Generation Sardinia(e.INS) and received funding from the European Union Next-GenerationEU (PIANO NAZIONALE DI RIPRESA E RESILIENZA (PNRR) –MISSIONE 4 COMPONENTE 2, INVESTIMENTO 1.5 –ECS00000038).
Conflicts of Interest: The authors declare no conflict of interest.

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