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NEW CHALLENGES FOR XXI CENTURY CITIES

Multilevel scientific approach to impacts of global warming on urban areas, energy transition, optimisation of land use and emergency scenario

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TeMA Journal was established with the primary objective of fostering and strengthening the integration between urban transformation studies and those focused on mobility governance, in all their aspects, with a view to environmental sustainability. The three issues of the 2025 volume of TeMA Journal propose articles that deal with the effects of Global warming, reduction of energy consumption, immigration flows, optimization of land use, analysis and evaluation of civil protection plans in areas especially vulnerable to natural disasters and multilevel governance approach to adaptation.

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The cover image shows a composition of two photos of the Temple of Serapis in Pozzuoli (Italy). Giuseppe Mazzeo took them in January 2009 and March 2025. At the top, the 2009 image shows the temple flooded, with the pavement not visible. In the down, the 2025 image shows the temple’s pavement dry and exposed. The Temple of Serapis is one of the leading visual indicators of the bradyseism phenomenon in the Phlegraean Fields. The bradyseism phase, highlighted by comparison, started in the first years of this century, as shown by the data published by the National Institute of Geophysics and Volcanology (INGV) on the website dedicated to the phenomena (https://www.ov.ingv.it/index.php/il-bradisismo).

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TeMA Journal was established with the primary objective of fostering and strengthening the integration between urban transformation studies and those focused on mobility governance in all their aspects, with a view to environmental sustainability. In other words, the mission of this initiative is to contribute to developing a novel theoretical and methodological framework that transcends the boundaries separating these research domains and develops innovative solutions for issues currently being addressed with methods and techniques rooted in the scientific culture of the last century.

The three issues of the 2025 volume of TeMA Journal propose articles that deal with the effects of Global warming, reduction of energy consumption, immigration flows, optimization of land use, analysis and evaluation of civil protection plans in areas especially vulnerable to natural disasters and multilevel governance approach to adaptation.

In this issue, the section "Focus" contains three researches.

The first paper, titled "Situating walkability examining walkability elements of recurring routes" by Jani Tartia (Tampere University in Finland), highlights that the walkability elements can act as important anchoring points in the study of the body-environment relations in the context of the habitual everyday urban mobility. The importance of 'imageability' and 'complexity' elements is discussed, as well as the role of temporality and 'rhythm' in the walking experience.

The second contribution is "Definition of spatio-temporal levels of accessibility. Isochronous analysis of regional transport networks", by Annunziata Palermo, Gaetano Tucci, and Lucia Chieffallo (University of Calabria in Italy) analyses analytically the levels of accessibility of individual administrative units to the main transport networks. To this end, a semi-automated method in GIS environment for the definition of municipal levels of space-time accessibility is proposed based on an isochronic analysis conducted on access nodes to major transport, motorway and rail networks, at the territorial scale.

The last contribution of the section is "The impact of transportation planning on agricultural areas and plant health: a case study of Antalya/Konyaaltı West Ring Road" by Engin Kepenek, Engin Kepenek, and Şerife Betül Çetinkaya (Akdeniz University in Turkey). This research analyzes the West Ring Road in the Konyaaltı district (Antalya), where a similar situation is experienced, and the surrounding agricultural areas. It is claimed that the agricultural lands around the West Ring Road have lost their agricultural quality.

The section "LUME" (Land Use, Mobility and Environment) contains three articles.

The first contribution is "Campi Flegrei and the Metropolitan Area of Naples. Emergency" by Giuseppe Mazzeo (Pegaso University in Italy). This study analyzes and evaluate the emergency planning tool developed for the Red Zone of Campi Flegrei. To achieve this result, a comparative methodology is used. This approach is based on the analysis of various national and international sources, from which the main elements that

should be included in an emergency plan are extracted. These general elements are then compared with the contents of the emergency plan for the Campi Flegrei.
The second contribution is "Revitalising abandoned historical districts. Application of an incremental and adaptive approach to regeneration" by Diksha Dody, Daniele Ronsivalle, and Maurizio Carta (University of Palermo in Italy). The article addresses the challenge of balancing heritage conservation with contemporary urban innovation. Previous approaches have often overlooked the need for integrated strategies. This study applies the Cityforming Protocol, an incremental methodology that reconnects urban infrastructures (blue, green, grey, brown, and red systems) to restore urban metabolism.
The third article, "Mobilising equity. Emerging evidence for integrating vulnerable communities" by Irina di Ruocco (University of Insubria in Italy), throughs a literature review, analyses emerging research evidence on transportation for vulnerable groups, emphasizing the need to integrate technological solutions for individuals with reduced mobility into digital mobility platforms and land-use planning. The study highlights the lack of focus on rural regions and diverse vulnerable groups, stressing the importance of better integrating technology and land-use planning to improve transportation accessibility.
The fourth article of the section, "Multilevel governance approach to adaptation. The construction of the Italian mid-Adriatic green infrastructure", by Timothy Daniel Brownlee, Rosalba D'Onofrio, and Chiara Camaioni (University of Camerino in Italy), aims to investigate the enabling factors and obstacles of a multilevel approach in adaptation governance in the Life+A_GreeNet project territory and possible public and private strategies to be deployed to overcome the criticalities of possible integration and to enhance the potential of network governance at the territorial and urban scale, with possible forms of replicability in other Italian and European contexts.
The Review Notes section proposes five insights on the themes of the TeMA Journal. The Urban planning practice section of Review Notes, "Urban energy transition between regulatory evolution and scientific production: a bibliometric analysis", by Valerio Martinelli, explores how scientific research on urban energy transition has evolved alongside European climate policies. It highlights the role of urban governance and planning in supporting decarbonisation through tools like Positive Energy Districts and Renewable Energy Communities. These models integrate innovation with citizen engagement and local energy autonomy. The second section, "Digitalization in urban planning: a framework to realize smart cities", by Annunziata D'Amico, illustrates the key strategies and main programs implemented by the European Union and other International Organizations to promote the digital transformation of cities to make them "smart" and sustainable. The third contribution, "Competitive climate adaptation. Italian startups leading the way to adaptation to climate change in cities", by Stella Pennino, examines the role of climate-oriented startups in fostering urban adaptation and competitiveness, outlining their strategic potential and discussing key Italian case studies. The fourth section, "Exploring open and green space characteristics for climate change adaptation: a focus on the urban heat island", by Tonia Stiuso, provides an in-depth analysis of emerging issues in urban planning, mobility and the environment. This issue aims to explore how different characteristics of open and green spaces contribute to climate adaptation. By examining recent books, journals and reports, the aim is to shed light on effective approaches and innovative strategies to deal with heat islands (UHI). The last section, "Global warming reports: a critical overview of IGOs publications", by Laura Ascione, aims to examine reports produced by International Governmental Organizations (IGOs), analyzing their approach, findings, and potential limitations.

Reference

Ascione, L. (2025). Global warming reports: a critical overview of IGOs publications. *TeMA - Journal of Land Use, Mobility and Environment*, *18*(1), 169–175. https://doi.org/10.6093/1970-9870/11630

D'Amico, A. (2025). Digitalization in urban planning: a framework to realize smart cities. *TeMA - Journal of Land Use, Mobility and Environment*, *18* (1), 143–150. https://doi.org/10.6093/1970-9870/11626

D'Onofrio, R., Brownlee, T.D., Camaioni, C., Cecchi, J., Cocci Grifoni, R., Malavolta, S. & Marchesani, G.E. (2025). Multilevel governance approach to adaptation. The construction of the Italian mid-Adriatic green infrastructure. *TeMA - Journal of Land Use, Mobility and Environment*, *18* (1), 113-130, http://dx.doi.org/10.6092/1970-9870/11157

Di Ruocco, I. (2025). Mobilising equity. Emerging evidence for integrating vulnerable communities. *TeMA - Journal of Land Use, Mobility and Environment*, *18* (1), 95-111. http://dx.doi.org/10.6093/1970-9870/10872

Dody, D., Ronsivalle, D. & Carta, M. (2025). Revitalising abandoned historical districts. Application of an incremental and adaptive approach to regeneration. *TeMA - Journal of Land Use, Mobility and Environment*, *18* (1), 75-94. http://dx.doi.org/10.6093/1970-9870/11114

Kepenek, E., Aksoy, E. & Çetinkaya, Ş. B. (2025). The impact of transportation planning on agricultural areas and plant health: a case study of Antalya/Konyaaltı West Ring Road. *TeMA - Journal of Land Use, Mobility and Environment*, *18* (1), 39-54. http://dx.doi.org/10.6093/1970-9870/11174

Martinelli, V. (2025). Urban energy transition between regulatory evolution and scientific production: a bibliometric analysis. *TeMA - Journal of Land Use, Mobility and Environment*, *18* (1), 131–141. https://doi.org/10.6093/1970-9870/11625

Mazzeo, G. (2024). Campi Flegrei and the Metropolitan Area of Naples. Emergency planning in a high-risk territory. *TeMA - Journal of Land Use, Mobility and Environment*, *18* (1), 55-73. http://dx.doi.org/10.6093/1970-9870/11228

Mohamed Thariq, M. G., & Mohamed Mujithaba Mohamed, N. (2024). Environmental factors affecting living comfort perception in different localities in Sri Lanka. *TeMA - Journal of Land Use, Mobility and Environment*, *17* (3), 473–486. https://doi.org/10.6093/1970-9870/10865

Palermo, A., Tucci, G. & Chieffallo, L. (2025). Definition of spatio-temporal levels of accessibility. Isochronous analysis of regional transport networks. *TeMA - Journal of Land Use, Mobility and Environment*, *18* (1), 23-38. http://dx.doi.org/10.6093/1970-9870/11146

Papa, R. (2024). NEW CHALLENGES FOR XXI CENTURY CITIES Global warming, ageing of population, reduction of energy consumption, immigration flows, optimization of land use, technological innovation 3. *TeMA - Journal of Land Use, Mobility and Environment*, *17* (3), 393–396. https://doi.org/10.6093/1970-9870/11292

Pennino, S. (2025). Competitive climate adaptation. Italian startups leading the way to climate change adaptation in cities. *TeMA - Journal of Land Use, Mobility and Environment*, *18* (1), 151–159. https://doi.org/10.6093/1970-9870/11654

Stiuso, T. (2025). Exploring open and green space characteristics for climate change adaptation: a focus on the urban heat island. *TeMA - Journal of Land Use, Mobility and Environment*, *18* (1), 161–167. https://doi.org/10.6093/1970-9870/11636

Tartia, J. (2025). Situating walkability: examining walkability elements on recurring routes. *TeMA - Journal of Land Use, Mobility and Environment*, *18* (1), 7-22. http://dx.doi.org/10.6093/1970-9870/10999

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Situating walkability: examining walkability elements on recurring routes

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Abstract
Walking is widely regarded as a ubiquitous, affordable, healthy and zero-carbon mobility mode that enhances the liveliness and inclusivity of urban spaces. In recent years, the concept of 'walkability' has emerged as a central criterion for assessing the sustainability and liveability of cities. Walkability elements and metrics are often employed to map urban environments, evaluating their capacity to facilitate or hinder walking from the perspective of experts and professionals. However, how do these metrics relate to the situated subjective walker-street relations, contexts and experiences? This study employs ethnographic mobile research methods to examine the connections between walkability elements of the physical built environment and the everyday walking experiences on recurring day-to-day routes in two mid-sized cities in Finland. Utilizing walkability metrics related to visual urban design elements from research literature, the study explores the role of the elements in shaping the walking experience in the context of regularly travelled routes and the subjective body-environment relations. The study highlights that the walkability elements can act as important anchoring points in the study of the body-environment relations in the context of the habitual everyday urban mobility. The importance of 'imageability' and 'complexity' elements is discussed, as well as the role of temporality and 'rhythm' in the walking experience.

Keywords
Mobility; Walkability; Body-environment relations; Urban space; Urban temporality.

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1. Introduction

No city can solve its transportation problem if it neglects the greatest self-propelling vehicle of all: the pedestrian. (Mumford, 1964: 119). The American sociologist Lewis Mumford wrote about the neglected role of the pedestrian over sixty years ago. Walking has only in the past two decades started to regain attention in urban development discourse as a mobility mode to be taken 'seriously,' after almost a century of car-oriented city planning and urban mobility system development (Urry, 2007; Speck, 2012; Middleton, 2018). City planners are increasingly recognizing the importance of walking for the creation of healthy city districts and neighbourhoods (Boyce, 2010; Adkins et al., 2012) and liveable and attractive public spaces (e.g. Cervero et al., 2017; Balcetis et al., 2020). As cities face the urgent need to transition to sustainable transportation systems to reduce local greenhouse gas emissions and meet carbon-neutrality targets, walking has emerged as a key component in this development discourse as a zero-carbon and equitable urban mobility mode. For instance, cities such as Vancouver (City of Vancouver, 2012) and London (Greater London Authority, 2018) have elevated walking to the top of their transportation hierarchies, prioritizing it in the design and revision of traffic and zoning plans. The concept of the '15-Minute City' (Moreno et al., 2021), which has been a central conceptual approach to urban development in the wake of the recent COVID-19 pandemic, similarly prioritizes walking as a mobility mode, and challenges excessive private car dependency and mono-functional urban land use practices that have propelled urban sprawl in the past (e.g., Cargnin et al., 2024). The pandemic also gave the development of walking conditions a general boost, as cities placed new emphasis to public spaces, local green areas, and their accessibility on foot (Paydar & Fard, 2021). However, walkable urban infrastructure, in many cases, remains unevenly distributed between different populations and locations (Patton, 2007).

In this paper, I explore the role of recurring walking routes and subjective body-environment relations in the analysis of urban walkability. The term *walkability* generally refers to the level and quality of walking conditions provided by the built environment, including factors such as the quality of infrastructure, access to services within a reasonable walking distance, the integrity of the pedestrian network, and the 'human-scale' of urban spaces. There is not just one, but multiple practical-theoretical approaches to walkability (Forsyth, 2015), each with its own set of elements, metrics, and units of analysis, ranging from policy measures to spatial design elements (Ewing & Handy, 2009; Speck, 2012; Adkins et al., 2012; Dovey & Pafka, 2020; Roper et al., 2023). Walkability is often approached from the (objective) expert's – the researcher's, the planner's, the architect's – perspective through the measurement and quantification of physical elements for comparisons and the setting of target values (Forsyth, 2015; Shashank & Schuurman, 2019). However, there has been less emphasis on the experiential and embodied dimensions of walkability (also Fancello et al., 2020), and this paper aims to further contribute to that emergent theoretical and practice-oriented discussion.

To explore the interconnections between walking experience and walkability elements, I approach the topic by focusing on the recurring body-environment relations that emerge on repeated walking routes. There is a growing body of research on mobility, which underlines the experienced and embodied nature of mobilities (Sheller & Urry, 2006; Middleton, 2011; Jensen, 2013). Here, I utilize predefined walkability elements from existing research literature and ask: What role does the recurring and situated embodied context of a 'walking route' play in defining the walkability of a space? I explore how the different walkability elements, which focus on the quantities and qualities of the physical space, can be used to provide practical anchors for studying the experienced and embodied aspects of urban spaces. The study's research data is composed of participant-produced photographs and related route narratives from urban walking routes in two major cities in Finland, collected originally for a doctoral dissertation (Tartia, 2020). The dissertation focused on the temporal body-environment relations and rhythms in street spaces, and towards the end of the dissertation process, the aspect of walkability was also highlighted as a prospective analytical approach, warranting a focused look at the topic here.

The structure of the paper is as follows: First, I present the key walkability metrics, and the overall theoretical framework, that was used in the exploration of the situated walker-street relationships. The methods and data are presented in more detail next. Then, the analysis of the research data through the selected walkability metrics is presented, followed by a discussion highlighting the key insights gained. The conclusion follows at the end.

2. Walking and walkability

Walking is a complex phenomenon that can be understood from multiple perspectives. It can be approached as a mode of physical transportation (Cappe, 1987; Tekolla et al., 2024), a place-making practice (Gehl, 1971), a mode of social interaction (Middleton, 2011; 2018), a mode of dwelling (Thoreau, 1862; Ingold, 2004), a form of physical travel linked to health and well-being (Adkins et al., 2012), or even as a political act (de Certeau, 1990; Lorimer, 2011; Coverley, 2022; Beaumont, 2024), among others. Nearly all human movements and modes of mobility involve walking in some form (Urry, 2007: 63-64). As a result, all spaces in the city – whether private or public, indoor or outdoor – must address walking and its facilitation in some manner, either explicitly or implicitly. Improving walking conditions, therefore, involves tackling a multifaceted issue that encompasses policy and legislation issues, social and cultural dynamics, and the physical transformation of the built environment, as well as changes in practices and mobility cultures (Urry, 2007; Cresswell, 2010).

In recent years, walking has become almost synonymous with desirable built environment quality in urban planning and design literature (Forsyth, 2015; Cervero et al., 2017; Dovey & Pafka, 2020; Fonseca et al., 2022; D'Amico, 2024). Walking has been highlighted for its health benefits and place-making qualities of attractive and lively public spaces (Forsyth, 2015). Walking has been targeted in many contemporary urban development plans, either in district-level development of the 'walking grid' or in the general 'betterment' of a public space, especially related to the sustainable urban development frameworks (Banister, 2008). Many contemporary (positive) urban future visions are based on walkable and green and close-community-based districts and neighbourhoods – in contrast to visions of the early and mid-20th century that often focus on the facilitation of private car use (Dunn & Cunerton, 2020: 48). Currently, walking possibilities are, however, unevenly distributed between cities and different areas within cities (see Aparicio et al., 2024; Patton, 2007), and the history of automobile-focused planning paradigms – that have dominated urban planning and development processes for most of the 20th century (Böhm et al., 2006) – have generally had a negative impact on walking as a mobility mode.

From a research perspective, walking can be approached from multiple methodological perspectives (Türken & Conticelli, 2024). The theoretical background of walkability metrics can be traced partially to the influential work of Lynch (1960) on the perceived city image and 'imageability', Jacobs (1961) on the 'sidewalk ballets', Cullen (1961) on the 'serial vision' of space experienced in motion, Gehl (1971) on the nurturing of 'life between buildings', and Appleyard (1981) on the 'liveable street ecology', among others. Their works all emphasize, in different ways, the experienced aspects of the urban environment and the relations between the walking body and the environment. Forsyth (2015) identifies various uses of the term 'walkability' by academics and practitioners: walkability is used to describe either the 'means' (e.g., physical accessibility, safety, and compactness of urban spaces) or the 'outcomes' (health benefits and exercise, sustainable transportation, liveliness of urban space), or it can be used to convey meanings related to a 'better' urban environment in general.

Different walkability metrics have emerged to map and score factors that enable or hinder walking. Southworth (2005) explores criteria for a pedestrian network, including its connectivity, linkages with other mobility modes, and safety. Speck (2012) approaches walkability as a policy and planning issue, which can be distilled into practical planning and design rules, including setting limits for private car use and developing mixed-use districts. Roper et al. (2023) explore walkability as a metric for access, considering both spatial and temporal

factors facilitated by the street grid. Similarly, Dovey and Pafka (2020) explore walkability through metrics such as city-level and district-level density, mix of uses, and access. Adkins et al. (2012) present an audit tool for walkable and green streets. The walkability elements have also been coded into different digital tools, such as the WalkScore website (WalkScore, 2023). Ewing and Handy (2009) approach walkability through visually perceivable urban design elements that affect the walking experience, which is utilized as the main reference of this study.

2.1 Walkability as visual urban design elements

In this paper, walkability is approached through visually perceivable urban design elements, following the work of Ewing and Handy (2009) (also Ewing & Clemente, 2013). They identify fifty-one 'perceptual qualities' from urban design and planning literature that contribute to the level of walkability of the built environment. They argue that these perceptual qualities are shared and identifiable elements of the space, which can be assessed by an objective observer, as they hold relevance in the walkability of the environment regardless of the ultimately *subjective* experience of walking (Ibid.). They highlight five key qualities of the environment, which their studies show to be most significant and relevant to walkability based on various case studies: 'imageability', 'enclosure', 'human scale', 'transparency', and 'complexity'.

Imageability refers to 'the quality of a place that makes it distinct, recognizable and memorable'. This includes landmarks and other specific recognizable and memorable signs that give perceivable identity to the place. *Enclosure* elements are 'visual termination points' that define and delineate a space, separating it from its surroundings. *Human scale* 'refers to a size, texture, and articulation of physical elements that match the size and proportions of humans and, equally important, correspond to the speed at which humans walk'. *Transparency* 'refers to the degree to which people can see or perceive what lies beyond the edge of a street and, more specifically, the degree to which people can see or perceive human activity beyond the edge of a street'. *Complexity* 'refers to the visual richness of a place. The complexity of a place depends on the variety of the physical environment, specifically the numbers and types of buildings, architectural diversity and ornamentation, landscape elements, street furniture, signage and human activity' (Ewing & Handy, 2009: 71-81; Ewing & Clemente, 2013).

In this paper, these five perceptual qualities of the environment form the focus for exploring the relations between situated subjective experiences, recurring walking routes, and the built environment. In the next section, an empirical study is presented that makes use of participant-produced photographs and mobile interviews from recurring daily walking routes to examine the role of the recurring and situated body-environment relations in the context of walkability. It should, however, be noted that the elements examined below - related to the built environment quality and its uses – can only be considered relevant once the basic requirements of the walking practice are met, including considerations of distance, accessibility, and physical ability, among others (Adkins et al., 2012).

3. Data and methods

The research data consists of in-depth qualitative interviews and participant-produced visual material documenting ten (10) recurring walking routes in urban areas. These routes represent the day-to-day walking routes of ten different individuals in their home cities of Tampere and Turku, Finland – cities which are located in the second and third largest urban areas by population in the country, after the capital Helsinki metropolitan region, each with approximately 200,000 inhabitants. The data were collected for a doctoral dissertation that examined the various urban rhythms that contribute to the (re)making of urban space (Tartia, 2020).

The research employed ethnographic mobile methods, including 'go-along' walking interviews (Kusenbach, 2003) and collaborative visual methods (Pink, 2007; Foster et al., 2023), namely photo-elicitation (Harper, 2002), where participants took photographs during the walking interviews of the issues discussed, and these

photographs were later discussed in a more traditional sedentary interview (Tartia, 2020). Walking interviews, in general, are versatile in style and can be used in both researcher-driven settings – where the area of interest is predefined by the researcher – and in participant-driven research settings – where the focus is on the subject's interests, everyday environments, and specific locations of personal significance (Evans & Jones, 2011). The former approach is often employed in walking environment studies and participatory urban development processes, such as 'planning walks' or other citizen engagement activities in zoning and urban planning (Raisio & Ehström, 2017). In this study, the participant-driven approach was adopted.

The goal of the empirical study was to join individuals in their daily travel and gain an understanding of their urban experiences and embodied interactions with the built environment, all within the context of the recurring route. The focus on the route context here entails three specific aspects: (1) a route is a path travelled repeatedly, often with a certain frequency (e.g., daily, weekly); (2) a route is a succession of spaces, connected by the specific context of 'the movement from place A to place B'; and (3) a route is more or less fixed in both spatial and temporal terms. Recurring walking routes ground us in our surroundings, and the route itself can be conceptualized as a specific (recurring) 'mobile place' (Jiron, 2010; Tartia, 2020). This view echoes Jacobs' (1961) observations on the urban neighbourhood feel, where frequent interactions with the built environment generate a deep understanding of its spatial and temporal dynamics, and the emerging 'sidewalk ballets'.

In this study, ten in-depth mobile interviews were conducted on location. The walking routes studied here are regularly used in the participants' everyday lives, and they are all (partially) located within the urban centres of Tampere and Turku, Finland. The participants were recruited through social media and email lists of local grassroots organizations. The criteria for the selection of the participants were kept quite open to reach people with different kinds of socio-economic backgrounds. The selection was based on two main things: the participant had a recurring walking route in one of the studied cities' centres, and the person was over 18 years of age. The studied walks were typical urban routes within the city centre, such as trips between home and the office, grocery store, or university. The participants, aged 26-73, included eight women and two men. The occupations of the participants were diverse, ranging from a university teacher to a worker in the public sector, and some of the participants were retired or unemployed. The routes varied in duration and length - ranging from about 1 to nearly 4 kilometres. The routes were primarily walked for convenience due to their relatively short distances (in most cases), though participants occasionally travelled by car, by bicycle, or by public transportation the similar types of trips due to hurry, bad weather, or other practical reasons.

The 'go-along' walking interviews were conducted to engage in a three-way dialogue between the participant, the interviewer, and the environment (Jokinen et al., 2010). The participants were given a task to draw a mental map of their route, and they were given a camera for the duration of the walk and asked, and encouraged during the walk, to take photographs of the things they were talking about, and also things that describe their route and their travel experience but were not discussed during the walk. A follow-up thematic interview (Aronson, 1995) focusing on the produced visual material was conducted after the walk.

The photographs, produced by the participants during the walking interview, are used here as the main source for the walkability analysis as they provide direct, practical anchoring points for the body-environment relations. As smartphones and cameras are nowadays found in almost every pocket, photographing has become a ubiquitous and mundane part of daily life (Foster et al., 2023). The photos were examined through the participant's own narration, which provided context for the photo, including the intended point of interest of the photograph, possible temporal relevance ("this always happens", "this has never been here before"), and whether the subjective experience was seen as positive, neutral or negative. Whereas in previous analyses of the same research data, a more interview-driven approach has been adopted focusing on the content analyse of the interviews (supported by the participant-produced photographs and mental maps) and focusing on the holistic experience of walking (Tartia, 2020), here the analysis was geared towards the photographs, examining them through the walkability metrics framework. Each photo was assigned one or more of the

previously identified visual design elements based on the thematic analysis of the interviews describing the photographs (see Tab.1). An example of this is provided below (quote translations from Finnish into English by the author):

Then we are at the train station [#imageability: neutral connotation]*, we've just passed the tunnel through* [#linkages: neutral]*. There's only three people in this photo but around four or five in the afternoon there are lots of commuters* [#complexity: neutral, with temporal relevance]*, it looks interesting when people masses come in those kind of pulses, and then they stop here at the traffic lights to wait, so it is, like some kind of a heart or an organ that pumps people into the traffic* [#imageability: positive, with temporal relevance]*. There's also this nice brick facade* [#human scale: positive] (Interviewee #9, Fig.2A).

As Tab.1 shows, the elements are closely related, and the boundaries between different elements are difficult to define strictly as they often overlap with one another. The elements should therefore not be treated as fully separate aspects of the urban experience, but strongly interconnected aspects emphasising slightly different sections of the built environment.

This exploration also highlighted the importance of three additional elements to the five previously mentioned: 'linkages', 'territoriality', and 'rhythm'. *Linkages* refer to the physical and visual links between different spaces acting as thresholds (Stevens, 2007), signalling continuation between two or more distinguishable spaces (Ewing & Clemente, 2013: 20). *Territoriality* refers to the visual signs and embodied practices of appropriation, such as street graffiti, or embodied practices challenging the space's uses and general narrative (such as through play and playfulness) (Rapoport, 1982: 152-153; Kärrholm, 2007; Stevens, 2007). *Rhythm* refers to the visual or physical signs of temporal patterns (Lynch, 1972: 70-77), and to the temporal changes in who occupies the space and how it is appropriated (Kärrholm, 2007; Tartia, 2020). In the next section, the visual research material and the different elements are examined.

Visual design element	**Assessed attributes in the photographs**
Imageability	Physical elements that capture attention
	Perceived identity of the place
Enclosure	Vertical surfaces defining the space
Human scale	Building details
	Pavement textures
	Trees and bushes
	Street furniture
Transparency	Perceivable human activity beyond the edge of the street
	Described human activity beyond the edge of the street
	Transparent vertical surfaces, openings to small spaces
Complexity	Visual richness
	High number and variation of type of buildings
	Architectural diversity
	Landscape elements
	Human activity
Linkages	Physical elements signalling route continuation

Territoriality	Physical signs that create the feeling of belonging to oneself
	Physical signs of appropriation of space
	Perceivable human activity and appropriation of space through different uses
Rhythm	Time-sensitivity of the depicted scene

Tab.1 Visual design elements and attributes related to walkability

4. Examining walkability in the context of a recurring route

In this section, the analysis of the photographs from the walking routes is presented through the visual design elements related to walkability. In the analysis, I examine how the different walkability metrics from previous research literature are represented in subjective and situated walking experiences on recurring urban walking routes.

In Fig.1, the share (%) of photographs related to the elements (based on the attributes presented in Table 1) is depicted to show how often the specific elements appear in the research data. The Fig.1A depicts the general frequency of the elements in the research material based on the process of combining the analysis of the participants' route narrations (interviews) with the pre-existing design elements, as described in the previous research literature.

The analysis also shows that the different elements are closely linked to one another: it was possible to assign two or more elements for half of the photos based on the narrations (1 element=51%, 2=27%, 3=16%, 4=5%, 5 elements or more=1%).

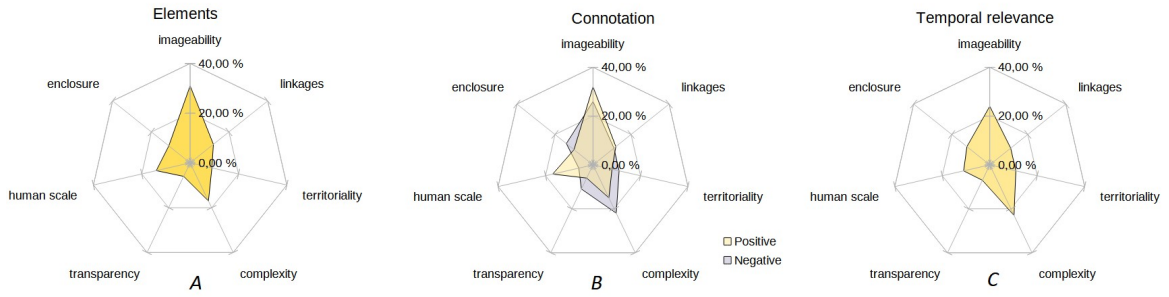

Fig.1 The share of the photographs relevant to different visual design elements

The elements of 'imageability' and 'complexity' were the most frequent elements identified in the participant-produced photos. The Fig.1B shows the share of positive/neutral and negative connotations of the elements identified in the photos, as the photographs were taken by the participants to show both positive/neutral and negative aspects of the environment and the general walking experience.

Around one-fourth of the photos presented negatively perceived elements of the environment, which, based on the participants' own narrations, mostly related to the lack of something desired – such as the lack of a perceivable identity of a place or urban life – or there being 'too much' of something, such as difficult to pass crosswalks due to heavy motor traffic.

The Fig.1C presents the level of time-sensitiveness of the pictures: around two-thirds (63%) of the photographs were time-sensitive, meaning that the passing of time and changes – *rhythm* – in the activities of the space on a daily, weekly or seasonal level were critical for the described (by the participant) environmental experience (whether positive/neutral or negative).

The different elements are examined next in more detail with quotes from the participants and examples of the examined photographs (Fig.2).

Fig.2 Participant-produced photographs A-P

4.1 Imageability

Imageability is a recurring element in the data: around one-third (31%) of the photos depicted aspects related to imageability. Positive imageability relates to the perceived identity and character of a specific place, its pleasing or 'eye-catching' environmental aesthetics, or the general enjoyable atmosphere of the environment: *Here's everything I like in this route. There are those birds [plastic material bird-shaped art installations] in the river (laughter), which are nice. Then there are those old buildings on the other side [of the river], I like them because they have those pastel colors. Then you can see the [name] bridge there, it's really, I like it a lot, sometimes I go that way [the other side of the river, across the bridge] even though it is kind a more inconvenient route for me* (Informant #8; Fig.2B).

The aspects related to imageability were often time-sensitive. The research participants described the effects of the time of the day on the perceived identity and the specific characteristics of the space that make it 'that' space. This temporal element was mostly related to different human uses of the space, which were inseparably linked to the space's perceived character and atmosphere:

[…] there's the [name] department store, it is really like an old landmark in the city, everyone knows it and goes there, for their own business. Now since it is a rainy day, it is a bit quiet here [the city's main market square], but especially on Saturday mornings the market is always full and there's a lot of vendors here […] Informant #3, Fig.2C).

Likewise, the negative remarks on imageability were aspects related to the absence of these identifying characteristics, including perceived lack of character or 'anything special'. Such in-between spaces do not raise attention or have distinguishable characteristics. These also may have been lost due to redevelopment of a specific area, such as the construction of highways and new development sites (Fig.2D).

4.2 Complexity

The presence or absence of human activity, and the perceived liveliness of the environment – in the form of different spatial uses, social groups, and social interactions - were key attributes related to *complexity* in the data. Most (89%) of both positive and negative aspects related to complexity were also time-sensitive:

- *[…] the people of this area have, in a way, claimed this place [a small park next to the river] to as their own, but that, all this liveliness and vividness is mostly due to the fact that the [name of a university] buildings are right over there you should just come and see here the buzz and chatter you hear on a summer day* (Informant #4, Fig.2E);
- *[…] now in this photo there is no police car or ambulance, but it is really a recurring sight around that [a large street-side bench made of a stone slab]. It always varies who is causing the disturbance, that whether it's the younger people or the older people or what, but this is a bit chaotic place* (Informant #9, Fig.2F).

As expected, complexity was more prominent in squares, market areas, major pedestrian streets, and other pedestrian-friendly places on the route, which are connected by more corridor-like spaces between with less perceived complexity (and imageability, see above). Some notes on architectural, aesthetic, and visual complexity were also highlighted (Fig.2G). The absence of human activity, and the related perceived 'emptiness' of the space, was one of the key negative aspects related to the topic of complexity, especially in areas that are focused on motor-traffic optimization and an emphasis on car use (Fig.2H).

4.3 Human scale

In the data, attributes related to human scale included small physical and visual landscape features, street furniture, urban art (Fig.2N), pavement textures, and green spaces (see Fig.2I). The small details of the built environment were also often highlighted in the street scenes:

Well, this is, like, beautiful, this gate, this fence and the gate. […] These kind of things are the highlights of any street, and I don't think that all things that are old should be preserved, not at all, but it's sad that we can't, in a way, afford to make these kinds of craftmanship or other works anymore, so that those that still are left, even if it is a small gate, it should be preserved so that it shows this diversity and expressiveness (Informant #4, Fig.2J).

In some cases, the lack of such features was noted, particularly in relation to specific places where the informants regarded there being potential to add these kinds of features to improve the space. It should be noted that human scale elements are closely linked with the imageability and complexity elements, each representing a slightly different perspective on the same issue of places with distinguishable character. The analysis of the data highlights the two other elements more than the human scale, which is more about the finer details – textures, fixtures, and others – of the space, which are part of the larger in/tangible characteristics of the space (imageability) and the social liveliness of the space (complexity).

4.4 Enclosure

Enclosure refers to the physical or visual boundaries that define a space. From a positive perspective, the creation of clearly defined spaces, or distinct physical and/or visual barriers between motor-traffic and pedestrians through street-side fixtures (Fig.2K), was noted in the route narrations. This also creates boundaries for how the environment is perceived, which can direct the attention towards the different 'human scale' elements (or the lack of them) in the experience of the space.

However, the enclosure of the space can also evoke negative feelings and anxieties, particularly at night or in narrow passages or other similar places with limited visibility ('transparency'):

[…] this is maybe a bit darker section, or shadowy section of the walk […] there are those hollow spaces [under the balconies of an apartment building] […] it's not nice to walk past these, you always get this feeling that someone might be lurking there […] (Informant #5, Fig.2L).

4.5 Linkages

Elements related to linkages connect different places along the route together, and they also signal transitions between different distinct places as well as different route contexts (Fig.2B). In the data, these elements included crosswalks, intersections, street corners, and 'gate-like' thresholds - both tangible and physical, and intangible and imaginary - that separate different distinguishable places or neighbourhoods.

These linkage elements can also act as points of friction along the route, such as specific crosswalks where the speed and priority of different mobility modes (e.g., pedestrians, cyclists, motor vehicles) have to be negotiated every time through the movements and the emerging choreographies of the different bodies in motion (Figure 2M).

4.6 Territoriality

Elements of territoriality in the data included different signs of spatial appropriation by different people and groups. These were mostly related to the physical presence of people, and to what kind of activities they were engaged in (Fig.2F). The user groups and their uses were notably perceived as varying depending on the time of day and season:

[…] [talking about a small kiosk building] this is kind of a meeting place in the neighbourhood, especially for men, this terrace is often full of different groups of men that talk loudly and who seem to comment on everyone who passes by and so on. (Informant #3, Fig.20).

Additionally, these appropriations of the space also took more implicit and less direct forms, such as street art, graffiti, and street-side advertising stands, which all mark the space through various visual signs and physical materialities:

I took a photo of that cat [a cat-shaped graffiti on a concrete wall], this is the kind of street art that we usually try to look for [while walking] with the kids (Informant #8, Fig.2N).

4.7 Transparency

The least relevant visual design element in the data was transparency (6%). Notably, most of the transparency-related elements were negative in connotation, often related to the lack of transparency and obscured visual aspects of the space, such as windowless ground floors of street-side buildings (Fig.2H and 2L). There were also a few positive aspects of transparency highlighted, such as window shopping as a form of passing by certain buildings and stores (Fig.2P), but overall, transparency did not play a significant role in the participants' narrated experiences.

5. Discussion

The analysis has explored how the different walkability elements, identified in research literature, relate to the subjective and situated walking experience on recurring routes. The analysis has highlighted both the rich variation of different aspects related to specific built environment qualities in the subjective route narrations as well as their broader, collective patterns. Here, we focus shortly on three elements, which appeared frequently in the data – imageability, complexity, and rhythm – to discuss their potential to inform urban planning and development processes to enhance the walkability of urban environments. In the context of developing sustainable and walkable cities, increased imageability and complexity, as attractive and distinct public spaces, and mixed-use urban areas, respectively, are often desired planning and design outcomes, as

they can support the utilization walking as a mobility mode and lower carbon dioxide emissions, and to increase possibilities for social interaction and participation (Gehl, 1971; Cervero et al., 2017).

While these walkability elements emerge frequently in the data, it is important to recognise that the research setting, the chosen analytical methods, and the cultural practices related to visualizing the urban environment (as photographs depicting the route) (Harper, 2002), among others, all influence the results. Furthermore, it is important to note that the research setting particularly focuses on the aspects of the urban environment which *were* photographed by the participants – the data cannot provide insight on why something was *not* photographed, and what kinds of visual urban design elements remain not visualised between the shots along the route. In the next section, further below, we continue to assess the used methods.

Imageability, the memorability and distinctiveness of the space, is, as Ewing & Clemente (2013: 6) note, a sort of a 'net effect' of multiple different elements, and its appearance in the narrated walking experiences was therefore also anticipated. In the data, imageability is both subjective (e.g., personal focus, points of interest) and collective (e.g., distinctive landscapes, historical spaces), and both tangible (e.g., specific urban forms, unique details, also related to 'human scale' elements) and intangible (e.g., personal memories, experiences of past interactions and happenings). While imageability certainly refers to visual markers like 'landmarks', as identified by Lynch (1960), it also encompasses the more subjective and less tangible meanings of the space, as suggested by the data. For example, the linkage elements, which also appeared in the data frequently, are closely connected with imageability, and affect the walking experience by signalling context-dependent cues of the route progression for the body-environment relations, or the transfer from identifiable 'place' to another, which might not be evident for the outside observer (Ewing & Clemente, 2013: 21-22).

Similarly, complexity of the urban environment is multifaceted. Complexity can mean both purely visual and physical form as well as human presence related aspects. In the recurring walking experience, though, complexity seems to be related more often to the perceivable human activity and less to the visual richness or architectural diversity of the space. From a planning perspective, multi-use and mixed-use areas, create the conditions for complexity to emerge. Designing for complexity can also be seen as designing for 'connectivity' (Southworth, 2005), which can support the increase of walking as a mobility mode beyond a specific public space. But at the same time, depending on the embodied and situated context of movement, this complexity can, however, be positive or negative: complexity can be a driving force for an attractive urban space – lively and busy, people attracting other people (Ewing & Clemente, 2013; Gehl, 1971) – which awakes interest also in the context of the routine walking route, as evident in the data, and at the same time the same space can seemingly be overrun by different mobilities, practices, and uses of the space, creating undesired friction and sensory overload (Ibid.). Creating complexity through planning and policy means a balancing act between these two opposites.

Furthermore, the route narratives in this study highlight the temporal dimension of the body-environment relations in terms of the walking experience, or the element of rhythm. The relations change and oscillate corresponding to the various the daily/weekly/yearly rhythms of the space, which are affected by different patterns of uses of the space, such as the opening times of shops and services, the intensities of the people flows (daily peaks/lows, events), and the various appropriations of the street space by different people groups (Kärrholm, 2007; Werner et al., 2018, Lynch, 1972). Here, especially the cyclical patterns of everyday activity are highlighted in the walking experience. These various recurring patterns, related to the space and its perceived users and uses – which make the space familiar, 'known' and one's 'own' (Jacobs, 1961) – often intertwine with other temporalities, including the more linear processes of urban (re)development (construction, decay, demolition). This temporal dynamism of urban space is difficult to translate into direct planning and development tools, practices, or policies (Tonkiss, 2013) - as it is closely linked to different larger time regimes and cultural perceptions of time that cross-cut everyday lives in complex ways (Fernandes et al., 2015) – but the results of this study, however, highlight their importance in the everyday walking experience,

and, thus, should be paid increasing attention in urban development for more walkable urban environments. Here, for example, the connections between the space and its regulation (Kärrholm, 2007) can be identified as one mechanism to promote different uses of the space by different groups and individuals.

The conglomerations of multiple subjective and shared layers of the elements, as evident in the research data, are hard to directly or explicitly (re)create through planning and design practices. The three elements – imageability, complexity, and rhythm – have also been juxtaposed recently in unprecedented ways during the COVID-19 pandemic. Intentional decrease of complexity, and separation of different rhythms through social distancing measures, were some of the ways in which the 'usually' favourable and explicitly promoted elements of proximity and social interaction were turned on their heads, albeit at the same time also other kinds of measures to increase walking and cycling infrastructure were made. It remains to be seen, how much the pandemic era contradiction between personal well-being and public urban life influences the planning paradigms of the near future, and how the different novel concepts that formed as reactions to the pandemic, are integrated, such as the 15-minute-city (Cargnin et al., 2024), and how they come to influence walkability.

5.1 Notes on the method

In the light of this study, the framework of the visual design elements related to walkability is a useful tool to approach the walking experience and recurring situated body-environment relations. The focus on the subjective and situated route narrations can benefit from the vocabulary and categorisation of the physical space through the walkability elements, which can help 'anchor' the subjective experiences to physical, shared typologies of space related to walkability.

Additionally, the utilization of the elements in a subjective and a situated context driven research setting can further expand the view on walkability elements by shifting the focus to three specific issues. First, it highlights the plurality and heterogeneity of the relationships between the bodies and the environment. The elements that are at the forefront of the subjective and situated experience on the recurring walking route might differ from the elements that an expert planner or designer would place emphasis on, based on an objective examination of the space. Second, some of the key elements affecting urban walking experience are created on the grassroots level and in a bottom-up fashion through human activity and appropriation of the built environment. The routine interactions and encounters with the space and its users on the recurring route are essential to the walking experience – the physical space provides the physical setting for these interactions and encounters to play out. And third, the different temporal dimensions of walkability, such as the effects of the time of day or seasons, play an important role in the body-environment relations, and they are highlighted in the subjective narrations of the walking experience.

These insights on what makes urban spaces walkable from an experiential and situated perspective, can support the re-orientation of urban planning and design practices to increase walking in the context of climate change mitigation (Tekolla et al., 2024). However, the study is based on data from only ten in-depth interviews. This means that no definitive conclusions should be made on the individual elements of the walkability framework in general – rather, the analysis here provides an in-depth look at the different ways in which the framework on the visual design elements related to walkability can further enhance the analysis of the subjective and situated route narratives and participant-produced visual research material. As Türken and Conticelli (2024: 93) note, different research methods and technologies provide 'different capacities' in understanding walkability. The research could be further expanded with more participants to draw more definitive conclusions, or more focused attention on a specific element could be made to have a more rigorous understanding of the role of that element in the everyday urban walking experience.

6. Conclusion

This paper has explored the utilization of the framework of the visual urban design elements related to walkability in the context of subjective and situated walking experiences on recurring walking routes. The walkability elements provide 'anchors' for analysing the subjective research material, gathered from mobile interviews and participatory processes utilizing visual methods, providing a shared typology of elements of the urban environment for analysis, including imageability and complexity, which were often represented in the studied data.

The focus on the subjective perspective also highlighted the dynamic and time-sensitive nature of the walking experience, and how the recurring interactions between the body and the environment make the route spaces 'known' both spatially and temporally.

The research data utilized in the study are small in sample size. Further studies utilizing a similar methodological setting could increase the validity of the results presented here, and, perhaps, could also reveal more variety in the different experiences related to specific walkability elements. The results of the study could also be further connected with other types of research materials – including objective assessments of the environment – to validate the results and to draw an even more detailed picture of the interrelations between the walkability metrics and the subjective walking experience. Further studies on the matter could also expand the scope of the study by examining how the walking spaces come to be, and what kind of relations (top-down, down-top) impact their making and remaking.

However, the results of the study can help to expand the view of walking metrics and their dynamism and context-dependency.

The insights from this study can support the utilization of walkability elements as tools for practical planning and policymaking towards walkable urban environments by providing experiential insight into how the 'walkable' urban environment is encountered and interacted with in the real-life context of recurring walking routes. The increase in walking-enabling and walking-encouraging public spaces and street networks is increasingly critical for climate mitigation in the urban context.

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Conflict of interest

There are no conflicts of interest to declare.

References

Adkins, A., Dill, J., Luhr, G. & Neal, M. (2012). Unpacking Walkability: Testing the Influence of Urban Design Features on Perceptions of Walking Environment Attractiveness. *Journal of Urban Design*, *17* (4), 499-510. https://doi.org/10.1080/13574809.2012.706365

Aparicio, J. T., Arsenio, E., Santos, F. C. & Henriques, R. (2024). Walkability defined neighborhoods for sustainable cities. *Cities*, *149*, http://dx.doi.org/10.1016/j.cities.2024.104944

Appleyard, D. (1981). Livable Streets. University of California Press.

Aronson, J. (1995). A Pragmatic View of Thematic Analysis. *The Qualitative Report*, *2* (1), 1-3. http://dx.doi.org/10.46743/2160-3715/1995.2069

Banister, D. (2008). The sustainable mobility paradigm. *Transport Policy*, *15* (2), 73-80. https://doi.org/10.1016/j.tranpol.2007.10.005

Beaumont, M. (2024). *How We Walk: Frantz Fanon and the Politics of the Body.* Verso.

Boyce, C. (2010). Walkability, Social Inclusion and Social Isolation and Street Redesign. *Built Environment*, *36* (4), 461-473. https://doi.org/10.2148/benv.36.4.461

Böhm, S., Jones, C., Land, C. & Paterson, M. (2006). Introduction: Impossibilities of automobility. In S. Böhm, C. Jones, C. Land & M. Paterson (Eds.), *Against Automobility*. Blackwell.

Cappe, L. (1987). Including Transit. In A. V. Moudon (Ed.), *Public streets for public use*. Van Nostrand.

Cargnin, M. J., Marino, C. de C. & Silva, T. L. da. (2024). The 15-minute cities concept applied to a Brazilian neighborhood: case study of the cidade universitária Pedra Branca neighborhood in Palhoça-SC. *TeMA - Journal of Land Use, Mobility and Environment*, *17* (2), 189-191. https://doi.org/10.6093/1970-9870/10314

de Certeau, M. (1990). Arkipäivän kekseliäisyys 1: Tekemisen tavat (T. Kilpeläinen, Trans.). Niin&näin. (Original work published 1980)

Cervero, R., Guerra, E. & Al, S. (2017). *Beyond Mobility: Planning Cities for People and Places*. Island Press.

City of Vancouver. (2012). *Transportation 2040*. City of Vancouver.

Coverley, M. (2022). *The Art of Wandering: The Writer as Walker*. Oldcastle.

Cresswell, T. (2010). Towards a politics of mobility. *Environment and Planning D: Society and Space*, *28* (1), 17-31. https://doi.org/10.1068/d11407

Cullen, G. (1961). *Townscape*. The Architectural Press.

D'Amico, A. (2024). Examples of good experiences for child-friendly cities. Comparison of sustainable practices in Italy and around the world. *TeMA - Journal of Land Use, Mobility and Environment*, *17* (2), 143-155. https://doi.org/10.6093/1970-9870/10886

Dovey, K. & Pafka, E. (2020). What is Walkability? The urban DMA. *Urban Studies*, *57* (1), 93-108. https://doi.org/10.1177/0042098018820937

Dunn, N. & Cureton, P. (2020). *Future Cities: A Visual Guide*. Bloomsbury.

Evans, J. & Jones, P. (2011). The walking interview: Methodology, mobility and place. *Applied Geography*, *31* (2), 849-858. https://doi.org/10.1016/j.apgeog.2010.09.005

Ewing, R. & Handy, S. (2009). Measuring the Unmeasurable: Urban Design Qualities Related to Walkability. *Journal of Urban Design*, *14* (1), 65-84. https://doi.org/10.1080/13574800802451155

Ewing, R. H. & Clemente, O. (2013). *Measuring Urban Design: Metrics for Livable Places*. Island Press.

Fancello, G., Congiu, T. & Tsoukiàs, A. (2020). Mapping walkability. A Subjective value theory approach. *Socio-Economic Planning Sciences*, *72*. https://doi.org/10.1016/j.seps.2020.100923

Fernandes, J., Chamusca, P., Gasnier, A., Kärrholm, M. & Pujol, C. (2015). Time policies, urban policies and planning. *Geografia e Ordenamento do Território*, *7*, 129-157. https://doi.org/10.17127/got/2015.7.129-157

Fonseca, F., Ribeiro, P. J., Conticelli, E., Jabbari, M., Papageorgiou, G., Tondelli, S. & Ramos, R. A. R. (2022). Built environment attributes and their influence on walkability. International Journal of Sustainable Transportation, 16 (7), 660-679. https://doi.org/10.1080/15568318.2021.1914793

Forsyth, A. (2015). What is a Walkable Place? The Walkability Debate in Urban Design. *Urban Design International*, *20* (4), 274-292. https://doi.org/10.1057/udi.2015.22

Foster, K. A., Davis, B. & Foell, A. (2023). Innovations to Photovoice: Using Smartphones & Social Media. *Urban Affairs Review*, *59* (5), 1728-1744. https://doi.org/10.1177/10780874221100263

Gehl, J. (1971). *Life Between Buildings: Using Public Space* (J. Koch, Trans.). Island Press. (Original work published 1971)

Greater London Authority. (2018). *Mayor's Transport Strategy*. Greater London Authority.

Harper, D. (2002). Talking about pictures: a case for photo elicitation. *Visual Studies*, *17* (1), 13-26. https://doi.org/10.1080/14725860220137345

Ingold, T. (2004). Culture on the Ground. The World Perceived Through the Feet. *Journal of Material Culture*, *9* (3), 315-340. https://doi.org/10.1177/1359183504046896

Jacobs, J. (1961). *The Death and Life of Great American Cities*. Modern Library. (Original work published 1961)

Jensen, O. B. (2013). *Staging Mobilities*. Routledge.

Jiron, P. (2010). Repetition and Difference: Rhythms and Mobile Place-making in Santiago de Chile. In T. Edensor (Ed.), *Geographies of Rhythm: Nature, Place, Mobilities and Bodies*. Ashgate.

Jokinen, A., Asikainen, E. & Mäkinen, K. (2010). Kävelyhaastattelu tapaustutkimuksen menetelmänä. *Sosiologia*, *41* (3), 286-296.

Kärrholm, M. (2007). The Materiality of Territorial Production: A Conceptual Discussion of Territoriality, Materiality, and the Everyday Life of Public Spaces. *Space and Culture*, *10* (4), 437-453. https://doi.org/10.1177/1206331207304356

Kusenbach, M. (2003). Street phenomenology. The go-along as ethnographic research tool. *Ethnography*, *4* (3), 455-485. https://doi.org/10.1177/146613810343007

Lorimer, H. (2011). Walking: New Forms and Spaces for Studies of Pedestrianism. In T. Cresswell & P. Merriman (Eds.), *Geographies of Mobilities: Practices, Spaces, Subjects*. Ashgate.

Lynch, K. (1960). *The Image of the City*. MIT Press.

Lynch, K. (1972). *What Time Is This Place?*. MIT Press.

Middleton, J. (2011). 'I'm on Autopilot, I Just Follow the Route': Exploring the Habits, Routines, and Decision-Making Practices of Everyday Urban Mobilities. *Environment and Planning A*, *43* (12), 2857-2877. https://doi.org/10.1068/a43600

Middleton, J. (2018). The socialities of everyday urban walking and the 'right to the city'. *Urban Studies*, *55* (2), 296-315. https://doi.org/10.1177/0042098016649325

Moreno, C., Allam, Z., Chabaud, D., Gall, C. & Pratlong, F. (2021). Introducing the "15-Minute City": Sustainability, Resilience and Place Identity in Future Post-Pandemic Cities. *Smart Cities*, *4* (1), 93-111. https://doi.org/10.3390/smartcities4010006

Mumford, L. (1964). *The Highway and the City*. Harcourt, Brace & World.

Patton, J.W. (2007). A pedestrian world: competing rationalities and the calculation of transportation change. *Environment and Planning A, 39* (4), 928-944.

Paydar, M. & Fard, A.K. (2021). The Hierarchy of Walking Needs and the COVID-19 Pandemic. *International Journal of Environmental Research and Public Health (MDPI), 18*. http://dx.doi.org/10.3390/ijerph18147461

Pink, S. (2007). *Doing visual ethnography: images, media and representation in research.* London: Sage.

Raisio, H. & Ehström, P. (2017). Taking Deliberation to the Streets: Reflections on Deliberative Walks. *Scandinavian Journal of Public Administration*, *21* (4), 27-51.

Rapoport, A. (1982). *The Meaning of the Built Environment : A Nonverbal Communication Approach.* London: Sage.

Roper, J., Ng, M. & Pettit, C. (2023). Incorporating diminishing returns of opportunities in access: Development of an open-source walkability index based on multi-activity accessibility. *The Journal of Transport and Land Use, 16* (1), 361-387

Shashank, A. & Schuurman, N. (2019). Unpacking walkability indices and their inherent assumptions. *Health & Place, 55*, 145-154. http://dx.doi.org/10.1016/j.healthplace.2018.12.005

Sheller, M. & Urry, J. (2006). The new mobilities paradigm. *Environment and Planning A, 38* (2), 207-226.

Southworth, M. (2005). Designing the Walkable City. *Journal of Urban Planning and Development*, *131* (4), 246-257. https://doi.org/10.1061/(ASCE)0733-9488(2005)131:4(246)

Speck, J. (2012). *Walkable City: How Downtown Can Save America One Step at a Time.* New York: Farrar, Straus and Giroux.

Stevens, Q. (2007). *The Ludic City: Exploring the potential of public spaces*. Routledge. https://doi.org/10.4324/9780203961803

Tartia, J. (2020). *The Temporality and Rhythmicity of Lived Street Space* (Doctoral dissertation, Tampere University). Retrieved from https://urn.fi/URN:ISBN:978-952-03-1387-6

Tekolla, A. W., Tarekegn, A. G. & Tulu, G. S. (2024). Measuring the walkability of areas around Addis Ababa LRT stations by integrating Analytic Hierarchal Process (AHP) and GIS. *TeMA - Journal of Land Use, Mobility and Environment*, *17* (3), 423-438. https://doi.org/10.6093/1970-9870/11025

Thoreau, H. D. (1862). Kävelystä (A. Immonen, Trans.). Basam Books. (Original work published 1862)

Tonkiss, F. (2013). *Cities by Design: The Social Life of Urban Forms*. Polity Press. https://doi.org/10.51347/jum.v19i1.4861

Türken, A. Ö. & Conticelli, E. (2024). Role of new technologies on pedestrian walking behaviour research. *TeMA - Journal of Land Use, Mobility and Environment*, *17* (3), 83-96. https://doi.org/10.6093/1970-9870/10929

Urry, J. (2007). *Mobilities.* Polity Press.

WalkScore. (2023). Walk Score. Website. Retrivred form: https://www.walkscore.com/

Werner, C. M., Brown, B. B., Stump, T., Tribby, C. P., Jensen, W., Miller, H. J., Strebel, A. & Messina, A. (2018). Street use and design: daily rhythms on four streets that differ in rated walkability. *Journal of Urban Design*, *23* (4), 603-619. https://doi.org/10.1080/13574808.2018.1503085

Image Sources

Fig.1: The share of the photographs relevant to different visual design elements. Source: Authors.

Fig.2: Participant-produced photographs A-P. Source: participants.

Author's profile

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Definition of spatio-temporal levels of accessibility. Isochronous analysis of regional transport networks

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Abstract
Accessibility to transport networks affects the ability of citizens to carry out necessary activities in their daily lives. In particular, in small and medium-sized centres where only some essential services retain a proximity attribute, we are seeing an increasing number of daily travels, the distances travelled and the time taken by local citizens for primary (work, health, education, etc.) and secondary (leisure, etc.) mobility needs. In polycentric and widespread territorial contexts, such as those typically Italian, accessibility is therefore synonymous with spatial equity.
In this disciplinary debate, the present research aims to analyse analytically the levels of accessibility of individual administrative units to the main transport networks. To this end, a semi-automated method in GIS environment for the definition of municipal levels of space-time accessibility is proposed based on an isochronic analysis conducted on access nodes to major transport, motorway and rail networks, at the territorial scale. The paper also presents the results obtained from the method application in the Calabrian regional context useful to support the adoption of a planning approach oriented towards territorial integration between mobility needs and the programming of the network of services that typically characterizes the urban planning discipline.

Keywords
Accessibility; Isochronous analysis; Spatial equity.

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1. Introduction

The issue of accessibility to transport networks is significantly influences planning policies at all levels, from the suburban to metropolitan and regional one (Cargnin et al., 2024; Chen et al., 2024; Costa & Delponte, 2024; D'Amico, 2024; Di Ruocco, 2022; Erçetin, 2024; Stiuso, 2024). It has a particularly important role in relation to small and medium-sized centres with predominantly rural vocation, where carrying out all the activities necessary for everyday life moving outside the administrative boundaries is difficult for citizens. In particular, those living in such contexts, also widely marked by a thinning of local services, are forced to an increasing number of daily travels.

Similar reflections encouraged urban and territorial planners to study the effects of accessibility on urban quality of life and social inclusion/exclusion dynamics (Allen & Farber, 2020; Altay & Şenay, 2023; Cascetta et al., 2020; Handy, 2020; Jian et al., 2020; Vitale Brovarone & Cotella, 2020a; Mouratidis, 2021; Wang et al., 2021; Alberti & Marzi, 2022; Pucci et al., 2022). These effects arise not only from primary mobility needs, linked to so-called essential services (education, health, work, etc.), but also from secondary needs, no less important, related to the leisure and recreation of people (Borlini & Memo, 2009). In line with the statement by Allen & Farber (2020), recognising that transport planning has historically focused on increasing mobility offers, alleviating congestion and reducing environmental impacts, too often it has not been considered whether the choices made actually promote widespread and equitable participation in a wide range of day-to-day activities. In fact, in polycentric and widespread territorial contexts, such as those typically Italian, accessibility is synonymous with spatial equity (Canu, 2016).

In the light of these premises, the focus of the paper is not on the presence or location of specific services, but on the connection between places and services useful for meeting daily needs. Therefore, the fundamental elements placed at the centre of the subsequent analysis processes are the possible "routes" of connection, which underlie the relative flows of people that connect places and services. In this respect, Vilhelmson (1999) defined two categories of trips, depending on their degree of temporal and spatial flexibility, which fit well with the anticipated primary and secondary mobility needs. In particular, "fixed" trips are those intended to reach activities where both time and geographical location are fixed and hardly modifiable (for example, relating to travel to school or work). The "non-fixed" trips are those which are flexible in time and destination, typical of leisure activities.

These considerations have been the starting point for the authors' research, which proposes an analytical analysis of the levels of accessibility to the main regional transport networks of the individual administrative units in the Calabrian regional context. In particular, through a semi-automated methodology in GIS environment, the study aims at defining the above-mentioned levels of space-based accessibility time based on an isochronic analysis carried out at the main regional transport network access points, namely motorway and railway.

To this end, the paper proposes preliminary experimental results obtained for the Calabrian context that push towards the adoption of a planning approach oriented to territorial integration between mobility needs and the programming of the network of services that typically characterizes the urban discipline.

Given the content introduced, the paper is structured as follows. Section 2 presents a brief overview of the state-of-the-art in accessibility to non-infrastructural "major" areas, with particular attention to the main methods of analysis based on the construction of isochronic lines for the assessment of accessibility levels. Section 3 presents the semi-automated methodological framework in GIS environment. Specifically, the steps indicated include mapping transport network nodes, distinguishing between motorways and railways; building isochronic lines from each node considering journey times of 15, 30, 45 and 60 minutes by car; the allocation of a level of accessibility for each transport type to each administrative unit. Finally, Section 4 critically examines the experimental results obtained by applying the methodology in order to draw useful conclusions for the experimental context and generalizable for other reference contexts.

2. State of the art summary on the research topic

The issue of accessibility to "major" infrastructure nodes is a crucial topic in spatial planning with specific reference to the transport sector. The current state of the art shows a growing focus on multimodal integration and efficient connectivity, aimed at ensuring smooth and rapid access to strategic infrastructures. Recent studies have shown that accessibility to these nodes significantly affects economic development (Lin et al., 2024) and quality of life of surrounding areas, helping to reduce regional disparities and improve social inclusion (Melzi, 2011). In this respect, the literature highlights how motorway and railway nodes play a major role for sustainable rural development that can enhance the territory (Fazio et al., 2023; Zheng et al., 2024). In particular, the recent study by Huang et al. (2024) has highlighted how motorway and railway accessibility affect urban-rural income inequality and their resulting spatial heterogeneity, affirming that only through the promotion of an integrated system of transport networks can the level of urban-rural fragmentation be reduced.

In this context, advanced spatial analysis technologies such as GIS and network models are increasingly being used to assess accessibility conditions and design targeted interventions (Massaro & Rotondo, 2020). Many studies (Gkiotsalitis & Cats, 2021; Hillel et al., 2021; Pamucar et al., 2021) propose specific methodologies which can, for example, help to design new routes but also optimise the stopping points of different modes of transport, and to estimate the impact of changes in the transit network or urban planning. All these improvement measures promote sustainable urban mobility by contributing to environmental and social benefits and thus to the quality of life of citizens. (Xu, 2014; Montero-Lamas et al., 2024). The transposition of similar methodologies to the territorial scale, with reference to the estimation of the levels of accessibility of the territories to the main connecting infrastructures, allows an indirect measure of the degree of peripherality of the territory. This result provides a direction for planning activities to be directed, for example, towards the provision of additional specific services in more peripheral contexts or new connecting infrastructures.

Accessibility is also a major focus in European and national policies that emphasize the importance of improving infrastructure links, promoting the construction of new transport lines and improving existing infrastructures (Gargiulo et al., 2022). However, there is a complex relationship between accessibility and sustainable rural development due mainly to the disparity in access to these nodes between urban and rural areas, calling for a more equitable and integrated approach from the political class to ensure that all citizens can benefit from the opportunities offered by major infrastructure hubs (Große, 2024). The consequences of increasingly complex political processes that often hinder the real possibility of implementing the degree of accessibility of a territory are borne by smaller centres, or the marginal and internal areas already suffering from social and territorial fragmentation (Cerasoli, 2024).

In order to propose a methodology for assessing the level of accessibility of individual administrative units, the authors adopted the technique of isochronic analysis that underlies the measure of the spatio-temporal efficiency of the coverage of a service in a given area (Śleszyński et al., 2023). This choice is based on a recognition of the methods of analysis based on the construction of the isochrones already proposed in the literature, with a focus on the purpose of the assessment of the degree of accessibility.

This study showed that in some studies (Lahoorpoor & Levinson, 2020; Zhao & Zhou, 2024) the isochronic technique was used as a tool to define the catchment area of specific services in order to assess their demand. Of particular interest is the application by Yang et al. (2022) that uses this methodology to identify the shortest time possible to reach specific housing structures. The purpose of this study is in line with that of the authors' research, as it concerns the definition of an accessibility zoning model to determine the guiding mechanism and the route for optimising rural accessibility, using a "supply and demand threshold" coupling perspective. Furthermore, in this respect, a further specific application in the literature is related to the verification of the efficiency of public or private transport networks. This approach can identify any gaps to be filled in relation

to specific services, manage traffic flows, plan urban spatial development and improve the degree of accessibility to urban and extra-urban transport (Kurlov et al., 2022).
Specifically, the isochrone lines connect places that can be reached at the same time from the same starting point. For planning purposes, it is necessary to automate the mapping of these elements on the territory using GIS applications that ensure the automation of cartographic workflows, with the objective of analyzing and integrating geospatial information (Lü et al., 2019), after setting specific reference times, called cut-off times (Higgins, 2019). With reference to the computational aspects, the authors found that there is almost no study on the elements that influence the various cut-off times, or the time reference thresholds considered in an isochronic analysis. In this regard, Xi et al. (2018) notes that different cut-off times affect the interpretability of accessibility measures in the isochronic approach and that a cut-off time defined for general use may not exist because of the different factors that may come into play in the reference application fields. On the basis of these considerations, as will also emerge in the discussions, with reference to the proposed methodology, future developments in research provide for the implementation of corrective indices which, taking into account the various risk phenomena present in the territory, refine the isochronic analysis by returning more realistic projections to be used in defining relative potential optimal spatial scopes.

3. Methodological framework

In the current context of increasing attention to the development and revitalization of rural areas, which are mainly made up of small and medium-sized centres, the need to develop effective tools that can assess the real degree of accessibility of these centres, in order also to conduct specific analyses on the usability of services present on the territory by citizens (Merengo, 2023). These considerations have led to the birth and affirmation of the well-known Italian National Strategy for Inner Areas (called SNAI), which represents a national policy to combat depopulation and promote strategic interventions useful to make the internal and marginal areas again competitive in a territorial panorama characterized by polycentrism of large cities (Carrosio & Barca, 2020; Vitale Brovarone & Cotella, 2020b). Nevertheless, the authors believe that some of the theoretical assumptions on which SNAI is based have weaknesses in assessing accessibility, both with regard to identifying services limited to essential ones (education, health and mobility) defined in the framework of the strategy and mapping of the areas of intervention, defined through a preliminary classification of the territory based on the distance of the individual administrative units from the main urban centres, calculated in terms of travel times. Also, in order to fill these gaps, based on the above, this paper proposes the definition and first application of a semi-automated methodological framework in GIS environment, designed to analyse the degree of accessibility of administrative units, in relation to the main regional motorway and railway nodes. This methodology is based on an isochronic analysis from specific infrastructural nodes, conducted considering time ranges of 15, 30, 45 and 60 minutes and car journeys. The isochronic assessment is a crucial process for defining levels of spatial accessibility, as it allows distances from various starting points to be visualised and measured within a specific time range. The isochrons are graphic lines that connect all the reachable points within the same time, offering a clear and easily readable graphical representation. The choice of this technique was guided by studies found in literature, partly mentioned above (e.g. Montero-Lamas et al., 2024; Xi et al., 2018), which agree on the usefulness as an analysis tool to assess and identify areas with poor accessibility to services and infrastructure, as well as planning support for the identification of interventions aimed at reducing territorial inequalities and the consequent improvement of citizens' quality of life.

3.1 Steps of the framework

The methodological framework proposed by the authors is structured in consequential steps, which together aim to ensure a complete and accurate assessment of the level of territorial accessibility.

The first phase consists of data collection and includes the collection and digitisation of relevant geographic and infrastructure information, which is then translated into mapping the territorial context of analysis of major transport network nodes, by distinguishing two types: road nodes considering the intersections of the motorway network; railway nodes considering the stations in the regional territory.

Implemented in a GIS environment, the second phase involves spatial analysis of data by building isochrone lines from each transport node previously mapped. Specifically, we proceed to the construction of 4 isochrones for each node, considering car trips and time ranges of 15, 30, 45 and 60 minutes. For the construction of the isochrones a plugin of the software QGIS called TravelTime was used. It is an advanced tool designed to create lines, called isochrones, connecting points within a given travel time and using different modes of transport. This plugin allows users of the software to evaluate the accessibility and connectivity of territories in a precise and efficient way. The main features of the plugin are:

- A multimodal type support, which allows the construction of isochrones based on different means of transport (car, public transport, bicycle, walking, etc.). This allows for precise, comparative analyses on the accessibility of a given area according to the means of transport used;
- A user-friendly, intuitive interface that facilitates the configuration and generation of isochrones. Users can define the desired travel time parameters and select starting points directly on the QGIS map;
- Integration with external data sets of road and public transport networks, allowing for improved level of analysis accuracy;
- A detailed output, which allows the export in various formats (shapefile, GeoJSON, etc.) of the generated isochrones, allowing further processing and analysis within QGis or other GIS software;
- Advanced analysis, in fact, TravelTime allows to perform insights, such as the calculation of service coverage and the identification of less served areas, supporting urban planning activities and infrastructure management.

The use of the TravelTime plugin in QGIS is a significant research advantage, in order to elaborate detailed analyses on accessibility and mobility within a territorial context, providing powerful and flexible tools to achieve accurate results that are useful for strategic planning.

The product from the first two steps was then overlayed on the raster data for the population census provided by EUROSTAT, with data updated to 2021 that has allowed to derive and systematize different demographic information for each administrative unit and for each isochrone considered.

The fourth step consists of assigning the level of accessibility to individual administrative units, based on the percentage of population served and differentiated for each type of transport, based on the distribution of the population in relation to the isochrones and regardless of the extent of coverage of the territory. This classification is characterised by 10 bands, each with an alternation of 10 percentage points between 0 and 100. The classification of administrative units on the basis of this scale is accompanied by an analytical legend, which facilitates the understanding of the results, namely the following levels:

- Very satisfied, containing the 80-90 and 90-100 bands. This level represents the maximum degree of accessibility by users, it is indicated through a bright and dominant color, which highlights the administrative units with the highest possible rating compared to the parameters analyzed;
- Satisfied, containing the 60-70 and 70-80 bands. This level still represents a high degree of accessibility and although it is below the maximum level, the administrative units falling in this category have a significant degree of accessibility compared to the parameters analysed;
- Neutral, containing the 40-50 and 50-60 bands. Located in the middle of the proposed scale, this level represents a condition of accessibility close to sufficient, and is indicated with a colour gradient that degrades towards lighter tones;
- Dissatisfied, containing the 20-30 and 30-40 bands. This level represents a poor degree of accessibility and is indicated by soft colours tending to white. This category includes administrative units which do

not adequately respond to users' needs and are therefore in a position of functional isolation;

- Very dissatisfied, containing the 0-10 and 10-20 bands. This last level represents the minimum degree of accessibility of an administrative unit and is indicated with a colour almost absent that reaches white at zero percentage. This category includes administrative units with a very low percentage of population covered and therefore in a position of severe and total functional isolation in some cases.

As already mentioned, this classification concerns, at the territorial scale, administrative units, which, in this case, also through the use of GIS tools, has been applied to the Calabrian regional context for which the specifications and unpublished maps depicting the different levels of accessibility will be presented in the next section. This process generally facilitates the identification of areas with greater or lesser difficulty of access, leading to the definition of targeted strategies for improving connectivity and access to services, with the aim of reducing territorial inequalities and promoting a balanced and inclusive development of medium and small-scale centres. Specifically, such applications can provide a sound and objective basis for strategic planning and development policies aimed at reducing territorial disparities and promoting equitable access to resources and services for all citizens.

4. Experimental results

As already mentioned, the field of application of the semi-automated methodology in GIS environment was the entire territorial context of the Calabria Region. This section describes the experimental results obtained in the reference context, which are expressed in the construction of analytical data and quantitative tables synthesized in specific maps. Through the use of GIS tools and the construction of isochrone lines based on the main road and rail transport nodes, it was possible to accurately assess the different degrees of accessibility between the different areas of the Region. The data collected revealed significant disparities in connectivity between communities, highlighting local phenomena of functional isolation as well as contexts that benefit from a good degree of accessibility.

The first operation was the digitisation of the main nodes with reference to the motorway network and the rail network. The result was the identification of 208 knots related to railway stations, divided by service provider company: 61 nodes of Ferrovie della Calabria (FDC) and 147 of Rete Ferroviaria Italiana (RFI) and 31 nodes related to motorway interchanges. As shown in Fig.1, while the distribution of motorway nodes is concentrated on the Tyrrhenian side of Calabria, railway nodes are distributed throughout the regional territory, concentrated along the coastal borders and in the central-northern hinterland.

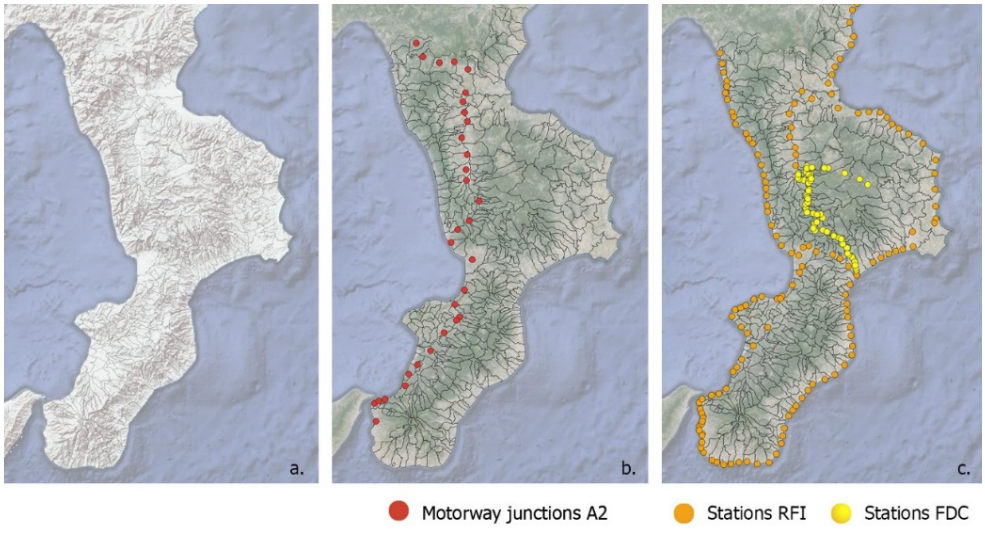

Fig.1 Topographic map of the Calabria Region (a) and digitisation in GIS environment of the main motorway (b) and railway nodes (b) of Ferrovie della Calabria (FDC) and Rete Ferroviaria Italiana (RFI)

Subsequently, through the Travel Time plugin, the isochrone lines relative to each node for each of the two types of nodes considered were built using time ranges of 15, 30, 45 and 60 minutes, choosing as a means of transport the car, and setting as day and time of "departure" on March 18 at 09.00 am.
The isochrones thus elaborated were superimposed with the demographic data on the regional basic cartography. This information was obtained through the vectorization of the raster image updated to 2021 provided by EUROSTAT (Fig.2), also verified with the analogues Istat data which provides, compared to EUROSTAT, additional information on the composition of the population.

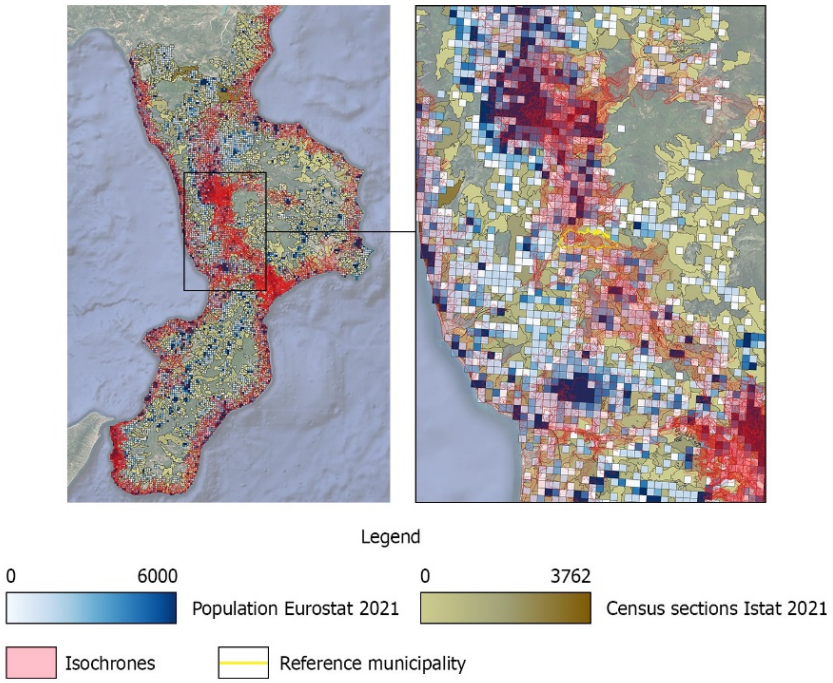

Fig.2 Map of overlap between the isochrone lines and the EUROSTAT and ISTAT population data (2021)

By means of semi-automated processes in GIS environment it was possible to obtain information useful for the assessment of the degree of accessibility of the different administrative units of Calabria. For logistical reasons, it was not possible to include all the information obtained from the above operations in the contribution; only a part of this data is shown below in tabular form.
The overlapping operations carried out in a GIS environment between the isochrones constructed from the infrastructure nodes mapped in the regional context and demographic data have allowed to verify: which isochrones concern the 404 Calabrian Municipalities and how many inhabitants fall within the different isochrones.
In Tab.1, which refers to the railway nodes, are listed in alphabetical order the first five and the last five Municipalities of Calabria, and for each is indicated: the total number of isochrones from which they are reached starting from the reference infrastructural nodes; and the number of inhabitants of the Municipality itself that fall within the area of the isochrones present in its administrative boundaries. The data in Tab.1 clearly show the direct proportionality that exists between the increase of the time range considered and the numerical values related to both the isochrones present in the Municipality and the number of inhabitants falling into them. In this respect, it is noted, for example, that the Municipality of Zumpano, located in the province of Cosenza, and that of Africo, in the province of Catanzaro, have a high degree of accessibility, in fact, the totality of their population already falls within the 15-minute isochronous. In contrast, the Municipalities of Acquaformosa (CS), Acquaro (VV) and Zagarise (CZ) are characterized by a lower level of accessibility, since they do not have a population served within 15 minutes.

Municipality (Province)	Total population	Time Ranges for Railway Nodes			
		15 minutes	30 minutes	45 minutes	60 minutes
		Number of isochrones affecting the Municipality			
		Number of inhabitants falling within the isochrone group			
1. ACQUAFORMOSA (CS)	1,018	-	3	12	31
		-	259	1,018	1,018
2. ACQUAPPESA (CS)	1,295	5	15	26	48
		1,261	1,295	1,295	1,295
3. ACQUARO (VV)	1,848	-	1	11	36
		-	26	1,831	1,848
4. ACRI (CS)	19,056	3	20	52	71
		21	14,571	18,955	18,967
5. AFRICO (RC)	1,535	4	10	15	36
		1,535	1,535	1,535	1,535
…	…	…	…	…	…
		…	…	…	…
400. ZACCANOPOLI (VV)	523	4	10	15	19
		512	523	523	523
401. ZAGARISE (CZ)	1,384	3	21	30	61
		-	1,135	1,335	1,376
402. ZAMBRONE (VV)	1,726	5	10	15	24
		1,709	1,726	1,726	1,726
403. ZUMPANO (CS)	4,658	19	34	50	78
		4,658	4,658	4,658	4,658
404. ZUNGRI (VV)	1,906	3	13	16	28
		1,015	1,906	1,906	1,906

Tab.1 Analysis of the population coverage of isochrones related to railway nodes for each administrative unit in Calabria

The data in Tab.2, which refer to motorway interchanges, show that all Municipalities reported have zero values within the 15-minute time frame, with the exception of Zumpano (CS) which, also in this case, as for rail nodes, its strategic location ensures a high level of accessibility. There are also specific cases, such as that of the Municipality of Africo (RC), which despite having a maximum degree of accessibility to the rail network, is in a condition of functional marginality compared with the motorway network, because it cannot guarantee coverage for its inhabitants even in 60 minutes. For a complete view of the degree of accessibility of all Calabrian centres, please refer to the figures below.

Municipality (Province)	Total population	Time Ranges for Motorway Nodes			
		45 minutes	60 minutes	45 minutes	60 minutes
		Number of isochrones affecting the Municipality			
		Number of inhabitants falling within the isochrone group			
1. ACQUAFORMOSA (CS)	1,018	-	4	10	14
		-	1,008	1,018	1,018
2. ACQUAPPESA (CS)	1,295	-	2	7	12
		-	-	1,130	1,295
3. ACQUARO (VV)	1,848	-	5	8	12
		-	1,487	1,848	1,848
4. ACRI (CS)	19.056	1	6	10	15
		1	10,416	17,796	18,958

5. AFRICO (RC)	1,535	-	-	-	5
		-	-	-	-
...	...	...	...	...	...
		...	...	...	...
400. ZACCANOPOLI (VV)	523	-	-	6	10
		-	-	510	523
401. ZAGARISE (CZ)	1,384	-	-	1	4
		-	-	-	1.244
402. ZAMBRONE (VV)	1,726	-	1	6	11
		-	46	1,726	1,726
403. ZUMPANO (CS)	4,658	2	9	12	15
		4,168	4,658	4,658	4,658
404. ZUNGRI (VV)	1,906	-	4	7	12
		-	63	1,906	1,906

Tab.2 Analysis of the population coverage of isochrones related to motorway nodes for each administrative unit in Calabria

In Tab.3 are the results of the analyses of the catchment area for the individual isochrones constructed from the reference infrastructural nodes. In particular, through this type of analysis it was possible to verify the actual efficiency in terms of population coverage of each mapped node, also to support the planning of strategic interventions aimed at improving the degree of accessibility of a given administrative unit by making a specific node more reachable.

Identification of isochrones (Transport company)		**Time Ranges**			
		15 minutes	**30 minutes**	**45 minutes**	**60 minutes**
		Number of inhabitants falling within the isochrone group			
Railway nodes	Acquappesa (RFI)	14,904	46,720	102,761	331,366
	Acri - Bisignano (RFI)	9,929	221,305	340,279	490,015
	Adami (FDC)	6,350	60,545	128,258	421,833
	Africo Nuovo (RFI)	17,632	32,351	74,557	125,797
	Amantea (RFI)	13,999	38,413	130,539	443,099
	...	...	...	...	...
Motorway nodes	Laino Borgo	1,698	9,302	54,067	125,187
	Mormanno - Laino Castello	3,712	26,085	66,431	161,391
	Campotenese	1,121	34,328	81,218	222,262
	Morano C. - Castrovillari	11,142	44,462	102,518	252,961
	Frascineto - Castrovillari	19,690	57,994	137,215	370,037
	...	...	...	...	...

Tab.3 Analysis of the population coverage of individual isochrones built from railway and motorway nodes

After having collected all the information, some of which is presented in tabular form, the adoption of semi-automated processes developed with QGIS software made it possible to synthesise the data collected and obtain a classification of the administrative units of Calabria. This classification is based on the percentage of inhabitants, in relation to the total population of each Municipality, that falls within the set of isochrones that affect that specific local administrative unit. The above classification of the territory of Calabria is shown below, in relation to the four-time ranges defined.

In Fig.3 reference is made to the isochrones built from railway nodes. Specifically, analysing the results obtained from classification it is noted that within the 15-minute range (Fig.3a), the highest degree of accessibility is concentrated mainly in the regional coastal areas and in the northern hinterland, consistent with the placement of stations in Fig.1. It is also evident that the high number of Municipalities in the 15-

minute range has percentage values between 0% and 20%, a sign of a level of accessibility that is highly insufficient.

This condition improves by extending the time limit to 30 minutes (Fig.3b), despite remaining unsatisfied entire portions of the territory located: at the extreme north in correspondence with the Pollino National Park, in the central eastern part of the Sila National Park and in the southern hinterland in the "Parco delle Serre" and the Aspromonte National Park.

With the time range of 45 minutes (Fig.3c) a maximum degree of accessibility is obtained for almost all centres, in fact, there are only ten Municipalities that do not reach the level "Very satisfied" and even two of them (Fabrizia and Laino Castello) have a percentage value below 10%.

Finally, only by referring to the time range of 60 minutes the entire territory of Calabria reaches a maximum coverage (Fig.3d).

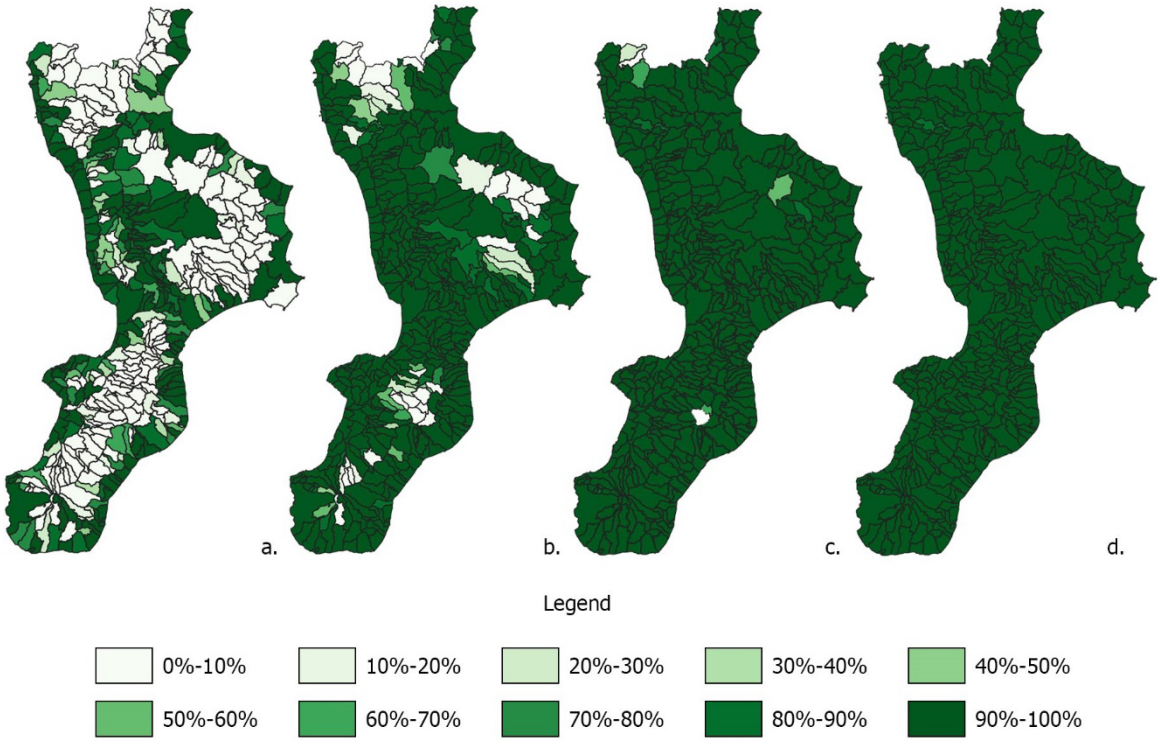

Fig.3 Classification of the administrative units in Calabria with reference to railway nodes according to the following time ranges: 15 minutes (a), 30 minutes (b), 45 minutes (c), 60 minutes (d)

In Fig.4 the same classification of the administrative units of Calabria is shown, but this time with reference to the motorway nodes mapped previously.

The road network in Calabria has several critical points, in terms of general degradation of the network, or tortuosity of the road sections due to the orography of the territory. In this context, the motorway route is a crucial element for determining the degree of accessibility of a given centre, especially considering the lack of mobility services at regional level. In addition, most of the inhabitants of small and medium-sized Municipalities in Calabria travel by car to reach their places of work, leisure or essential services not present in their own centres. Therefore, through the analysis conducted it is possible to verify which are the most accessible areas and those characterized by a marked functional marginality.

In Fig.4a, you can see how the degree of accessibility of administrative units within the 15-minute range is concentrated around the highway axis, leaving the rest of the territory uncovered.

In the interval of 30 minutes (Fig.4b) the same condition occurs, although the catchment area covered increases, but nevertheless the entire Ionic belt of Calabria remains characterized by percentages close to zero, as well as the northern Tyrrhenian belt.

Within the range of 45 minutes (Fig.4c) increases further the degree of accessibility of the Municipalities, although compared to the same analysis made on railway nodes, in this case the number of administrative units with low percentage values in this range is significantly higher. In fact, the Ionic belt and the extreme north of the Tyrrhenian belt are still almost entirely undiscovered.

Finally, analysing the time range of 60 minutes (Fig.4d) it is noticed that, despite the percentage of Municipalities falling in the lower bands has decreased, almost the whole of Silan and four other smaller areas are still characterized by a marked degree of functional marginality. In this respect, the difference with the result obtained by the same analysis in reference to the same interval for railway nodes is obvious.

While the isochronic analysis in the range of 60 minutes ensures a total coverage of the territory of Calabria with reference to railway nodes, the same analysis carried out on motorway nodes highlights a split of Calabria, that despite the large interval of time considered presents almost 20% of the Municipalities in conditions of functional marginality.

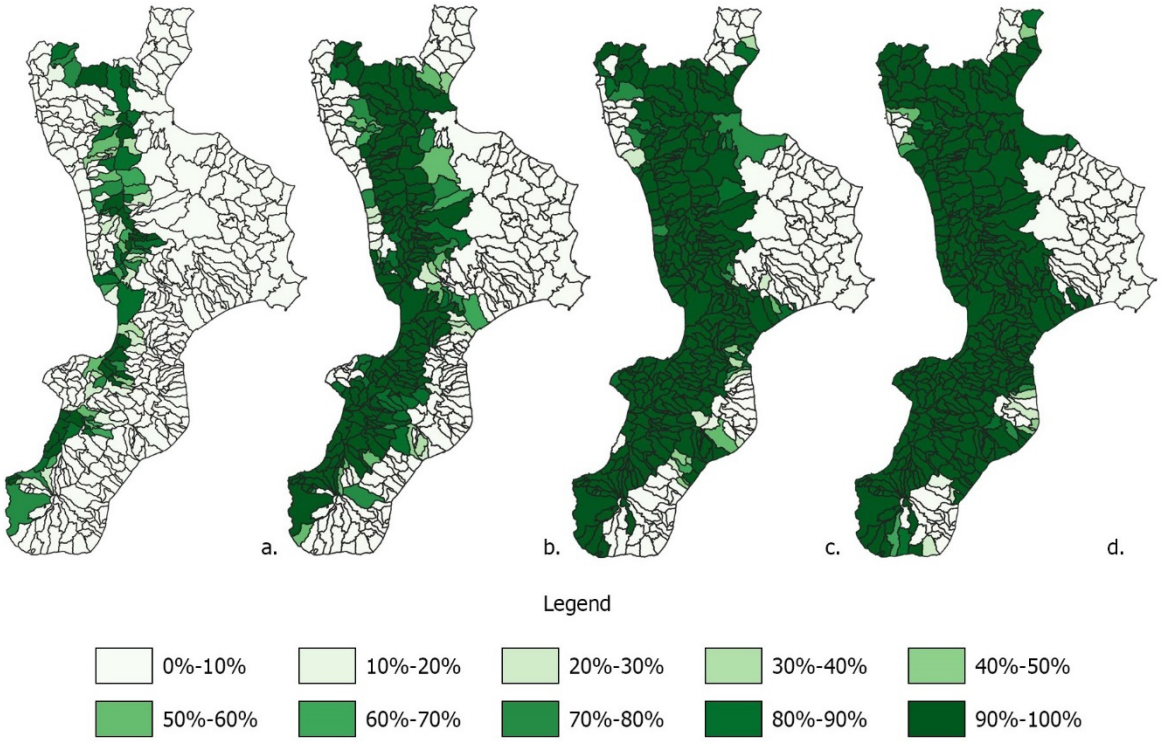

Fig.4 Classification of the administrative units in Calabria with reference to motorway nodes according to the following time ranges: 15 minutes (a), 30 minutes (b), 45 minutes (c), 60 minutes (d)

5. Discussion and conclusion

This study proposed a semi-automated methodology in GIS environment for the analysis of levels of accessibility to the main transport, highway and railway nodes, municipal administrative units based on isochronic analysis, Presenting the results of its application to the context of the Calabria Region.

In this context, it should be specified that the contents presented in this paper are part of a wider research project, which aims to revitalise and transform the most fragile territories, with specific reference to small and medium-sized centres, in sustainable and resilient models. Specifically, future research developments include the definition of potential optimal territorial areas within which to promote inter-communal forms of association for the management of specific functions and services. This approach finds a useful reference in the assumptions of the National Strategy for Inner Areas (called SNAI) that, similarly, identifies institutional associationism as the prerequisite for the definition of project-areas (Palermo et al., 2024). However, the results obtained in this study with regard to accessibility levels highlight the need to include, in such strategic

spatial planning processes, additional municipal contexts not mapped by SNAI, which are affected by similar problems (Fig.5).

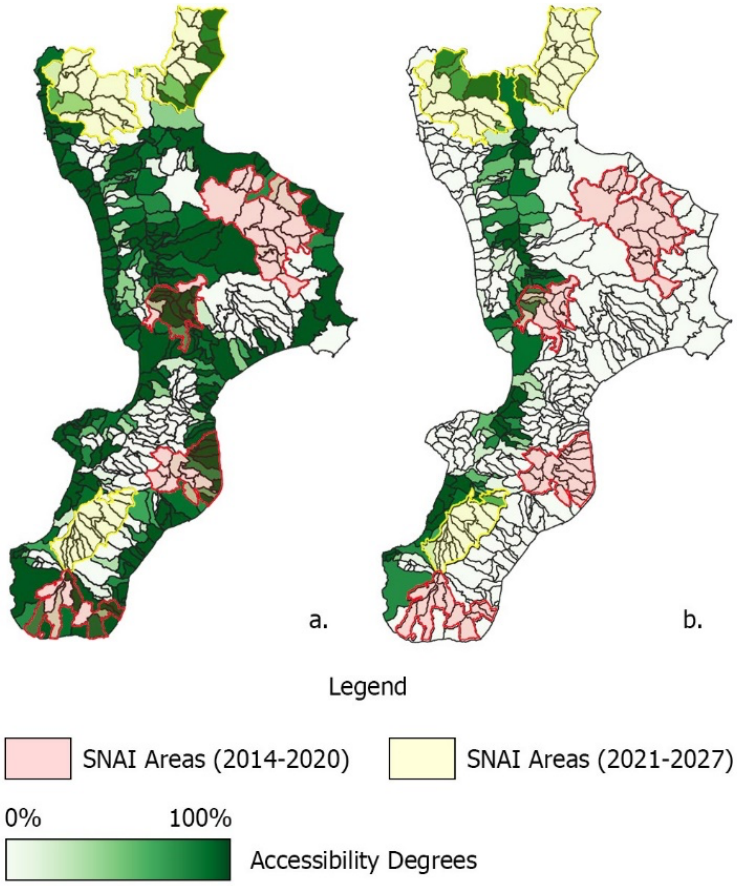

Fig.5 Overlap between the mapping of the National Strategy for Inland Areas (SNAI) related to the programming periods 2014-2020 and 2021-2027 and the degree of accessibility achieved considering the time range of 15 minutes with reference to railway nodes (a) at motorway junctions (b)

The inconsistencies between the municipalities selected for the SNAI in Calabria Region and the proposed results are explained by the different methodological approach underlying the mapping technique. In this case, the use of the isochronic analysis is recommended in literature for several practical purposes in relation to different possible spatial and transport planning needs, to ensure greater spatial equity and a reduction in territorial fragmentation (Śleszyński et al., 2023). In fact, with reference to the experimental context, the results have allowed to highlight significant disparities in connectivity between the various areas of the Region, also attributable to the morphology of the territory, The characteristics of infrastructure networks and spatial distribution of population centres. The results have been presented in a disaggregated form for each of the transport types considered, also in order to highlight the effect induced by the concentration of motorway nodes on the Tyrrhenian side of Calabria and the more homogeneous distribution of railway nodes throughout the region. Indeed, this different distribution has direct implications on the overall levels of accessibility, with some areas benefiting from good transport services and others suffering from significant functional isolation, In most cases, this is the case of small and medium-sized centres located mainly in the mountain areas of Calabria. In this regard, the isochronic analysis has been a valid tool not only to assess levels of accessibility, but also to deduce further elements of reflection useful for planning purposes in the regional context of Calabria.

In particular, with reference to the first aspect, the results obtained, systematized for time intervals of 15, 30, 45 and 60 minutes, provided a detailed representation of the levels of accessibility of administrative units. This

technique showed that most of the Calabrian Municipalities were served by transport nodes within 60 minutes, but with significant variations between them. The integration of demographic data has further enriched the analysis, allowing for an assessment of accessibility in terms of population served. This phase confirmed that the large urban centres tend to have better levels of accessibility, while the medium and small centres have lower levels of accessibility. Especially in these contexts, this result represents a considerable challenge also because of the low population density and the complex local morphological context which tends to increase distances and travel times, making it more difficult to satisfy in terms of service provision (Bertram & Chilla, 2023).

With reference to the second aspect, it is even more evident that the methodology developed can be applied in practice. The results reveal specific local needs to be met in terms of quality of life, and guide planning choices towards optimising the transport sector with the aim of better managing the movements needed by the community, and increasing local, basic and ancillary services, especially in those contexts marked by unsatisfactory levels of accessibility to the main transport infrastructures.

In conclusion, this study highlighted the importance of a planning approach oriented to territorial integration between mobility needs and service network programming. The results suggest that to improve accessibility in the less-served areas of Calabria, it is necessary to promote targeted and integrated development policies which take into account local peculiarities and specific mobility needs. This approach can provide a solid basis for planning and development policies that aim to reduce territorial disparities and promote equitable access to resources and services. It is therefore argued that it is important to incorporate social equity into planning activities, especially in the transport sector, because of the close relationship between accessibility, Ease of reaching the various destinations and risks of social exclusion, which can be understood as the repressed ability to carry out daily activities, also in accordance with what stated by Allen & Farber (2020).

In addition, the proposed methodology can also be applied to other regional contexts, offering a versatile tool for accessibility assessment and supporting the planning of interventions aimed at improving territorial connectivity. In this respect, the results obtained could be a useful input to vary or update the methods underlying the choice of distance thresholds for measuring the degree of peripherality of territories proposed by SNAI, currently calculated in minutes of travel to the nearest pole.

Finally, from the methodological point of view, the application to the regional context of Calabria has made it possible to highlight some aspects to be taken into account for future research presages, also in order to carry out further investigations and add to the analyses carried out. In particular, with regard to the methodological framework, it is envisaged that synthetic indices of space-time accessibility may be computed, at least one for each type of infrastructure node considered. These indices will take account of a weighing system to be defined, for example by applying a multi-criteria analysis. In addition, as anticipated it is planned to implement corrective indices in order to take into account the various types of risk phenomena present on the territory, thus refining the isochronic analysis in order to return more realistic projections of actual travel times.

References

Alberti, F. & Marzi, L. (2022). Visioni e strumenti per un'urbanistica dell'accessibilità. *URBANISTICA*, 164, 49-53.

Allen, J. & Farber, S. (2020). Planning transport for social inclusion: An accessibility-activity participation approach. *Transportation Research Part D: Transport and Environment*, 78, 102212. https://doi.org/10.1016/j.trd.2019.102212

Altay, E. E. & Şenay, D. (2023). Usability and accessibility of urban service areas with increasing epidemics: the case of Bursa/Turkey. *TeMA - Journal of Land Use, Mobility and Environment*, 16(1), 147-163. https://doi.org/10.6093/1970-9870/9591

Bertram, D. & Chilla, T. (2023). Polycentricity and accessibility in mountain areas: the Alpine case. *European Planning Studies*, 31 (12), 2425-2445. https://doi.org/10.1080/09654313.2022.2145874

Borlini, B. & Memo, F. (2009). Ripensare l'accessibilità urbana. *Cittalia Fondazione Anci ricerche*, 2.

Canu, D. (2016). Misure di accessibilità nella valutazione dell'equità urbana: una raccolta dei metodi. *Archivio Di Studi Urbani E Regionali*: 116, 2 (2016), 115-138, Milano: Franco Angeli. https://doi.org/10.3280/ASUR2016-116006

Cargnin, M. J., de Castro Marino, C. & da Silva, T. L. (2024). The 15-minute cities concept applied to a Brazilian neighborhood: case study of the cidade universitária Pedra Branca neighborhood in Palhoça-SC. *TeMA - Journal of Land Use, Mobility and Environment*, *17* (2), 189-191. https://doi.org/10.6093/1970-9870/10314

Carrosio, G. & Barca, F. (2020). Un modello di policy place-based: la Strategia nazionale per le aree interne. In G. Osti & E. Jachia. AttivAree. Un disegno di rinascita delle aree interne, 63-72, Bologna: Il Mulino.

Cascetta, E., Cartenì, A., Henke, I. & Pagliara, F. (2020). Economic growth, transport accessibility and regional equity impacts of high-speed railways in Italy: Ten years ex post evaluation and future perspectives. *Transportation Research Part A: Policy and Practice*, 139, 412-428. https://doi.org/10.1016/j.tra.2020.07.008

Cerasoli, M. (2024). Infrastrutture, accessibilità e aree interne. *Urbanisticatre*, NU3(5), 65-74.

Chen, J., Cui, M. & Levinson, D. (2024). The cost of shopping: measuring virtual and physical access for obtaining goods. *TeMA - Journal of Land Use, Mobility and Environment*, *17* (1), 129-145. https://doi.org/10.6093/1970-9870/10688

Costa, V. & Delponte, I. (2024). User-centred mobility management and social inclusion. Urban insights from the University of Genoa. *TeMA - Journal of Land Use, Mobility and Environment*, 33-45. https://doi.org/10.6093/1970-9870/10299

D'Amico, A. (2024). Strategies and instruments for active mobility: the main Italian policies. *TeMA - Journal of Land Use, Mobility and Environment*, *17* (3), 509-515. https://doi.org/10.6093/1970-9870/11166

Di Ruocco, I. (2022). Resilient marginal cities by encouraging intermodality strategies. *TeMA - Journal of Land Use, Mobility and Environment*, *15* (3), 377-396. https://doi.org/10.6093/1970-9870/9031

Erçetin, C. (2024). Right-based approach to urban accessibility: analysis of user perspective. *TeMA - Journal of Land Use, Mobility and Environment, 17* (2), 249-264. https://doi.org/10.6093/1970-9870/10510

European Union (2023). Parlamento Europeo. Tratto da https://www.europarl.europa.eu/doceo/document/TA-9-2023-0130_IT.html

Fazio, M., Borghetti, F., Giuffrida, N., Le Pira, M., Longo, M., Ignaccolo, M., Inturri, G. & Maja, R. (2023). The "15-minutes station": a case study to evaluate the pedestrian accessibility of railway transport in Southern Italy. *Transportation Research Procedia*. https://doi.org/10.1016/j.trpro.2023.02.205

Gargiulo, C., Maternini, G., Tiboni, M. & Tira, M. (2022). New scenarios for safe mobility in urban areas. *TeMA - Journal of Land Use, Mobility and Environment*, 3-5. https://doi.org/10.6093/1970-9870/8916

Gkiotsalitis, K. & Cats, O. (2021). At-stop control measures in public transport: Literature review and research agenda. *Transportation Research Part E: Logistics and Transportation Review*, *145*, 102176. https://doi.org/10.1016/j.tre.2020.102176

Große, C. (2024). Envisioning sustainable rural development: A narrative on accessibility and infrastructure from a Swedish region. *Journal of Rural Studies*, 109 (103319). https://doi.org/10.1016/j.jrurstud.2024.103319

Handy, S. (2020). Is accessibility an idea whose time has finally come?. *Transportation Research Part D: Transport and Environment*, 83, 102319. https://doi.org/10.1016/j.trd.2020.102319

Higgins, C. D. (2019). Accessibility toolbox for R and ArcGIS. *Transport Findings*. https://doi.org/10.32866/8416

Hillel, T., Bierlaire, M., Elshafie, M. Z. & Jin, Y. (2021). A systematic review of machine learning classification methodologies for modelling passenger mode choice. *Journal of choice modelling*, *38*, 100221. https://doi.org/10.1016/j.jocm.2020.100221

Huang, X., Kang, C., Yin, C. & Tang, J. (2024). Influence of Transportation Accessibility on Urban-rural Income Disparity and Its Spatial Heterogeneity. *Chinese Geographical Science*, 34 (3), 453-467. http://doi.org/10.1007/s11769-024-1427-8

Jian, I. Y., Luo, J. & Chan, E. H. (2020). Spatial justice in public open space planning: Accessibility and inclusivity. *Habitat International*, 97, 102122. https://doi.org/10.1016/j.habitatint.2020.102122

Kurlov, A. V., Materuhin, A. V., Dresvyanin, A. V. & Gvozdev, O. G. (2022). Geoinformational Approach to Assessing the Accessibility for Urban Areas. Tomsk: 2022 International Siberian Conference on Control and Communications, *SIBCON* 2022.

Lahoorpoor, B. & Levinson, D. M. (2020). Catchment if you can: The effect of station entrance and exit locations on accessibility. *Journal of Transport Geography*, *82*, 102556. https://doi.org/10.1016/j.jtrangeo.2019.102556

Lin, X., Shaozhuang, W. & Lingxiao, Y. (2024). Distributional effects of expressway access on rural entrepreneurial activities in China. *Socio-Economic Planning Sciences*, 94 (103319). https://doi.org/10.1016/j.seps.2024.101964

Lü, G., Batty, M., Strobl, J., Lin, H., Zhu, A. X. & Chen, M. (2019). Reflections and speculations on the progress in Geographic Information Systems (GIS): a geographic perspective. *International journal of geographical information science*, *33* (2), 346-367. https://doi.org/10.1080/13658816.2018.1533136

Massaro, A. & Rotondo, F. (2020). L'accessibilità urbana come forma di rigenerazione: un'esperienza a Taranto. In XXII Conferenza Nazionale SIU, Roma-Milano: *Planum-Publisher*.

Melzi, C. (2011). Qualità della vita ed equità socio-territoriale nelle aree metropolitane di Bologna, Milano e Torino. Uno studio empirico sulla mobilità territoriale e l'accessibilità ai servizi di prossimità. Università di Milano-Bicocca.

Merengo, M. (2023). Le aree rurali contemporanee fra rural gentrification e lifestyle migration. Studi di caso in Francia e in Italia. In M. Merengo (A cura di), La "Rinascita" dei territori marginali. Dalla desertificazione socio-demografica e funzionale alla gentrification rurale e le lifestyle migrations, 40-55, Genova: *Genova University Press*.

Montero-Lamas, Y., Fernández-Casal, R., Varela-García, F. A., Orro, A. & Novales, M. (2024). A spatial statistical approach to estimate bus stop demand using GIS-processed data. *Journal of Transport Geography, 118* (103906). http://doi.org/10.1016/j.jtrangeo.2024.103906

Mouratidis, K. (2021). Urban planning and quality of life: A review of pathways linking the built environment to subjective well-being. *Cities*, 115, 103229. https://doi.org/10.1016/j.cities.2021.103229

Pamucar, D., Deveci, M., Canıtez, F., Paksoy, T. & Lukovac, V. (2021). A novel methodology for prioritizing zero-carbon measures for sustainable transport. *Sustainable production and consumption*, *27*, 1093-1112. https://doi.org/10.1016 /j.spc.2021.02.016

Pucci, P., Carboni, L. & Lanza, G. (2022). Accessibilità di prossimità in un territorio montano. *Archivio di studi urbani e regionali*, 135, 3, 2022, 5-26. http://doi.org/10.3280/ASUR2022-135001

Śleszyński, P., Olszewski, P., Dybicz, T., Goch, K. & Niedzielski, M. A. (2023). The ideal isochrone: Assessing the efficiency of transport systems. *Research in Transportation Business & Management*, 46 (100779). http://doi.org/ 10.1016/j.rtbm.2021.100779

Stiuso, T. (2024). Exploring approaches and solutions for urban safety: a focus on the elderly. *TeMA - Journal of Land Use, Mobility and Environment*, *17* (3), 525-533. https://doi.org/10.6093/1970-9870/11172

Vilhelmson, B. (1999). Daily mobility and the use of time for different activities: the case. *GeoJournal*, (48), 177-185. http://doi.org/ 10.1023/A:1007075524340

Vitale Brovarone, E. & Cotella, G. (2020a). Improving rural accessibility: A multilayer approach. *Sustainability, 12* (7), 2876. https://doi.org/10.3390/su12072876

Vitale Brovarone, E. & Cotella, G. (2020b). La Strategia Nazionale per le Aree Interne: una svolta place-based per le politiche regionali in Italia. *Archivio di studi urbani e regionali*: 129, 3, 2020, 22-46, Milano: Franco Angeli. http://doi.org/ 10.3280/ASUR2020-129002

Wang, S., Wang, M. & Liu, Y. (2021). Access to urban parks: Comparing spatial accessibility measures using three GIS-based approaches. *Computers, Environment and Urban Systems*, 90, 101713. https://doi.org/10.1016/ j.compenvurbsys.2021.101713

Xi, Y., Miller, E. J. & Saxe, S. (2018). Exploring the Impact of Different Cut-off Times on Isochrone Measurements of Accessibility. *Transportation Research Record*, 2672 (49), 113-124. http://doi.org/10.1177/0361198118783113

Xu, M. (2014). A GIS-based pedestrian network model for assessment of spatial accessibility equity and improvement prioritization and its application to the Spoken Public Transit benefit area. Washington: *Washington State University*.

Yang, Z., Liu, Y., Luo, X., An, R. & Jiang, Y. (2022). Evaluation of the rural accessibility at a county level from the coupling perspective of "Threshold-Supply and Demand". Nongye Gongcheng Xuebao/Transactions of the Chinese Society of *Agricultural Engineering*, 38 (11), 279-288.

Zhao, Y. & Zhou, Y. (2024). Isochrone-Based Accessibility Analysis of Pre-Hospital Emergency Medical Facilities: A Case Study of Central Districts of Beijing. *ISPRS International Journal of Geo-Information*, *13* (8). https://doi.org/10.3390/ijgi13080288

Zheng, Q. Y., Law, T. H., Wong, S. V. & Ng, C. P. (2024). Relative improvements between roads and railways and economic performance: A panel data analysis. *Transport Policy*, 153, 87-96. https://doi.org/10.1016/j.tranpol.2024.05.012

Image Sources

Figg.1-5: Authors' elaboration.

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The impact of transportation planning on agricultural areas and plant health: a case study of Antalya/Konyaaltı West Ring Road

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Abstract
It is stated in the literature that changes in land cover/land use may have positive or negative effects on accessibility and rural-urban distinction in the region. Similarly, increasing accessibility in an area may lead to unplanned urbanization, traffic congestion, air, and noise pollution, and a decrease in the environmental quality of life due to the impact on land use and, most importantly, the destruction of agricultural areas. In the planning of urban and rural areas, the interaction with each other and the formal separation of rural and urban areas are important, and many analyses, such as accessibility, protection of agricultural areas, building density, and population, should be carefully made in order to avoid negative impacts on each other. In the studies without such analyses, unplanned or unjustified urban areas emerge where the direction of urban development has not been determined. This study analyzes the West Ring Road in the Konyaaltı district (Antalya), where a similar situation is experienced, and the surrounding agricultural areas. It is claimed that the agricultural lands around the West Ring Road have lost their agricultural quality. With this study, we seek empirical answers to these claims. Our aim is to analyze the effects of the West Ring Road on the agricultural areas around it, in conjunction with plant health, through GIS (Geographic Information System) and Remote Sensing methods. As a result of the study, the plant health in the rural agricultural areas on the periphery of the West Ring Road was not negatively affected.

Keywords: Agricultural land; Change detection; GIS; NDVI; Ring road; Transportation-land use.

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1. Introduction

The mass migration from rural to urban areas triggered by the increasing demand for the workforce by industrialization that started in the 1950s has taken a different path over recent decades, which requires reconstruction of the relationship between urban and rural areas. In Antalya, this relationship began to intensify in recreation and tourism in the 1980s, and now it has moved to a different dimension. As Sietchiping et al. point out, increasing rural-urban relationships cause environmental problems due to limited land and excessive consumption of resources. Improving the integration and balance between urban and rural areas necessitates devising various spatial planning systems and tools (Sietchiping et al., 2014). Lefebvre et al. state that phenomena like "total urbanization" and "entire city" are replacing industrial cities day by day, referring to the process that Turkey is going through today (Lefebvre, 2003).

Economic changes and developments that accelerated urbanization also led to the development of labor-intensive industries, service sectors, and non-agricultural industries in rural-urban connections. Tao reports that Asian cities have been abandoning this dual rural-urban structure to strengthen rural and urban integration (Tao, 2007). The transformation of the countryside has brought about significant changes in the dynamics of the local economy, with agriculture being no longer the backbone of the rural economy, resulting in the rebuilding of rural populations. With the change in the rural population structure, new usage areas have emerged in the countryside, thus creating novel income and real estate sectors (Brereton et al., 2011). Urbanization not only stems from the movement from rural to urban areas but also from the need of those living in urban areas to be close to rural life. In this regard, the reason for the emergence of problems in the planning and spatial design of urban areas is the lack of understanding of the integrity of the part-whole relationship that solves urban problems and the priority given to the creation of weak urban areas that are incompatible with their surroundings and have no connection with their periphery.

One of the key components of economic growth, transportation aims to improve the capacity of individuals to access various economic and social activities, which is among the main objectives of urban transport policies (Foth et al., 2013; Zhu & Liu, 2004). Accessibility is the ability to access opportunities (services, goods, activities, facilities) from the current location using the existing transportation network. Accessibility is influenced by various factors such as transport type, demand, integrated transport, mobility, passengers' experience and knowledge, ability to pay, transport costs, management, topological interconnection of transport networks, and privatization. Accessibility is generally defined in the literature as the most basic product of the transportation network. In addition, accessibility is an important tool for measuring the impact of transportation decisions on the city (Geurs & van Wee, 2004). Accessibility directly impacts social, cultural, economic, and environmental technical factors as well as planning, land use, and transportation systems. The building supply created in a planned satellite city changes the location of activities, such as sports facilities and shopping centers in that region, which changes the demand for meeting areas. Changing land use will increase travel demand, thus requiring adequate transport infrastructure. This change has profound effects on sustainability in urban areas.

Since the 1960s, much research and work has been done to clarify the planning and interaction between transport networks and land use (Alonso, 1964; Anas, 1982; Boyce, 1980; Brandi et al., 2014; Buliung & Kanaroglou, 2006; Demirel, 2004; Hawkins & Nurul Habib, 2019; Ing et al., 2001; Lopez-Ruiz et al., 2013; Wegener & Fürst, 2004). In such studies, scholars determined that the urban-rural relationship and changes in land cover/land use could positively or negatively affect accessibility in the region. Indeed, increased accessibility in an area may lead to unplanned urbanization, traffic congestion, indistinguishable industrial and residential areas, air and noise pollution, a decrease in environmental quality of life due to the impact on land use, and, most importantly, the destruction of agricultural areas. In planning urban and rural areas, factors like urban-rural interaction and formal separation of such areas are vital. Therefore, various analyses should be carried out on accessibility, protection of agricultural areas, building density, and population so that they

exert no negative effects on each other. In regions without such studies, we often observe unplanned urban areas created without any justification or direction of urban development.

In measuring the impact of urban areas on rural areas, researchers have been using various methods across agricultural areas, such as on-site crop yield assessment, product diversity, plant health measurement by remote sensing technique, and soil moisture assessment. Recently, however, the high costs of field studies into the effects of urban areas on their periphery and problems experienced in measuring plant health and crop yield on site have caused the adoption of new research approaches that employ remote sensing technologies. However, it is stated that more empirical studies are still needed on the effects of resource uses on land cover change (Futemma & Brondízio, 2003). In order to determine the impact of infrastructure projects on the environment, it is important to determine changes in plant health along with changes in land cover. Thus, it will be predictable what impact infrastructure projects to be developed in a similar area will have on the environment.

The West Ring Road, planned on agricultural lands in the North of Konyaaltı district (in Antalya) in 2014, is an infrastructure project that has been discussed for many years and has brought about concerns about the above-mentioned transportation planning-environment interaction. This area is approximately 282.40 ha in size, including the agricultural lands around it. Authorized administrations claim that the agricultural area around this area lost its quality after the West Ring Road was opened, and they want to plan this area as a new settlement. Based on this, in this study, the effects of the West Ring Road on agricultural areas are analyzed with different algorithms using remote sensing and GIS methods. Scientific and quantitative answers are sought to the authorized administrations' claims that the transportation axis hurts agricultural areas. Thus, it has been revealed that the effects of the proposed transportation axis located on the urban periphery on the unbuilt environment can be evaluated.

2. Literature review

In 1989, Singh defined the simplest change detection method as subtracting the pixel values of two images registered at different times (Singh, 1989). Indices or band ratios, such as vegetation, are usually derived before any image differentiation. Thanks to the rapid advances in remote sensing technologies, which can yield various satellite data, we can rapidly and effectively detect the interaction between urban areas and agricultural lands. Thus, the number of studies conducted to determine the impacts of urban areas on farming lands through different indices and applications created with satellite images is increasing daily.

Futemma and Brondízio compared land cover-land use change (LULCC) in agricultural and forest lands before, during, and after constructing the Inter-Oceanic Highway (Futemma & Brondízio, 2003). As a result of this study, which used the maximum likelihood change detection algorithm, it was determined that there was a 2% decrease in forest areas in 11 years. Similarly, Michaelsen et al. also evaluated the impact of the highway on natural resources by comparing the 15-year LULCC change in Peru (Chávez Michaelsen et al., 2013). Arima et al. modeled the impact of road construction on forests (Arima et al., 2005). Samal and Gedam, in their study analyzing the change in land cover, associate the change in residential areas with the decrease in agricultural lands (Samal & Gedam, 2015). In their study on the coasts of India, Kaliraj et al. found that the increase in the built environment over 10 years poses a serious threat to coastal resources (Kaliraj et al., 2017). Alphan found that 30% of the changes in the built environment in 16 years affected agricultural lands in Adana, Turkey (Alphan, 2003). In the study of Wang et al., in which they examined the destruction of land along the China-Mongolia Railway, they found that the degree of land degradation increased due to reasons such as infrastructure construction and urbanization (Wang et al., 2019).

Landsat satellite images are frequently used in change detection studies in the literature. Although Landsat, one of the traditional Earth observation satellites, is effective in larger areas due to its resolution, it can achieve spatially satisfactory results with the help of new generation sensors working with different satellites. Other

factors in choosing Landsat satellite images are that the images have bands with different properties, are freely available, are radiometrically corrected, and have been successfully used in research for many years, leading to successful results. In addition, Landsat images are used extensively in measurement and change detection analyses of plant health and yield in agricultural areas.

2.1 Our motivation and urban development in surrounding agricultural areas

The impact of urban development on agricultural areas is a multidimensional transformation process involving planning, environmental sustainability, and economic dynamics. Changes in land use, infrastructure investments, air and water pollution, microclimate alterations, and rising land prices are among the primary factors directly or indirectly affecting rural areas. Uncontrolled urban expansion threatens long-term spatial sustainability by leading to the loss of agricultural land and the depletion of environmental resources (Samat et al., 2020).

The primary motivation for this study is the need for a scientific assessment of the risks posed by administrative decisions allowing urbanization of agricultural land surrounding the West Ring Road in Konyaaltı. The decision by the Antalya Soil Conservation Board on October 3, 2012, to allow non-agricultural use of the area, followed by the approval of a 1/25,000-scale master zoning plan by the Antalya Metropolitan Municipality Council on September 13, 2019, has subjected this land to significant urbanization pressures. Although local communities and civil society organizations have legally intervened, temporarily halting the construction process, large-scale real estate developers continue to exert pressure on local authorities.

In this context, our study evaluates the spatial and environmental consequences of converting agricultural land for urban use, emphasizing the necessity of sustainable planning. Remote sensing techniques and Geographic Information Systems (GIS) should be utilized to assess the impacts on agricultural areas, ensuring the implementation of sustainable land-use policies. In cases where urban expansion is not effectively managed, agricultural lands have been observed to face rapid urbanization pressures (Esopi, 2018). This study provides a scientific basis for managing this process in accordance with spatial planning principles.

3. Materials and methods

3.1 Case study area

A coastal city in the south of Turkey, Antalya ranks among the provinces with the highest population growth rate between 2013 and 2022. Our study area is located within the borders of Konyaaltı, which is the 5th most populous district of Antalya, with a population of about 200,000 according to 2021 data. Its continuously swelling population demands new settlement and housing areas.

The Konyaaltı West Ring Road, examined within the scope of the study, is a part of the D-400 Highway, the most important of the six main highway axes connecting the city to the country's transportation network. D-400 Highway starts from the Datça District of Muğla and ends at the Esendere border gate of the Yüksekova District of Hakkari. The roles and functions of this ring road in the urban and regional transport link can be listed as follows:

- Conveying traffic, mostly heavy vehicles, from Central Anatolia to the port of Antalya;
- Providing vehicle traffic from Anatolia and Istanbul to tourism-intensive regions (such as Göynük, Kemer, Çamyuva, Çıralı, and Adrasan);
- Allowing swift delivery of agricultural produce from intensive farming regions (such as Kumluca, Finike, Kemer, Turunçova) to Central Anatolia and big cities such as Ankara and Istanbul;
- Establishing a transportation link to various areas within the city.

Our study examined the 1900-meter-long section of the West Ring Road, surrounded by agricultural lands in the east and west. These lands cover an area of approximately 282.40 hectares, and the local authorities intend to convert this plot into a new residential area with the hypothesis that agricultural productivity has declined in the region since the West Ring Road opened. We also tested the validity of this hypothesis.

The planning and construction of the Western Ring Road is not merely a decision aimed at improving transportation infrastructure but is also closely linked to the municipality's strategy to offset expropriation costs. The expropriation of land for the road has created a significant financial burden for the municipality; thus, it was decided to open the surrounding areas for urban development to cover these costs. As part of this strategy, landowners affected by the expropriation were allocated newly created parcels in the rezoned areas, allowing the municipality to mitigate its financial liabilities.

However, this process was not limited to the immediate area occupied by the road, as the municipality decided to open a much larger area for development. This decision has directly led to the urbanization of agricultural lands, threatening environmental sustainability and accelerating urban sprawl. Moreover, since natural or artificial boundaries were not considered when determining the zoning limits, not only the areas adjacent to the road but also surrounding agricultural lands have been indirectly subjected to development pressure. In planning processes, it is crucial to establish clear natural or artificial boundaries for zoning decisions; otherwise, these boundaries may not remain permanent and could lead to further development demands (Suri, 2018). Natural and artificial thresholds play a critical role in maintaining ecological balance and preventing uncontrolled urban expansion in spatial planning.

The rezoning of this area not only expands transportation infrastructure but also represents a speculative economic approach that deviates from fundamental spatial planning principles, posing a significant risk to sustainable land management. In the long term, this process contributes to the decline of agricultural production areas, depletion of environmental resources, and disruption of ecological balance (Esopi, 2018).

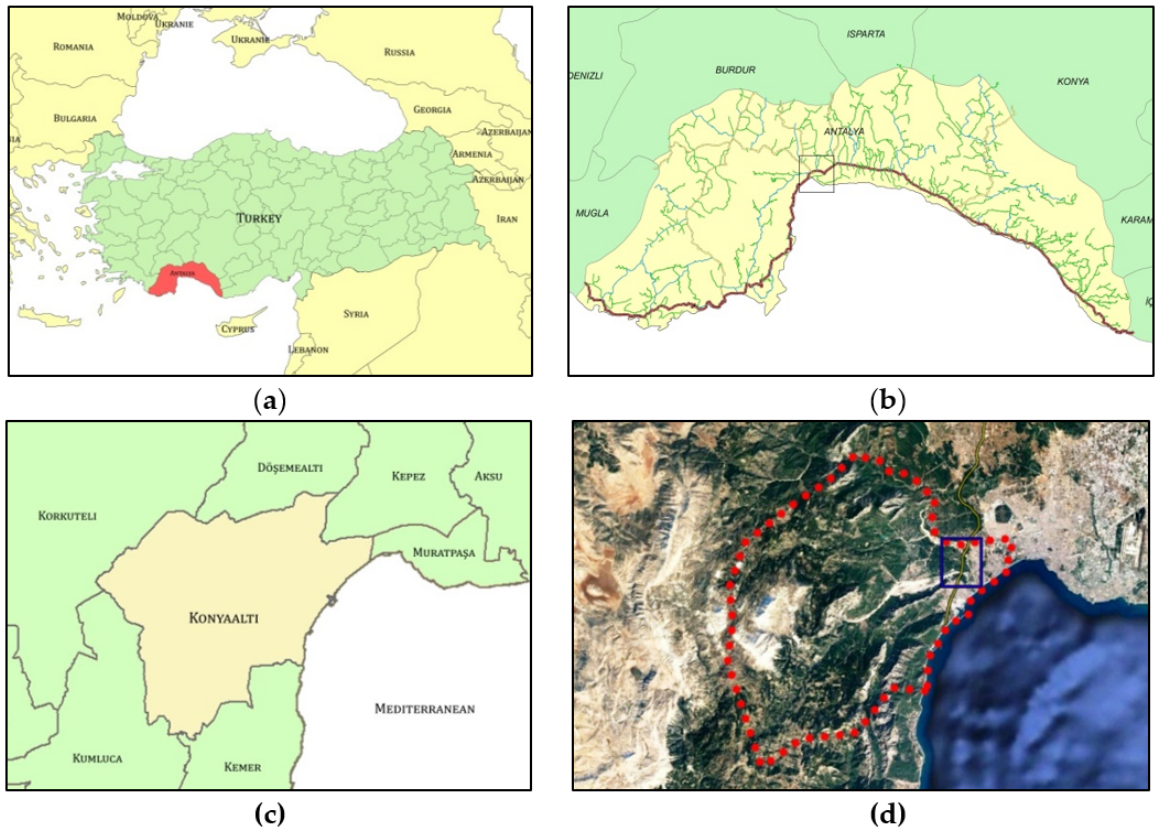

Fig.1 Location of the study area (a) Antalya province in Turkey (b) Konyaaltı district in Antalya province (c) Konyaaltı and surrounding districts (d) Satellite image of Konyaaltı district

The study area, which is approximately 282.40 hectares, is located between 286,000 – 288,000 x and 4,083,000 – 4,086,000 y coordinates according to the UTM ED50 projection system. NATO pipeline forms its western border, and Çandır Stream the southern border, while Karaman Stream draws its eastern and northern borders (Fig.s 2 and 3).

In this study, Geographic Information Systems (GIS) and Remote Sensing methods were employed to analyze land cover changes and plant health in agricultural areas surrounding the Western Ring Road. These techniques were chosen for their ability to process large-scale spatial data, detect temporal variations, and provide objective, replicable results in land-use transformation studies.

The Normalized Difference Vegetation Index (NDVI) was applied to assess plant health, while GIS-based spatial analysis integrated satellite imagery and topographical data to quantify land-use changes. This approach enables identifying spatial patterns and evaluating the impact of urban expansion on agricultural lands.

By combining remote sensing and GIS-based analysis, this study provides empirical evidence on the effects of infrastructure projects on agricultural areas, ensuring a scientific basis for sustainable land-use planning.

The lands around the study area are classified into three groups: "urban residential areas," "non-agricultural lands," which consist of riverbeds, and "absolute and cultivated agricultural lands." The interaction of non-agricultural lands and urban residential areas with the study area is the protected area effect created by the natural borders. Karaman Stream surrounds the area as an arc from the east and northeast of the agricultural areas, forming a border with the urban areas in the east. Similarly, Çandır Stream surrounds the area from the south and forms a border with the Muhasara urban settlement area. The natural border formed by these two streams prevented the urban pressure on the agricultural area in question. To the west of the study area, the Çakırlar region is a similar area that still maintains its agricultural character with its citrus groves and rural life. From the Karaman stream, agricultural lands continue uninterruptedly for about 5 kilometers in the west direction (Fig.2).

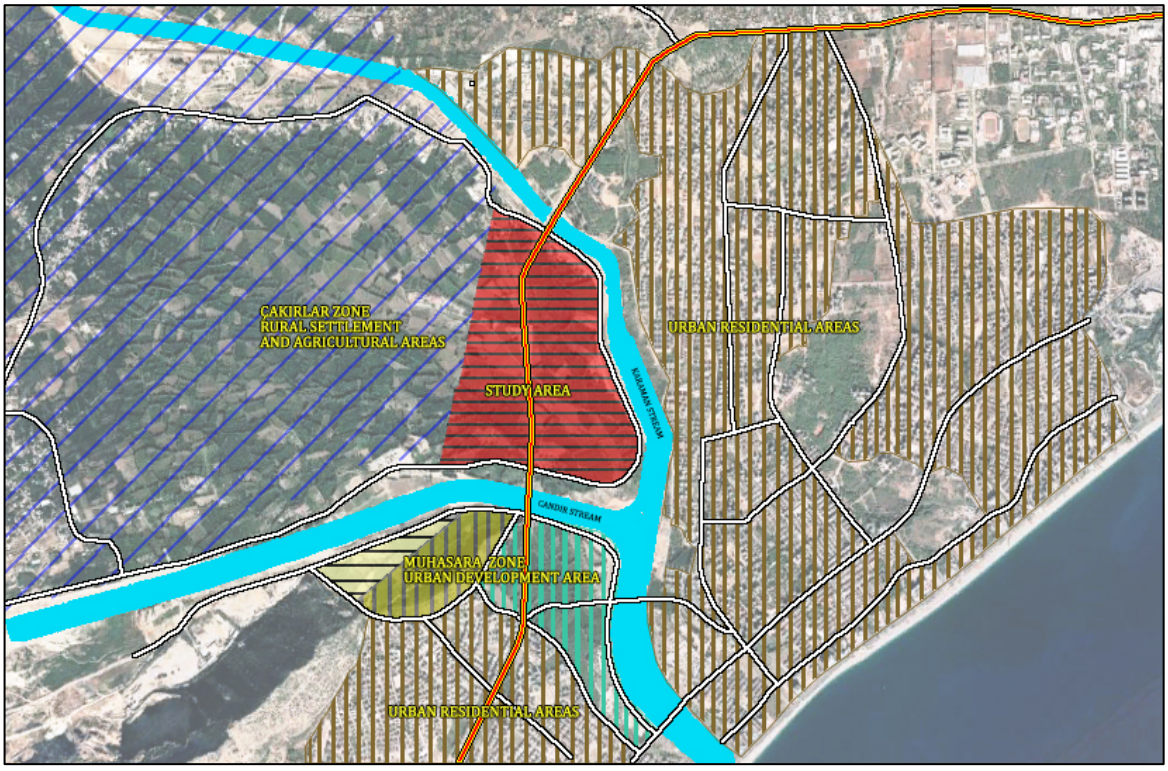

Fig.2 Location of the study area on topographic map and satellite image

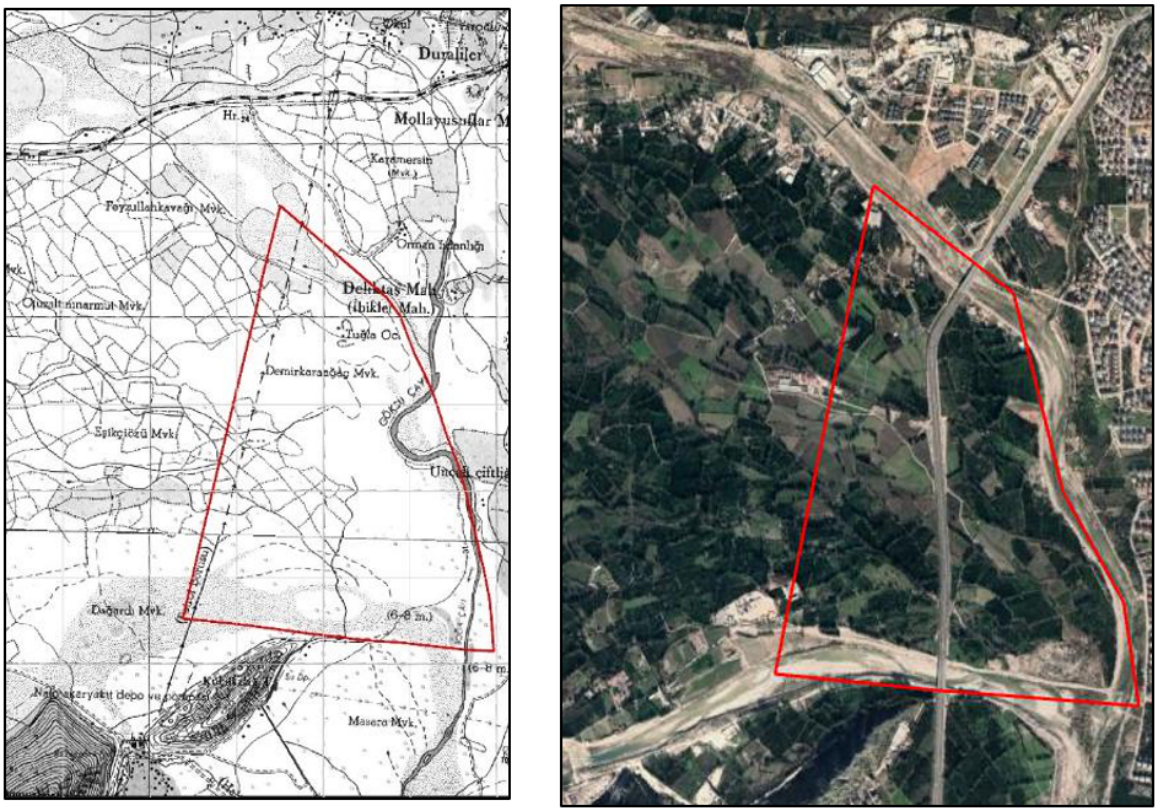

Fig.3 (a) Location of the study area on the topographic map (b) Location of the study area in the satellite image

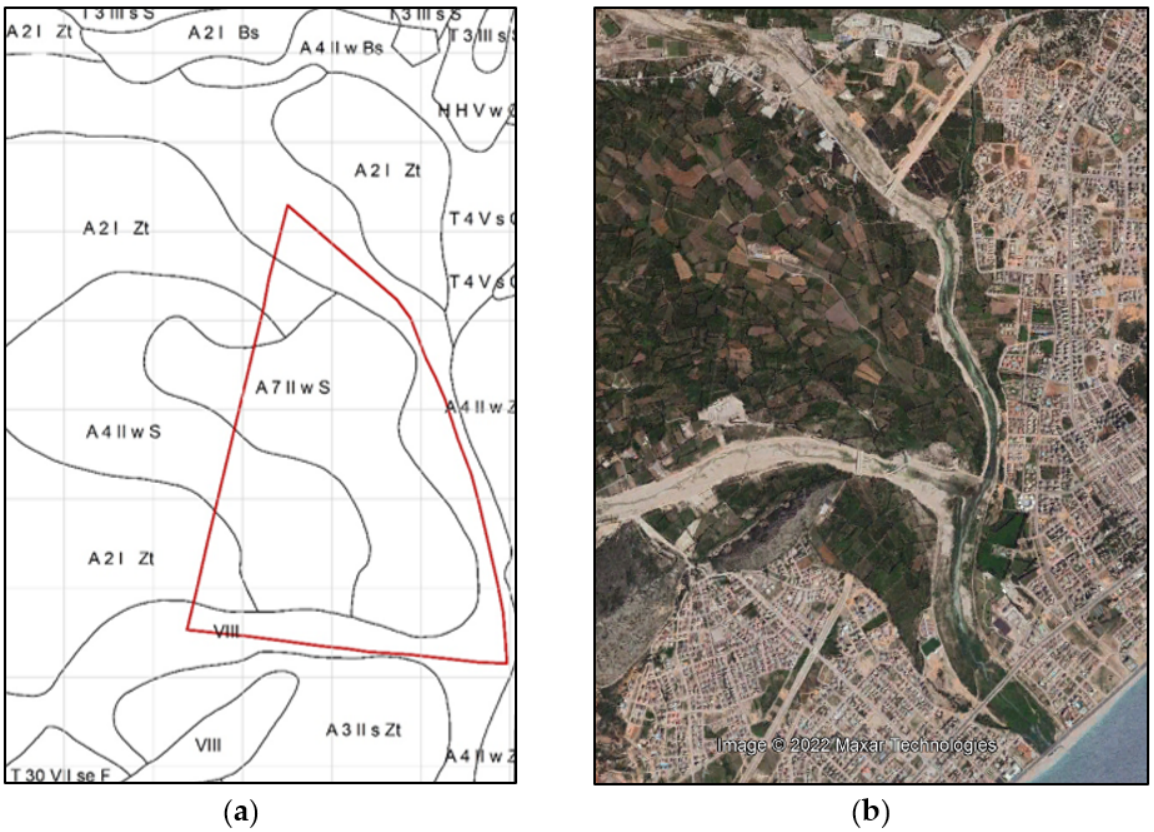

Fig.4 (a) Location of the study area on the soil map (Antalya Province Land Presence) (b) Satellite image of the area before the construction of the West Ring Road

The study area is a part of the agricultural basin. In the north of the area, there are agricultural lands in the villages of Bahtılı and Çakırlar, and they constitute agricultural areas as a whole with their soil, land use, and vegetation characteristics. The region located east of Karaman Stream and south of Çandır Stream maintains its current status as a planned urban area, as seen in Fig.4. The western part of the area is surrounded by cultivated agricultural lands, with citrus and pomegranate groves. The examinations performed in the area determined that the area consisted of irrigable lands with a slight slope (0-2%), deep (90 cm+) soils, no drainage problems, and with these features, it falls into the categories of Absolute Agricultural Lands and Cultivated Agricultural Lands.

Another classification conducted in terms of the agricultural capacity of the area was the Land Capability Classification. According to the Soil Map obtained from the Antalya Province Land Size Report, there are soil units with the symbols A2I Zt, A4 II wS, and A7 II wS in the study area. These lands are located in the Alluvial Great Soil group and are classified as type I and II, according to the Land Capability Classification. According to the same classification, type VIII lands also exist, which are riverbeds of Karaman Stream and Çandır Stream, and they are classified as non-agricultural areas. Accordingly, the measurements on the map revealed that approximately 240 hectares of the study area (282.40 hectares) consisted of agricultural lands and the remaining 42.4 hectares of non-agricultural areas, as seen in Fig.4.

3.2 Datasets

In an attempt to assess the damage to plant health in the agricultural lands, we performed (Normalized Vegetation Index) and dNDVI (Difference Normalized Vegetation) analyses using GIS and Remote Sensing (ArcGIS 10.5) programs on 30-meter resolution Landsat 8 and 9 images dated 17.06.2014, 20.06.2015, 22.06.2016, 25.06.2017, 12.06.2018, 15.06.2019, 03.07.2020, 06.07.2021, and 15.06.2022. The results of plant presence and plant health analyses were compared to show the areas with concentrated plant presence and determine the water presence.

Landsat satellite data are among the important datasets to detect the effects of urban areas. Landsat 8 and 9 satellites, which have eleven (11) spectral bands, have a resolution of 15 m in the eighth band and 100 m in the 10th and 11th thermal bands. The other bands have a resolution of 30 meters, so the studies in the literature frequently use these data to determine the field changes and their effects. The band, wavelength, and resolution properties of satellite images are given in Table 1.

Bands	Wavelength (micrometers)	Resolution (meters)
Band 1 - Coastal aerosol	0.43-0.45	30
Band 2 - Blue	0.45-0.51	30
Band 3 - Green	0.53-0.59	30
Band 4 – Red	0.64-0.67	30
Band 5 - Near Infrared (NIR)	0.85-0.88	30
Band 6 - SWIR 1	1.57-1.65	30
Band 7 - SWIR 2	2.11-2.29	30
Band 8 - Panchromatic	0.50-0.68	15
Band 9 - Cirrus	1.36-1.38	30
Band 10 - Thermal Infrared (TIRS) 1	10.6-11.19	100
Band 11 - Thermal Infrared (TIRS) 2	11.50-12.51	100

Tab.1 Landsat 8 and 9 Satellite Image Features (https://www.usgs.gov/faqs/what-are-band-designations-landsat-satellites)

3.3 Method

Remote sensing techniques are a contemporary method widely used in various fields, including identifying the spatiotemporal changes in land use (Dahanayake et al., 2024; Partheepan et al., 2023), determining suitable areas for urban development (Poudel et al., 2023), characterizing open spaces (Caprari & Malavolta, 2024), and analyzing the relationship between transportation and land use (Khatua et al., 2024).

Bands of satellite images and some remote sensing algorithms (NDVI, dNDVI) were evaluated together. According to the flowchart in Fig.5, the study consists of four basic stages: data collection, pre-processing, calculation of agricultural areas and vegetation affected by urban areas with different algorithms, and comparative evaluation.

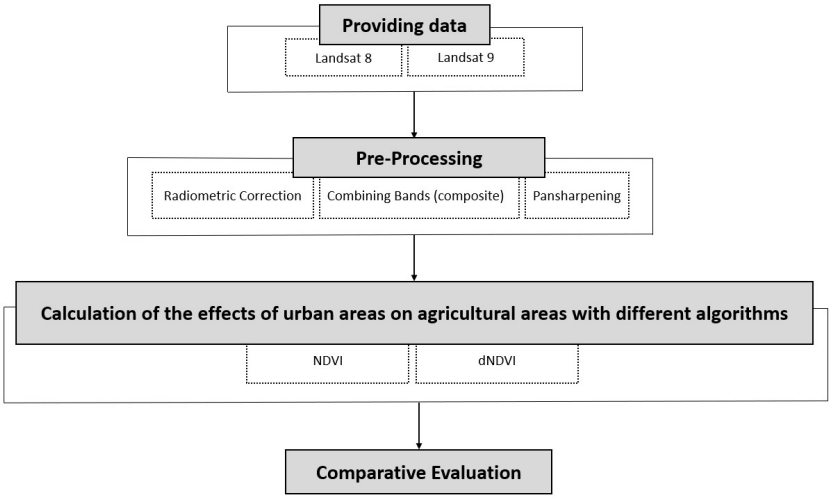

Fig.5 Flowchart

NDVI index is one of the remote sensing methods frequently used by research in the literature into the impacts of urban areas on farming lands to detect changes in damaged vegetation or living vegetation. While plants in the vegetation cover carry out photosynthesis by using the chlorophyll in their leaves, they utilize the electromagnetic energy coming from the sun in the range of 0.63μm – 0.69μm and corresponding to red light during the photosynthesis phase. Thus, it is expected that a satellite image measuring the reflection of red light will have low numerical values in areas with dense vegetation (Kandemir, 2010).

Near-infrared wavelength (0.68–0.78 μm), red wavelength (0.61–0.68 μm), NDVI indicates vegetation index value (Tucker, 1979). The NDVI index is defined within a range from -1 to +1, and in areas with dense vegetation, NDVI index values are close to NDVI + 1, while in sparse vegetation or bare surfaces, it is close to 0, and NDVI index values for water, snow, and clouds are close to -1 (Hatfield et al., 1985). dNDVI analysis is generally used in the literature to detect burned areas after forest fires. It is one of the algorithms developed in the discipline of remote sensing as one of the important analyses for the detection of changes in green areas (Afira & Wijayanto, 2022; Huang et al., 2016; Teodoro & Amaral, 2019).

$$NDVI = (NIR - RED)/(NIR + RED)$$

$$\text{for LANDSAT 8; } NDVI = (BAND5 - BAND4)/(BAND5 + BAND4) \quad (1)$$

$$dNDVI = NDVI(pre - road) - NDVI\ (post - road)$$

Colored infrared formed by band combinations is also called near-infrared (NIR) composite, with near-infrared (Band 5), red (Band 4), and green (Band 3) being used. Because chlorophyll reflects near-infrared light, this band composition analyzes vegetation presence. In particular, red-colored areas have better vegetation health.

Dark areas appear as those where water is present, while urban areas appear white. The presence of vegetation is revealed through colored infrared.

4. Results

The ring road construction in the study area started in October 2014. A cloudless satellite image of June 2014 was used to view the road construction. In order to visualize the after-road construction, eight cloudless satellite images for June 2015-2022 were obtained from Landsat 8 and Landsat 9 satellites. Calculations were made and mapped for the boundaries of the study area using NDVI (Normalized Vegetation Index) and dNDVI (Difference Normalized Vegetation Index) algorithms in a total of 9 satellite images. The beginning (2014) and end (2022) satellite images showing before and after road construction are shown in Fig.6.

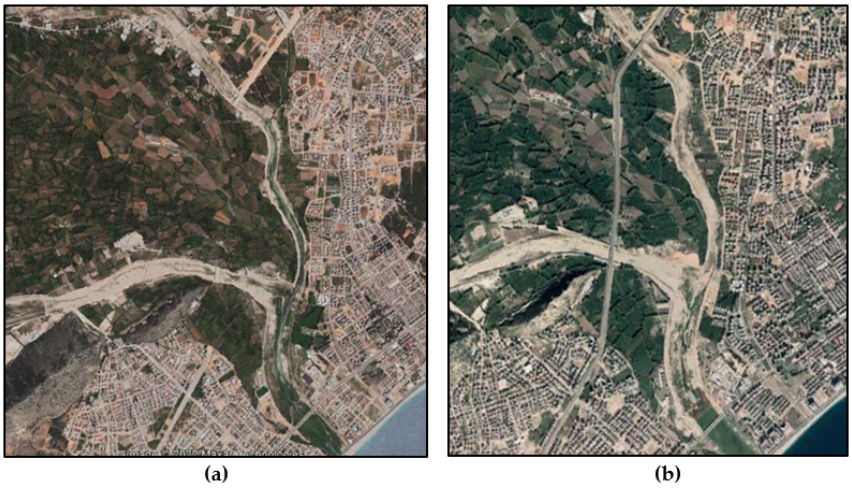

Fig.6 (a) Pre-Road Landsat 8 Satellite Image (2014) (b) Post-Road Landsat 9 Satellite Image (2022)

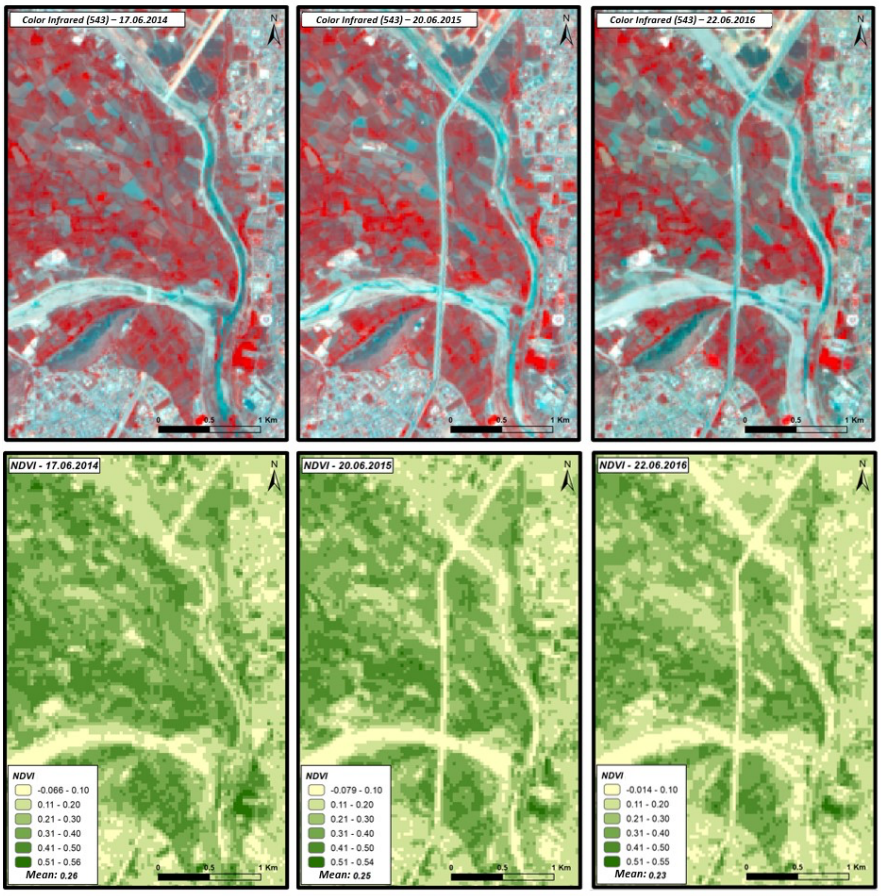

Fig.7 Color infrared satellite images and NDVI values for the years 2014 (Pre-Road)-2015-2016 (Post-Road)

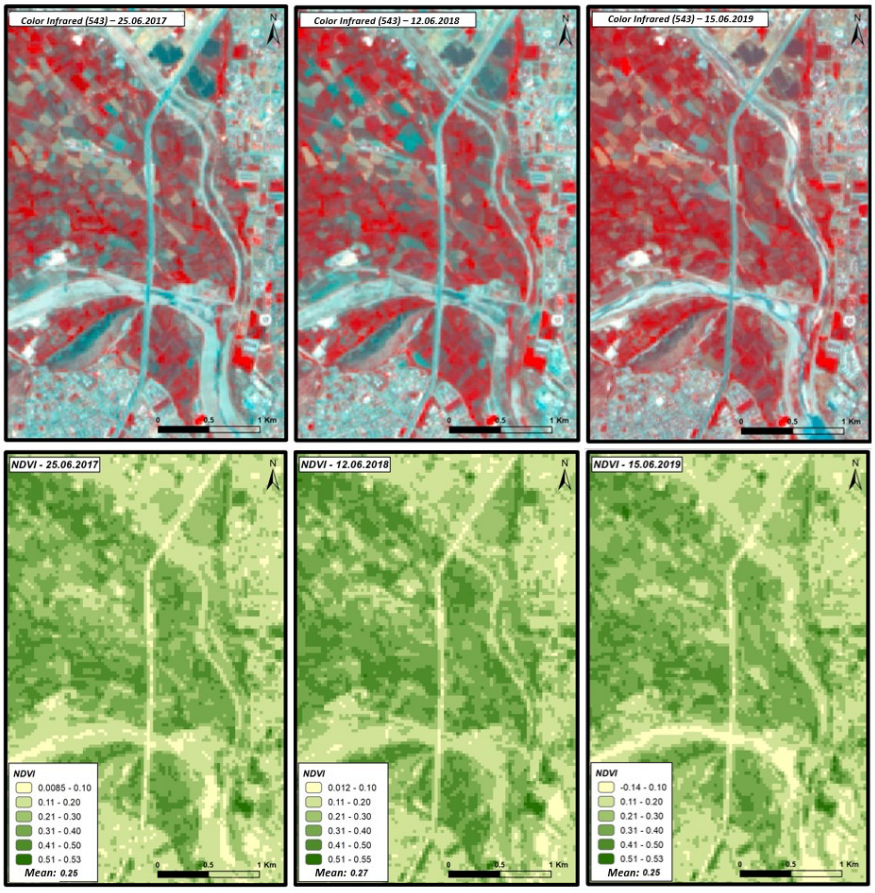

Fig.8 Color infrared satellite images and NDVI values for the years 2017-2018-2019 (Post-Road)

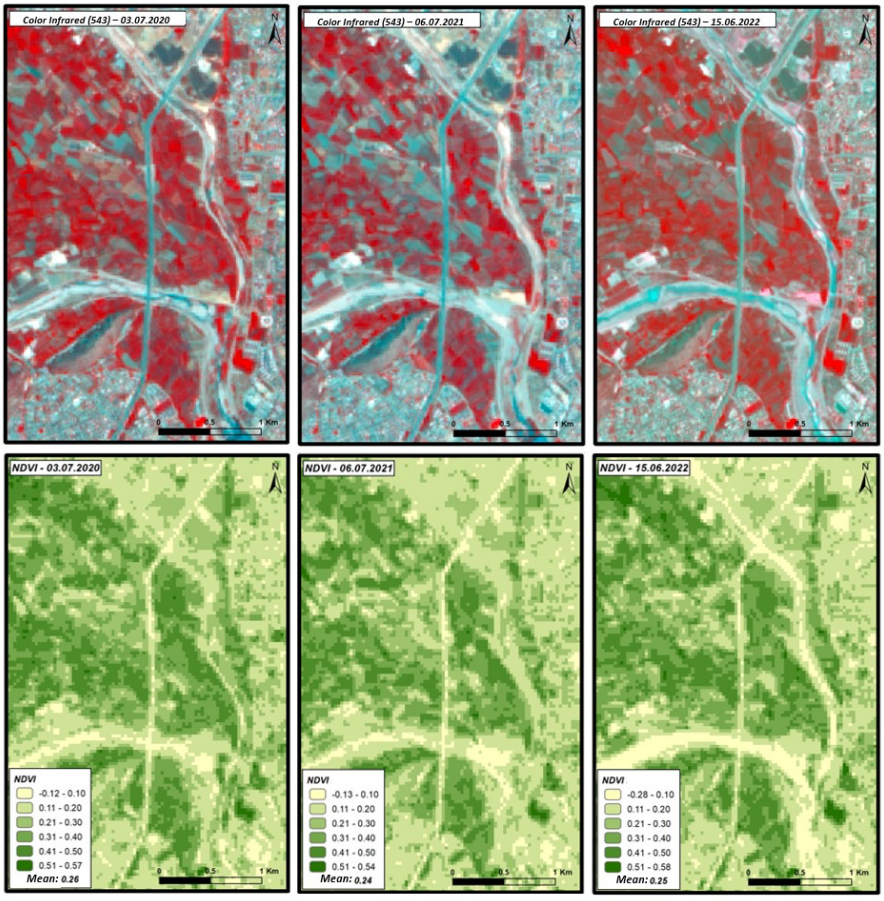

Fig.9 Color infrared satellite images and NDVI values for the years 2020-2021-2022 (Post-Road)

In statistical analyses, we compared plant health NDVI values by analyzing the average NDVI values of the study area created with the downloaded Landsat Satellite Image dated 17.06.2014 before the road construction and the average values of those dating from after the road construction (20.06.2015, 22.06.2016, 25.06.2017, 12.06.2018, 15.06.2019, 03.07.2020, 06.07.2021, and 15.06.2022). Fig.s 7, 8, and 9 show color infrared images and NDVI values for the specified years.

In the 9 years between 2014 and 2022, there are minimal differences in NDVI values. According to Fig.10, there were no significant differences between the NDVI values before and after road construction, and the maximum NDVI average increased. It was revealed that the ring road construction had no effect on plant health in the peripheral rural area. Therefore, the ring road had no negative impact on the agricultural area.

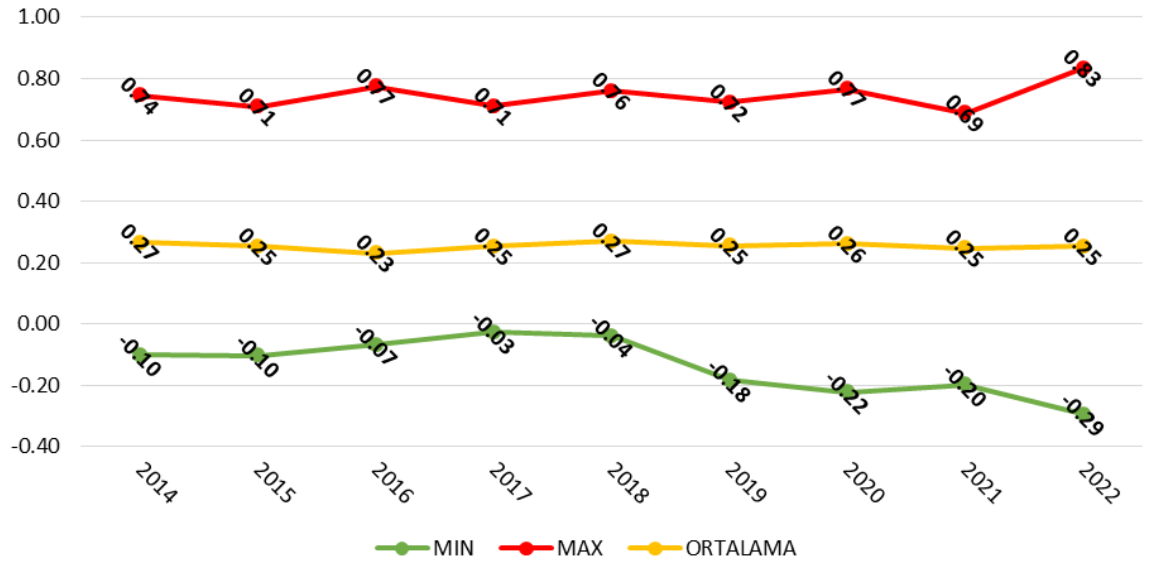

Fig.10 Changes in plant health in the study area over the years

Variance analyses showed a p-value of 0.094 ($p > 0.05$). Accordingly, Fig.6 shows no problem in plant growth in the study area during the 9-year monitoring period; maximum plant health data increased by 12.1%, whereas the average NDVI data decreased by only 0.7%. The cases where NDVI values showed slight variations in different years were determined, by on-site investigations, to be related to seasonal droughts, cultivation status, and irrigation of agricultural lands.

As seen in Fig.s 7, 8, and 9, the red areas in the images show areas with good plant health, and over the 9 years, there was no visible land use change other than the addition of the ring road.

In Fig.11(a), it is seen that the plant presence increased in the infrared images created by the combination of the bands between 2014 and 2022. We determined that some agricultural lands cultivated in 2014 were not cultivated in 2022 or that agricultural lands not cultivated in 2014 were cultivated in 2022, as in Fig.11, based on satellite images and on-site investigations.

The difference in plant presence and health was revealed as increasing and decreasing areas in the analysis of change, as in Fig.11d. In Fig.11c, the unchanged areas are indicated with yellow tones close to 0. Areas with agricultural lands that were not cultivated in 2014 but cultivated in 2022 and areas with increased plant health are close to -1, areas whose agricultural quality deteriorated due to roads, and areas with agricultural lands that were planted in 2014 and were not cultivated in 2022, with green color tones and close to +1. Agricultural areas that do not have any deterioration in plant health but have not been cultivated for various reasons will increase the minimum, average, and maximum NDVI values even more so when replanted. The dNDVI difference values will decrease, and the average variation will decrease.

The primary purpose of using the dNDVI (Differenced Normalized Vegetation Index) algorithm was to map regions that showed spatial variation in plant health within the agricultural area before and after road

construction. The peripheral areas with improved and impaired plant health before and after the road construction were determined as red and green areas, as seen in Fig.11d. Green areas indicate those with declined NDVI values, in other words, areas where plant health is impaired or turned into residential and water areas. In contrast, red areas indicate areas with improved plant health. In addition, while examining satellite images in the area, we determined that greenhouse areas increased after road construction, and these areas appear in red in the dNDVI analysis. It was determined that plant health increased in 597.5 hectares of 1171.7 hectares, while plant health decreased in 574.2 hectares (Tab.2).

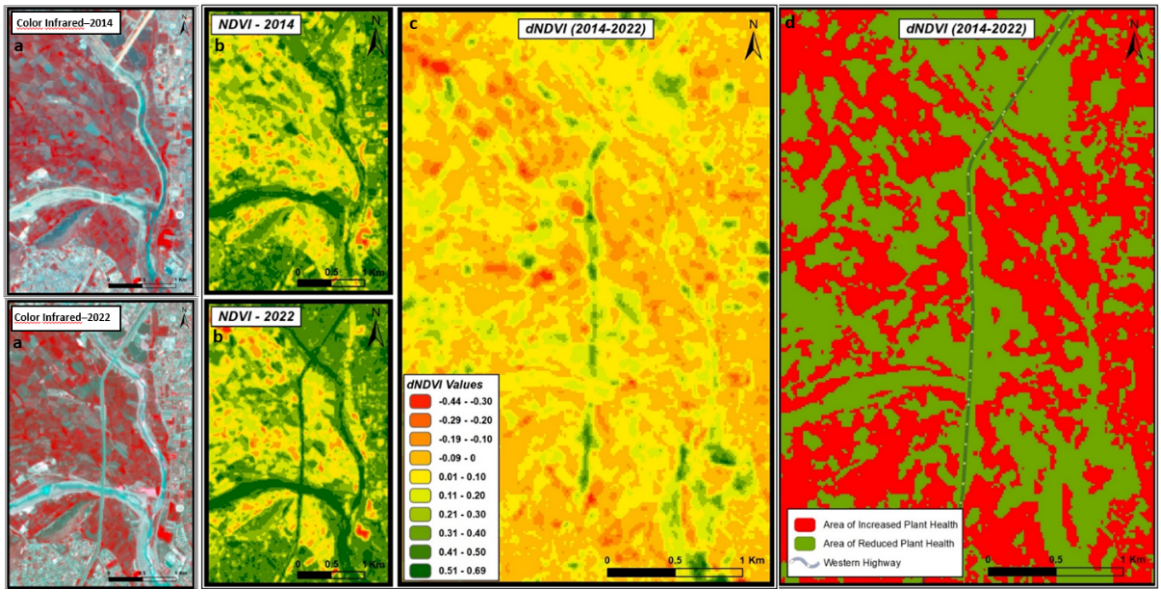

Fig.11 (a) Color infrared image before and after the change (b) NDVI analysis before and after the change (c) dNDVI results (d) Areas with increased and decreased plant health

Change of plant health (Hectares)	
Increase	597.5
Decrease	574.2
Total Working Area	1171.7

Tab.2 Changes in Plant Health by Land

5. Conclusion and findings

Our analyses, utilizing NDVI and dNDVI algorithms, infrared combinations, and dataset evaluations, indicate that the Western Ring Road in the northern Konyaaltı district of Antalya did not negatively impact plant health in the surrounding agricultural areas, nor did it diminish crop yield or productivity. These findings challenge the justification for rezoning agricultural lands based solely on assumptions of declining agricultural productivity. As a result, urban-rural dynamics should be assessed through an integrated part-whole approach, with planning strategies prioritizing conservation and sustainability. Ensuring that urban expansion follows rational and data-driven planning decisions will contribute to more sustainable development patterns.

Moreover, when planning a transportation network to enhance accessibility between urban areas, there is no inherent necessity to rezone peripheral agricultural lands unless clear evidence demonstrates a loss in agricultural productivity or land degradation post-construction. Transportation planning should involve rigorous analysis to determine whether routing through agricultural areas is the only viable option. If alternative routes exist, protecting agricultural land should be prioritized.

Furthermore, the mere decline of agricultural land quality should not be considered a sufficient criterion for rezoning an area for urban development. As observed in the case study, additional factors such as flood risk,

earthquake susceptibility, and ecological balance must be thoroughly assessed. At this stage, GIS and remote sensing technologies play a crucial role in ensuring objective, comparable, and sustainable planning decisions. However, considering only physical-environmental impacts is insufficient for sustainable planning. Prior to making zoning or land-use decisions, it is essential to incorporate stakeholder opinions, including those with direct rights and influence in the affected area. This participatory approach ensures that planning decisions align with social, economic, and environmental considerations.

Additionally, as demonstrated in this study, large infrastructure projects not only generate immediate environmental effects but also shape the microform of urban development in the long term. A limitation of this study is that the impact of the Western Ring Road was assessed solely concerning its effects on surrounding agricultural areas and plant health. Future research should adopt a broader perspective, evaluating the interaction between transportation infrastructure and urban growth within a larger spatial framework. This would provide a more comprehensive understanding of transportation-land use dynamics, contributing to more sustainable and holistic planning decisions.

Finally, our findings align with previous studies emphasizing the adverse effects of unregulated urban expansion on agricultural lands and the importance of defining clear planning thresholds to control development (Esopi, 2018; Samat et al., 2020). Without well-defined natural and artificial boundaries, zoning decisions may fail to remain permanent, leading to ongoing urbanization pressure on agricultural lands and ecologically sensitive areas (Tondelli et al., 2017). Our research reinforces the necessity of long-term strategic planning that integrates both environmental and socio-economic considerations in land-use decisions.

References

Afira, N. & Wijayanto, A. W. (2022). Mono-temporal and multi-temporal approaches for burnt area detection using Sentinel-2 satellite imagery (a case study of Rokan Hilir Regency, Indonesia). *Ecological Informatics, 69*, 101677. https://doi.org/10.1016/j.ecoinf.2022.101677

Alonso, W. (1964). *Location and land use: Toward a general theory of land rent*. Harvard University Press. https://doi.org/10.4159/harvard.9780674730854

Alphan, H. (2003). Land-use change and urbanization of Adana, Turkey. *Land Degradation & Development, 14* (6), 575-586. https://doi.org/10.1002/ldr.581

Anas, A. (1982). *Residential location markets and urban transportation: Economic theory, econometrics, and policy analysis with discrete choice models*. Academic Press.

Arima, E. Y., Walker, R. T., Perz, S. G. & Caldas, M. (2005). Loggers and forest fragmentation: Behavioral models of road building in the Amazon basin. *Annals of the Association of American Geographers, 95* (3), 525-541.

Boyce, D. E. (1980). A framework for constructing network equilibrium models of urban location. *Transportation Science, 14* (1), 77-96. https://doi.org/10.1287/trsc.14.1.77

Brandi, A., Gori, S., Nigro, M., & Petrelli, M. (2014). Development of an integrated transport-land use model for the relocation of activities in urban areas. *Transportation Research Procedia, 3*, 374-383. https://doi.org/10.1016/j.trpro.2014.10.119

Brereton, F., Bullock, C., Clinch, J. P., & Scott, M. (2011). Rural change and individual well-being: The case of Ireland and rural quality of life. *European Urban and Regional Studies, 18* (2), 203-227. https://doi.org/10.1177/0969776411399346

Buliung, R. N. & Kanaroglou, P. S. (2006). A GIS toolkit for exploring geographies of household activity/travel behavior. *Journal of Transport Geography, 14* (1), 35-51. https://doi.org/10.1016/j.jtrangeo.2005.05.002

Caprari, G. & Malavolta, S. (2024). Analysis of territorial fragilities through GIScience. *TeMA - Journal of Land Use, Mobility and Environment*, 169-190. https://doi.org/10.6092/1970-9870/10200

Chávez Michaelsen, A., Huamani Briceño, L., Fernandez Menis, R., Bejar Chura, N., Valera Tito, F., Perz, S., Brown, I. F., Domínguez Del Aguila, S., Pinedo Mora, R. & Alarcón Aguirre, G. (2013). Regional deforestation trends within local realities: land-cover change in southeastern Peru 1996–2011. *Land, 2* (2), 131-157. https://doi.org/10.3390/land2020131

Dahanayake, H. D., Dahanayaka, D. D. G. L., Hudson, P. & Wickramasinghe, D. (2024). Land use changes of coastal wetlands using remote sensing. A case study of Muthurajawela & Anawilundawa wetlands, Sri Lanka. *TeMA - Journal of Land Use, Mobility and Environment, 17* (1), 7-21. https://doi.org/10.6093/1970-9870/10281

Demirel, H. (2004). A dynamic multi-dimensional conceptual data model for transportation applications. *ISPRS Journal of Photogrammetry and Remote Sensing, 58* (5-6), 301-314.

Esopi, G. (2018). Urban commons: social resilience experiences to increase the quality of urban system. *TeMA - Journal of Land Use, Mobility and Environment, 11* (2), 173-194. https://doi.org/10.6092/1970-9870/5532

Foth, N., Manaugh, K. & El-Geneidy, A. M. (2013). Towards equitable transit: examining transit accessibility and social need in Toronto, Canada, 1996-2006. *Journal of Transport Geography, 29*, 1-10. https://doi.org/10.1016/j.jtrangeo.2012.12.008

Futemma, C. & Brondízio, E. S. (2003). Land reform and land-use changes in the lower Amazon: Implications for agricultural intensification. *Human Ecology, 31*, 369-402. https://doi.org/10.1023/A:1025067721480

Geurs, K. T. & van Wee, B. (2004). Land-use/transport interaction models as tools for sustainability impact assessment of transport investments: review and research perspectives. *European Journal of Transport and Infrastructure Research, 4* (3), 127-140. https://doi.org/10.1016/j.jtrangeo.2003.10.005

Hatfield, J., Kanemasu, E., Asrar, G., Jackson, R., Pinter Jr, P., Reginato, R. & Idso, S. (1985). Leaf-area estimates from spectral measurements over various planting dates of wheat. *International Journal of Remote Sensing, 6* (1), 167-175.

Hawkins, J. & Nurul Habib, K. (2019). Integrated models of land use and transportation for the autonomous vehicle revolution. *Transport Reviews, 39* (1), 66-83. https://doi.org/10.1080/01441647.2018.1507893

Huang, H., Roy, D. P., Boschetti, L., Zhang, H. K., Yan, L., Kumar, S. S., Gomez-Dans, J. & Li, J. (2016). Separability analysis of Sentinel-2A Multi-Spectral Instrument (MSI) data for burned area discrimination. *Remote Sensing, 8* (10), 873. https://doi.org/10.3390/rs8100873

Ing, C., Beattie, C. & Longhurst, J. (2001). Progress with implementing local air-quality management in rural areas of England. *Journal of Environmental Management, 61*(2), 137-147. https://doi.org/10.1006/jema.2000.0403

Khatua, A., Goswami, A. K. & Aithal, B. H. (2024). Building type classification using deep learning for transport planning. *TeMA - Journal of Land Use, Mobility and Environment, 17* (3), 397-410. https://doi.org/10.6093/1970-9870/10729

Kaliraj, S., Chandrasekar, N., Ramachandran, K., Srinivas, Y. & Saravanan, S. (2017). Coastal landuse and land cover change and transformations of Kanyakumari coast, India using remote sensing and GIS. *The Egyptian Journal of Remote Sensing and Space Science, 20*(2), 169-185. https://doi.org/10.1016/j.ejrs.2017.04.003

Kandemir, E. (2010). Uzaktan algılama tekniğinde NDVI değerleri ile doğal bitki örtüsü tür dağılımı arasındaki ilişkilerin belirlenmesi üzerine araştırmalar. *Fen Bilimleri Enstitüsü, Çevre Bilimleri Ana Bilim Dalı, Yüksek Lisans Tezi, 60*.

Lefebvre, H. (2003). *The urban revolution*. University of Minnesota Press.

Lopez-Ruiz, H. G., Christidis, P., Demirel, H. & Kompil, M. (2013). Quantifying the effects of sustainable urban mobility plans. *Report EUR, 26123*.

Partheepan, K., Musthafa, M. M. & Bhavan, T. (2023). Remote sensing investigation of spatiotemporal land-use changes. *TeMA - Journal of Land Use, Mobility and Environment, 16* (2), 383-402. https://doi.org/10.6093/1970-9870/9908

Poudel, S., Shahnawaz, S. & Shrestha, H. L. (2023). Suitable sites for built-up area expansion in Kamalamai municipality, Sindhuli district, Nepal. *TeMA - Journal of Land Use, Mobility and Environment, 16* (2), 279-305. https://doi.org/10.6093/1970-9870/9968

Samal, D. R. & Gedam, S. S. (2015). Monitoring land use changes associated with urbanization: An object-based image analysis approach. *European Journal of Remote Sensing, 48* (1), 85-99. https://doi.org/10.5721/EuJRS20154806

Samat, N., Ghazali, S., Hasni, R. & Elhadary, Y. A. E. (2020). Land Use Change, Spatial Interaction, and Sustainable Development in the Periphery of the Metropolitan Region. *Land, 9* (3), 95. https://doi.org/10.3390/land9030095

Sietchiping, R., Kago, J., Zhang, X. Q., Augustinus, C. & Tuts, R. (2014). Role of urban–rural linkages in promoting sustainable urbanization. *Environment and Urbanization Asia, 5* (2), 219-234. https://doi.org/10.1177/0975425315577170

Singh, A. (1989). Review article digital change detection techniques using remotely-sensed data. *International Journal of Remote Sensing, 10* (6), 989-1003. https://doi.org/10.1080/01431168908903939

Suri, L. (2018). Planlamada Doğal Eşik Değerlendirme Kriterleri. *İstanbul Ticaret Üniversitesi Fen Bilimleri Dergisi, 17* (34), 47-67.

Tao, L. (2007). A Study of the Tibetan Rural Urbanisation Model. *China Report, 43* (1), 31-42. https://doi.org/10.1177/000944550704300103

Teodoro, A. & Amaral, A. (2019). A statistical and spatial analysis of Portuguese forest fires in summer 2016 considering Landsat 8 and Sentinel 2A data. *Environments, 6* (3), 36. https://doi.org/10.3390/environments6030036

Tondelli, S., Bartolacci, S. & De Medici, S. (2017). Urban growth and planning sustainability: The role of natural and artificial thresholds. *TeMA - Journal of Land Use, Mobility and Environment, 10* (2), 153-172. https://doi.org/10.6092/1970-9870/5532

Tucker, C. J. (1979). Red and photographic infrared linear combinations for monitoring vegetation. *Remote Sensing of Environment, 8* (2), 127-150. https://doi.org/10.1016/0034-4257(79)90013-0

Wang, J., Wei, H., Cheng, K., Li, G., Ochir, A., Bian, L., Davaasuren, D., Chonokhuu, S. & Nasanbat, E. (2019). Spatio-temporal pattern of land degradation along the China-Mongolia railway (Mongolia). *Sustainability, 11* (9), 2705. https://doi.org/10.3390/su11092705

Wegener, M. & Fürst, F. (2004). Land-use transport interaction: State of the art. *Available at SSRN 1434678*. https://doi.org/10.2139/ssrn.1434678

Zhu, X. & Liu, S. (2004). Analysis of the impact of the MRT system on accessibility in Singapore using an integrated GIS tool. *Journal of Transport Geography, 12* (2), 89-101. https://doi.org/10.1016/j.jtrangeo.2003.10.005

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Campi Flegrei and the Metropolitan Area of Naples. Emergency planning in a high-risk territory

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Abstract
The territory surrounding the city of Naples is characterized by three active volcanic risk sources: Vesuvius, Campi Flegrei, and the island of Ischia. The objective of this study is to examine the characteristics of emergency planning in response to volcanic risk. The methodology of the paper consists of three steps. The first step identifies the fundamental elements of this type of planning using international studies and national frameworks. The second step analyzes the emergency plan for Campi Flegrei, focusing particularly on its primary objective: the evacuation of the population in the event of a volcanic eruption. Additionally, this section examines the recent worsening of bradyseism in the Pozzuoli area, which, due to its location, has increased experts' attention on the entire Campi Flegrei region. The third step involves a coherence analysis between the contents of the Campi Flegrei emergency plan and the guidelines outlined in the international studies and national frameworks introduced in the first step. The main results of the analysis highlight the strengths and weaknesses of the plan. Another significant finding confirms the close relationship between emergency planning and territorial planning. The current situation of the metropolitan area of Naples has been influenced by territorial plans that have paid insufficient attention to the risks present in the region. The next steps of the research emphasize the necessity for the new metropolitan plan to serve as an active tool for addressing territorial vulnerabilities. This should be approached with a focus on integrating risk mitigation into broader spatial planning initiatives.

Keywords
Campi Flegrei; Emergency planning; Territorial planning.

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1. Introduction

The territory surrounding the city of Naples is distinguished by its remarkable attractions which have historically acted as catalysts for settlement. Today, more than three million inhabitants are concentrated in the area, with nearly half directly affected by volcanic risks due to the presence of three active sources: Vesuvius, Campi Flegrei, and Ischia Island (Chester et al., 2000; Mazzeo, 2009; Mazzeo & Polverino, 2023). The three volcanic systems could be activated at any time with a hypothetical considerable destructive force: buildings and infrastructures could suffer considerable damage, while the number of victims and injured could be equally significant. The volcanic risk of Vesuvius and the Campi Flegrei has led to the delineation of two red zones, encompassing the areas directly affected by a potential eruption (Fig.1).

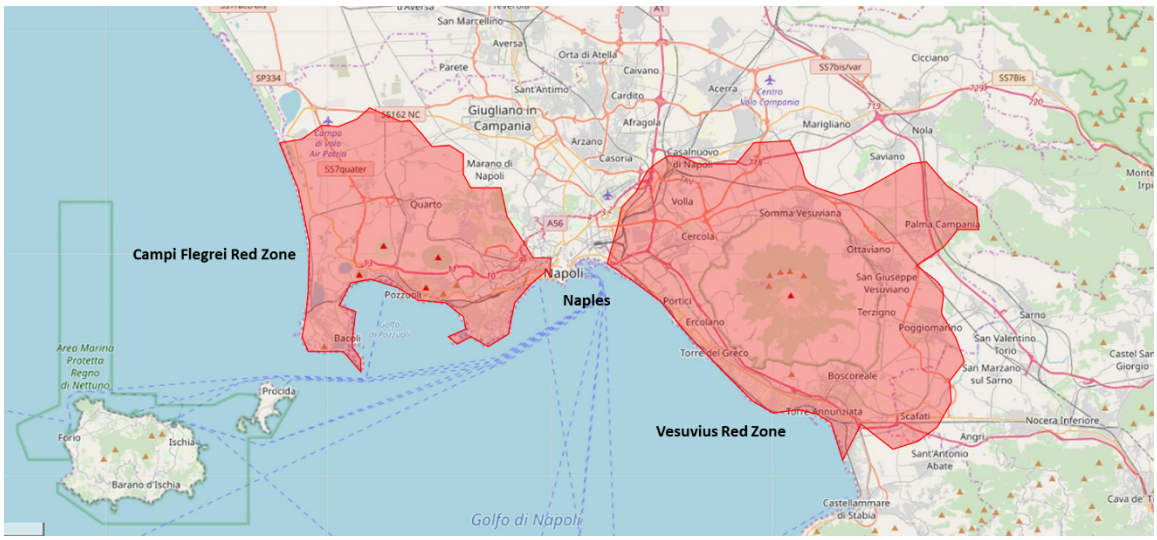

Fig.1 Metropolitan area of Naples. The Red Zones of Campi Flegrei to the West and Vesuvius to the East. The city of Naples is in the middle of the two areas

In this area the volcanoes are active geo-morphological structures that can generate both effusive eruptions (lava flows descending along the slopes) and explosive, or sub-Plinian eruptions. The greatest damage scenario follows an explosive eruption, where the main phenomenon is the formation of an eruptive column that generates pyroclastic flows consisting of a mixture of volcanic material and gases. These high-temperature flows move at high speeds with such destructive power that the only protective measure considered effective is the preventive and complete evacuation of the at-risk area (INGV, 2019).

A secondary phenomenon in this eruptive scenario is the fall and accumulation of ash, which can cause the collapse of structures and roofs. This phenomenon is linked to the pattern of stratospheric winds which, at the latitude of the area, predominantly blow from West to East. This means that the risk of ashfall on the city of Naples is greater in the event of an eruption of the Campi Flegrei rather than an eruption of Vesuvio.

The existence of such a significant risk represents a potential critical issue of national importance. For this reason, attention to possible responses in terms of emergency planning has greatly increased over the past years. Despite this attention leading to the creation of two emergency plans, doubts remain about the quality of the planning and its applicability, specifically whether it can provide an effective and substantial contribution when transitioning from a phase of peace to one of emergency.

The area concentrates both natural and anthropogenic risks. In addition to volcanic risk, there are hydrogeological and seismic risks, as well as an anthropogenic risk due to the presence of activities and a high population density. With over 3 million inhabitants on 1,171 square kilometers, the region ranks first in Italy for population density.

These figures alone necessitate careful territorial planning. However, this has only been partially achieved, resulting in largely chaotic and unregulated development (Papa & Mazzeo, 2014). The scale of illegal

construction is one of the main causes of the area's vulnerability (Mela et al., 2017). This is compounded by an infrastructure network that developed over time in response to settlement processes, rather than guiding them (Cascetta, 2001), posing significant challenges even during regular use. Human actions have therefore added a substantial level of settlement vulnerability to the existing natural vulnerabilities.

The scientific literature on volcanic risk planning encompasses various analytical factors. It starts from encyclopedic analyses, as in Aspinall et al. (2015) and in Wei (2021), to the value of uncertainty in emergency planning cases (Hicks et al., 2014; Norton et al., 2015), to volcanic risk management processes (Pareschi et al., 2000; Bonadonna et al., 2021; Brown et al., 2021). A significant portion of the literature over time has focused on the Neapolitan area, with particular attention to emergency planning (Rolandi, 2010; Baxter et al., 2008; Tomasone et al., 2022; Troise et al., 2022; Moraci et al., 2024; Sgambati & Stiuso, 2023), also in relation to sociological and anthropological factors (Gugg, 2018).

The aim of the paper is to analyze and evaluate the emergency planning tool developed for the Red Zone of Campi Flegrei. To achieve this result, a comparative methodology is used. This approach is based on the analysis of various national and international sources, from which the main elements that should be included in an emergency plan are extracted. These general elements are then compared with the contents of the emergency plan for the Campi Flegrei. The analysis has two objectives: to identify the differences and similarities and to qualitatively assess the coherence between them.

Starting with the introduction, the paper is organized as follows. Chapter 2 of the paper analyzes a range of national and international studies and sources focused on the content of emergency plans. Chapter 3 addresses the emergency plan for the Campi Flegrei and the phenomenon of bradyseism. Chapter 4 outlines the findings of the comparison between the general elements and the specific elements of the emergency plan for the Campi Flegrei and it discusses the results obtained. Chapter 5 highlights the minor role of the Territorial Plan of the Metropolitan City of Naples in the evolution of emergency planning.

2. Elements of a volcanic emergency plan

The development of an emergency plan related to volcanic risk falls within the broader topic of emergency planning that has evolved over recent decades. Both studies in areas such as planning and forecasting volcanic phenomena, and the experiences accumulated by national and international civil protection agencies have contributed to it. Together, these have enabled the formulation of guidelines aimed at creating emergency tools based on a high level of involvement of the communities affected by these phenomena (Quarantelli, 1982; Quarantelli, 1985; Lindell & Perry, 1992; Rockett, 1994; Alexander, 2003, Garau et al., 2023). According to Perry and Lindell (2003), there are a series of criteria that recur more frequently and are present in the emergency planning systems of some nations (Emergency Management Australia, 1998; New Zealand Government, 2002), namely:

- An accurate understanding of threats and the most likely human responses;
- Effective planning, to be translated into appropriate actions by civil protection;
- The recognition that natural phenomena occur in dynamic environments, implying that it is impossible to foresee all eventualities that may arise from an event;
- The necessity for emergency planning to be based on coordination among the various organizations involved;
- The necessity for plans to include substantial training;
- The provision for continuous and rigorous drills to test response operations;
- Awareness that emergency planning creates or encounters conflicts and resistance;
- Awareness that planning and management are distinct phases, so the true test of a plan is its actual implementation.

These general criteria must be specified in relation to the different types of risks to be addressed, such as hydrogeological risk (Hervás, 2003; Menoni & Pesaro, 2008) or seismic risk (Carreño et al., 2007).

Due to its characteristics, the listed criteria have even more specific significance in the case of volcanic risk. On one hand, it is precisely localized; on the other, it can cause significantly greater damage than other natural phenomena. Moreover, studies on volcanoes lead to the construction of scenarios that generally have greater accuracy compared to other risks. According to the Federal Emergency Management Agency (FEMA, 2020), a volcanic eruption can contaminate water sources, damage machinery and equipment, reduce visibility due to smog and harmful gases affecting lower-lying areas, and make breathing difficult while irritating the skin, eyes, nose, and throat.

To counter the harmful effects of a volcanic event, the only possible protection is to flee the threatened areas. Mass evacuation and other protective measures are more effective if planned and organized in advance. Mass evacuation, in fact, involves significant disruptions to the daily lives of a large number of people and can only be implemented when the risks associated with living in the dangerous areas are deemed unavoidable.

According to the United Nations (UN, 1985), the preparation of emergency plans in areas with volcanic risks requires the presence of some basic preconditions:

- A general awareness within the exposed community of the danger and the risks to life and property;
- The willingness to undertake collective action to reduce these risks;
- The existence of a regulatory framework to plan, organize, and implement appropriate protective measures at both national and local levels, including, if necessary, the evacuation of threatened areas and assistance to displaced persons;
- Sufficient scientific knowledge of the volcano to allow the development of eruption scenarios;
- The ability to recognize warning signs of an imminent eruption through visible signs of activity or scientific monitoring of the volcanoes, allowing for the possibility of taking appropriate actions.

Under these conditions, it is possible to develop a plan based on the following basic criteria (UN, 1985):

- Identification and mapping of hazardous areas;
- Creation of a register of valuable movable assets (excluding easily transportable personal effects);
- Identification of safe areas that can serve as shelters for the evacuated population;
- Identification, maintenance, and use of evacuation routes;
- Identification of assembly points for people awaiting transportation;
- Inventory of transportation means and traffic control systems;
- Preparation of shelter areas;
- Inventory of rescue personnel and equipment for search and security operations;
- Characterization of necessary hospital and healthcare services;
- Security of evacuated areas;
- Warning procedures;
- Procedures for drafting and disseminating public notices;
- Drafting of emergency communications;
- Provisions for updating the plan.

Overall, the ability of a plan to handle an emergency situation fundamentally depends on its components and specific characteristics such as completeness, operability, effectiveness, flexibility, speed, and rationality (Cheng & Qian, 2010).

The evolution of emergency planning has led to significantly more advanced results compared to the early experiences, with tools that have gradually moved away from simply predicting the means necessary to deal with an emergency. Consequently, although they continue to be structured as civil protection plans, they increasingly incorporate territorial content. This evolution is evident in the Directive of the President of the

Council of Ministers dated April 30, 2021, Guidelines for the Preparation of Civil Protection Plans at Various Territorial Levels (DPC, 2021).

The technical annex to the Directive defines the content of the plans. The core of the plan is the definition of optimal territorial and organizational scopes, which includes the geographical delineation of the areas covered by the planning and the organizational criteria, in terms of entities responsible for planning and managing emergencies. Once the scope is defined, the technical annex specifies the content of the civil protection plan at different scales. It must include:

- Introductive elements. Approval, update data and a summary of the main contents;
- Territorial framework. Key information on the physical layout of the territory, the meteorological and climatic regime, urban settlements, infrastructure, the productive system, urban and territorial planning, and the main natural and anthropogenic risks;
- Hazard and risk scenarios must be identified for planning purposes. This identification is a forecasting activity that serves both the warning and alert phases, as well as the construction of the Civil Protection Plan. The Civil Protection Code (Legislative Decree Nr. 1/2018) frames this activity as dynamic and evolving, anticipating a response that adapts to technological and organizational developments and requires continuous monitoring in specific cases. This applies to all territorial levels and covers events related to one or more types of risk, as outlined in Article 16 of the decree. For volcanic risk scenarios, reference must be made to national directives, operational guidelines, and plans issued for each specific volcano.
- Intervention model. It includes the organization of the civil protection structure, strategic elements, and operational procedures. It consists of organizing the civil protection structure, strategic and operational elements of civil protection planning, and operational procedures related to the actions of entities participating in emergency management.

3. Case study: Campi Flegrei

Campi Flegrei is a volcanic area. The caldera of Campi Flegrei was shaped by a series of major volcanic eruptions, the last one in 1538, forming a system of characteristics cones. A specific volcanic phenomenon of the caldera is the slow and continuous uplift and subsidence of the ground. This phenomenon goes by the name of bradyseism (from Greek βραδύς bradýs, "slow" and σεισμός seismós, "shake"). It occurs as a bell-shaped deformation of the inner caldera, which has a radius of a few kilometers, roughly centered at the town of Pozzuoli (Iervolino et al., 2024). Since the beginning of the last century, there have been periods of rapid rise and slow subsidence, as between 1982 and 1984, with uplift rates of several centimeters per month, and accompanied by seismicity featuring thousands of earthquakes, the largest of which had magnitude equal to 4.2.

After a period of slow subsidence without recorded earthquakes, there has been a steady rise in ground level since 2011. This uplift accelerated in 2018, reaching rates of about 2 cm/month in 2024 with about 9,000 recorded earthquakes, most of which since 2022, with peaks of about 1000 earthquakes per month, with largest one (Md = 4.4) in May 2024.

3.1 The Emergency Plan for Campi Flegrei

The Emergency Plan for the area of Campi Flegrei follows the guidelines of the twin plan for Vesuvius. The reference text for the Vesuvius emergency plan is the Decree of the Civil Protection Department dated February 2, 2015, which provides guidelines to the components and operational structures of the National Civil Protection Service for updating emergency plans related to the precautionary evacuation of the population in the Red Zone of the Vesuvius area. The plan identifies the risk zones and establishes operational intervention phases based on a reference scenario and specific alert levels.

Like the Vesuvius area, the Campi Flegrei region is also divided into a Red Zone and a Yellow Zone (Civil Protection Department, 2019a, 2019b).

The Red Zone, to be evacuated as a precaution in case of eruptive activity, includes the entire territories of Pozzuoli, Bacoli, Monte di Procida, Quarto, 7 Municipalities of Naples, and part of Marano di Napoli and Giugliano in Campania (Fig.2). The population of the Red Zone amounts to approximately 500,000 inhabitants.

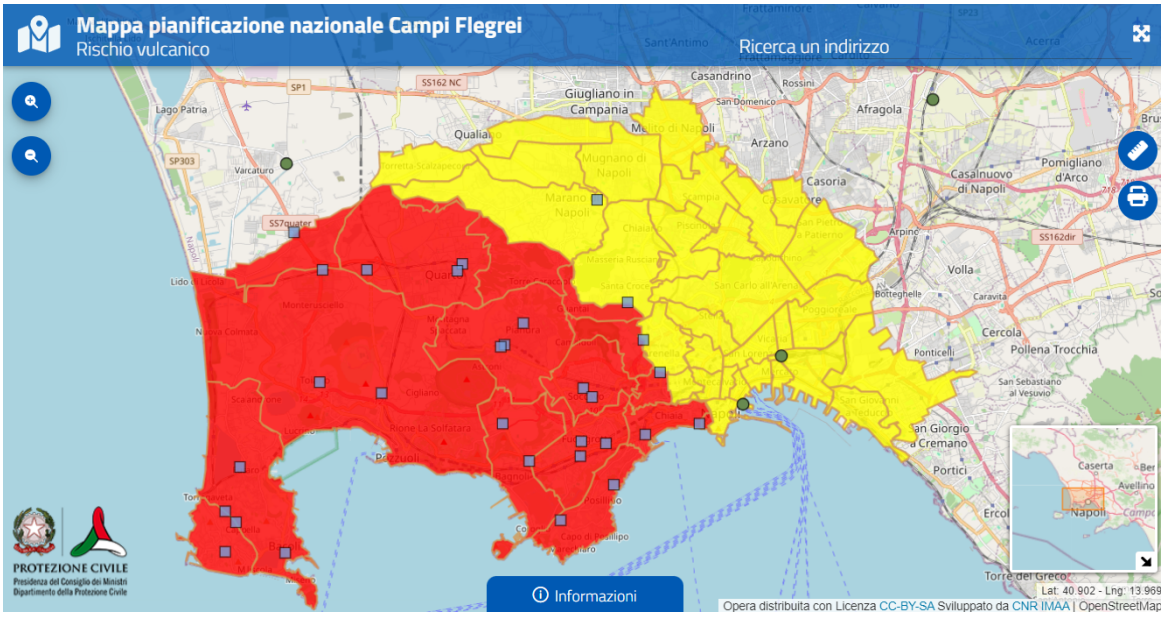

Fig.2 Red and Yellow Zones of Campi Flegrei

The most recent delimitation is the result of an update to the emergency planning with the redefinition of the Red Zone and the inclusion of the spread of pyroclastic flows as a risk factor due to the high probability of this phenomenon. This update has consequently led to the provision for precautionary evacuation in the event of renewed eruptive activity.

The Decree of the President of the Council of Ministers (DPCM) dated June 24, 2016, provides guidelines for updating the emergency planning. The Red Zone requires precautionary evacuation to safeguard human lives from the effects of an eruption. The evacuation can be carried out using private or Civil Protection resources, utilizing predetermined routes that include first-level gates and meeting areas (Galderisi et al., 2021) (Fig.3). To ensure subsequent assistance to the population, each Municipality of the Red Zone is twinned with a Region or Autonomous Province according to a distribution detailed in a specific annex.

The Yellow Zone is the area identified by studies as being exposed to the fallout of pyroclastic material. It includes the area that fall within a load curve of 300 kg/m² (a thickness of 30 cm), with an additional 5% probability of exceeding this load value. For this area, it will be necessary to adopt specific measures to safeguard the population, based on diverse, dynamic, and context-specific operational strategies at the time of the emergency. This is because its delimitation cannot be determined in advance, but only during the event. Ash accumulations of less than 30 cm may still affect areas outside the Yellow Zone. For this reason, municipalities are identified where ash accumulations of more than 5 cm are expected, with an additional 5% increase for exceeding the load threshold of 50 kg/m².

For the development and updating of emergency plans and evacuation plans for the population of the Red Zone of the Campi Flegrei, the guidelines contained in the provision for the Vesuvius area (DPCM February 2, 2015) are also valid, with appropriate adaptations to the territory of Campi Flegrei.

Each of the components and operational structures to which the guidelines provided by the Head of the Civil Protection Department are addressed were required to draft, update, and adapt their respective emergency plans within six months of the publication of the DPCM.

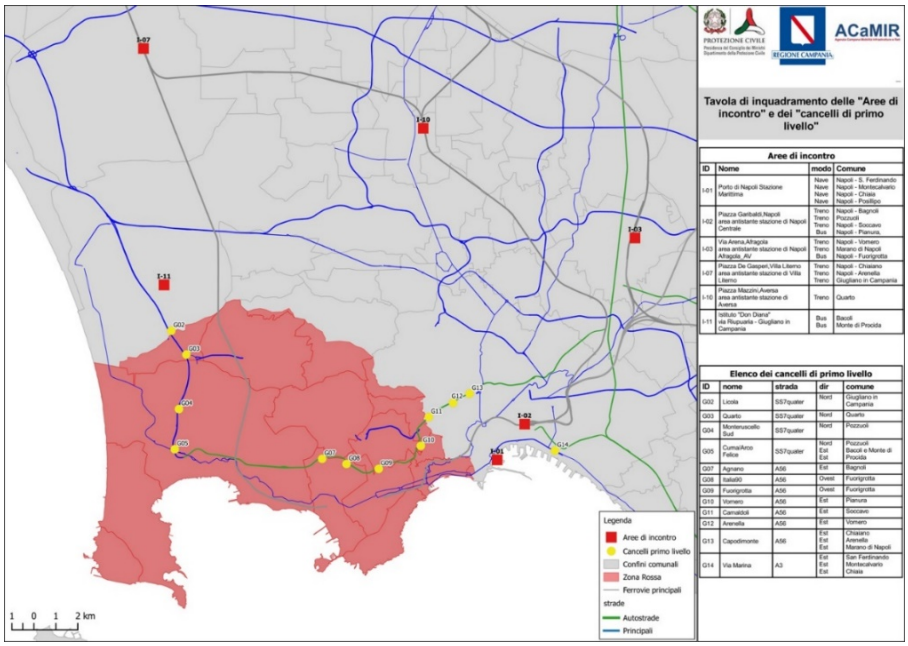

Fig.3 Campi Flegrei Emergency Plan-First level gates and meeting areas

The alert levels provided are four: base level, attention level, pre-alarm level, and alarm level. In case of activation, the National Commission for Major Risks, Volcanic Risk Sector, proposes moving to the next alert level based on monitoring data and technical-scientific reports from the Department of Civil Protection. The levels of attention, pre-alarm, and alarm correspond to significant variations in precursor signs detected by the monitoring system, which may indicate the approach of an eruptive phase.
Once activation starts, the duration of each level cannot be determined in advance. The transition to the next alert levels will occur based on the evolution of monitored parameters.

Alert level	Level activation time	State of the volcano	Actions planned for the population
Base	Undefined	No significant changes in the monitored parameters	No action
Attention	Undefined (a few months)	Significant variation in monitored parameters	Updating population data. Assessment and quantification of transportation, housing, health and psychosocial needs
Pre-alarm	From months to weeks	Further significant variation in the monitored parameters	Voluntary evacuation to autonomous alternative accommodations. Establishment of gates. Regulation of access to the Red Zone. Preparation of measures to be implemented in the third level
Alarm	From weeks to days	Appearance of phenomena / trend of monitored parameters that indicate a pre-eruptive dynamic. Event in progress	Population evacuation within 72 hours. Private traffic prohibited on the main evacuation network

Tab.1 Alert levels and activation times

In the absence of direct data on activation times, scientific literature is consulted, and precursor phenomena observed at other volcanoes are considered, hypothesizing that behavioral similarities may exist. These similarities could help transform seemingly random phenomena into signals that warrant close monitoring (Cashman & Giordano, 2008).

One consequence of this situation is that the times reported for pre-alarm and alarm may vary significantly (either more or less) compared to what is indicated in Tab.1. Another consideration is that the times refer to the beginning of the eruptive phase, which represents zero hour. However, they do not provide any information on the duration of the eruptive events, the relative state of alert, or the subsequent progression of the phenomenon.

Based on the variation of some monitoring data and the assessments made on multiple occasions (from December 2012 to January 2017) by the Major Risks Commission, the Civil Protection Department deemed that the alert level in the Campi Flegrei area should be raised from Green to Yellow (Fig.4).

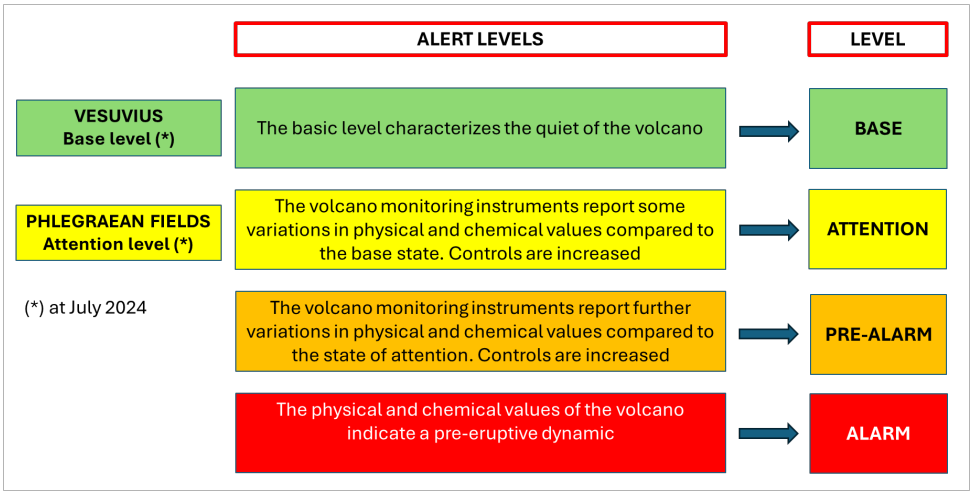

Fig.4 Alert levels for volcanic risk as Italian Civil Protection Department Alert state for volcanic area of Vesuvio and Campi Flegrei (July 2024)

Among these indicators are the size and rate of uplift of the ground level at monitoring points located in specific sites of the volcanic system. Other indicators include seismic activity originating in the area and measured CO_2 flows. The National Institute of Geophysics and Volcanology (INGV) issues weekly and monthly bulletins reporting the trends of these indicators (Fig.5).

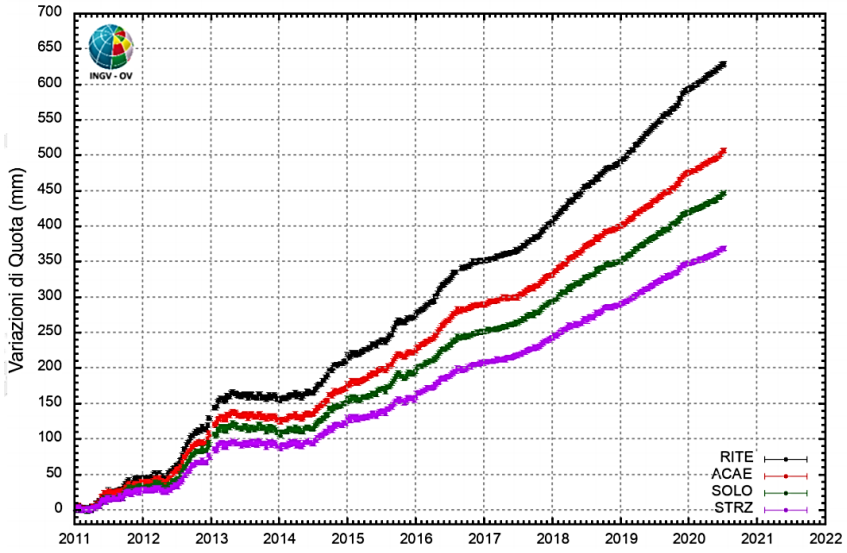

Fig.5 Time series of altitude variations of the RITE (Pozzuoli – Rione Terra), ACAE (Accademia Aeronautica), SOLO (Solfatara) and STRZ (Pozzuoli - Cimitero) stations from 01/01/ 2011 to 11/07/2020

In October 2019, a national civil protection exercise named Exe Flegrei 2019 was held to test the emergency response system. The exercise scenario simulated a significant variation in monitoring parameters and the

development of phenomena leading to a transition from the current state of the volcano (Yellow alert level) to a pre-alarm phase (Orange alert level), and eventually to an imminent eruption risk state (Red alert level). Without delving into organizational considerations that will need to be evaluated by Civil Protection, the exercise highlighted the limited involvement and participation of the population, despite the efforts of the involved entities to publicize the event.

In the session held on 17th September 2024, the Naples City Council approved the Resolution N. 284/2024 (July 11th) "Approval of the updated Municipal Evacuation Plan for the Volcanic Risk of the Campi Flegrei, the list of Civil Protection emergency areas, and the related layout of emergency signage."

The main contents of the Plan are not related to the ongoing bradyseismic crisis, but to a potential volcanic risk, which, at present, is not real. The evacuation plan involves 481,000 residents in the Campi Flegrei, of whom 286,000 live in the Red Zone of the City of Naples. The document outlines a pre-alarm phase, which may last months or even years, during which citizens can voluntarily leave, and an alarm phase, during which mandatory evacuation must take place within 72 hours. This evacuation can be carried out either with assisted transfer or through self-organized means.

The scale of the evacuation flows and timelines has been estimated with great caution, to be able to handle any unforeseen events or emergencies. According to the Plan, there will be 17 interchange areas, 29 bus routes, and 571 stops. The routes were planned in collaboration with Neapolitan Mobility Company (ANM), aiming to follow conventional paths. Specific signs will be placed on road signage. From the neighborhoods, citizens will move along designated routes leading to the seven gates located at the Port, via Marina, and the Naples Ring Road, from which they will be transported to regions paired with different city areas.

3.2 Bradyseism risk in Campi Flegrei

Since the second half of 2023, the Campi Flegrei has once again become a primary focus for Italian Civil Protection due to the resurgence of bradyseism risk, which, while related, should not be confused with volcanic risk. This resurgence has been marked by a significant increase in seismic events in the area (Fig.6).

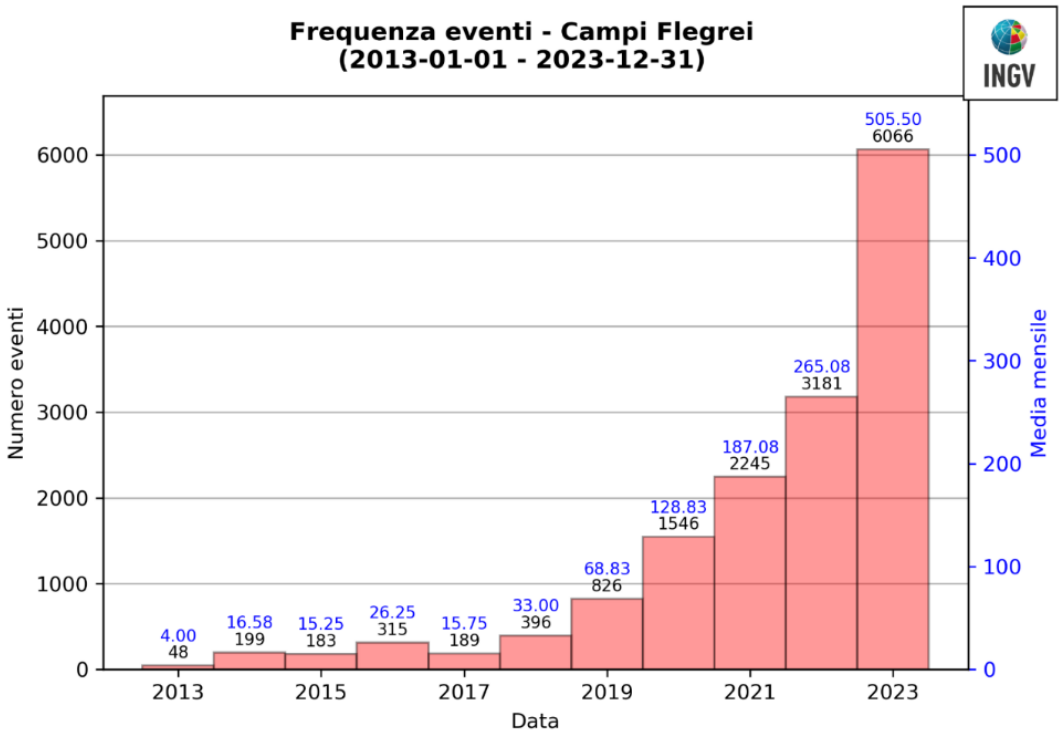

Fig.6 Frequency of seismic events in Campi Flegrei (2013-2023)

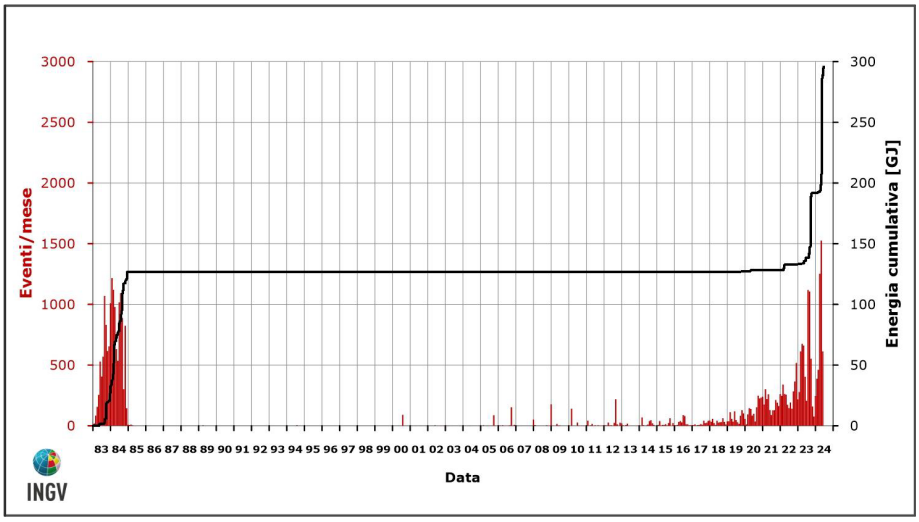

Fig.7 Earthquakes frequency in Campi Flegrei from 1983to present The black line represents the cumulative energy released

On September 26, 2023, a magnitude 4.2 earthquake occurs, followed by a magnitude 4.0 earthquake on October 2, 2023. On October 3, 2023, the Commission for Major Risks convened to discuss the strengthening of monitoring systems. The yellow alert level for the Campi Flegrei was confirmed, but the Commission highlighted the need to deepen monitoring and analysis due to the complexity of the issue and the potential evolution of the volcano's dynamics. The number of events continued to be high in 2024 (4,482 events until June, averaging 747 per month), with increasing magnitude in the months leading up to May, when it reached a peak of 4.4 (20/5/2024), very close to the maximum peak of 5.0 predicted by experts for the area (Fig.7). The tremors caused noticeable but not significant damage to the buildings in the affected areas, particularly in Pozzuoli. This series of events has created a situation of great alarm among the population and has forced the central government, through a series of acts, to address the ongoing emergency.

On October 12, 2023, Decree-Law No. 140 was published (converted into Law 183/2023) as the first response to the ongoing bradyseismic crisis, with both structural and non-structural prevention measures. The provision outlines the main actions that the Civil Protection System must implement to effectively respond to a complex risk situation.

On December 12th, 2023, the Emergency Expeditive Plan was approved (Fig. 8). Provided by Art. 4 of Law 183/2023, this planning arises from the need to define a specific strategy and operational procedures to respond to the effects and possible consequences of bradyseism. The expeditive plan was prepared by the Civil Protection Department, in coordination with the Campania Region, the Prefecture of Naples, and the local authorities and administrations, based on the hazard assessments developed by the Competence Centers.

There is a strong difference between bradyseismic risk and volcanic risk.

The current crisis is fundamentally bradyseismic, meaning it is due to the process of the earth surface uplifting in the Campi Flegrei area with its epicenter in Pozzuoli (Carlino, 2018). The term describes the slow vertical movements of the ground caused by pressure changes in the underground magma chambers. This movement generated frequent seismic events, localized in restricted areas. Seismic events are, therefore, a consequential risk. When they exceed certain magnitudes, they can cause damage to structures, property, and people. The volcanic risk is different and currently nonexistent in the area. However, it must still be considered because the Campi Flegrei is a volcano and historically, in addition to bradyseismic crises, it has caused the ejection of material and the formation of volcanic craters. If this situation arises, the only response is the evacuation of the population.

On July 2, 2024, Decree-Law No. 91 was published. It regulates seismic retrofitting interventions on public and private buildings, aimed at ensuring the functionality of transport infrastructure and essential services in the Campi Flegrei. The decree foresights the appointment of an extraordinary commissioner. Interventions are

approved to maintain schooling in Pozzuoli and to assist the population displaced by the May 20, 2024 earthquake.

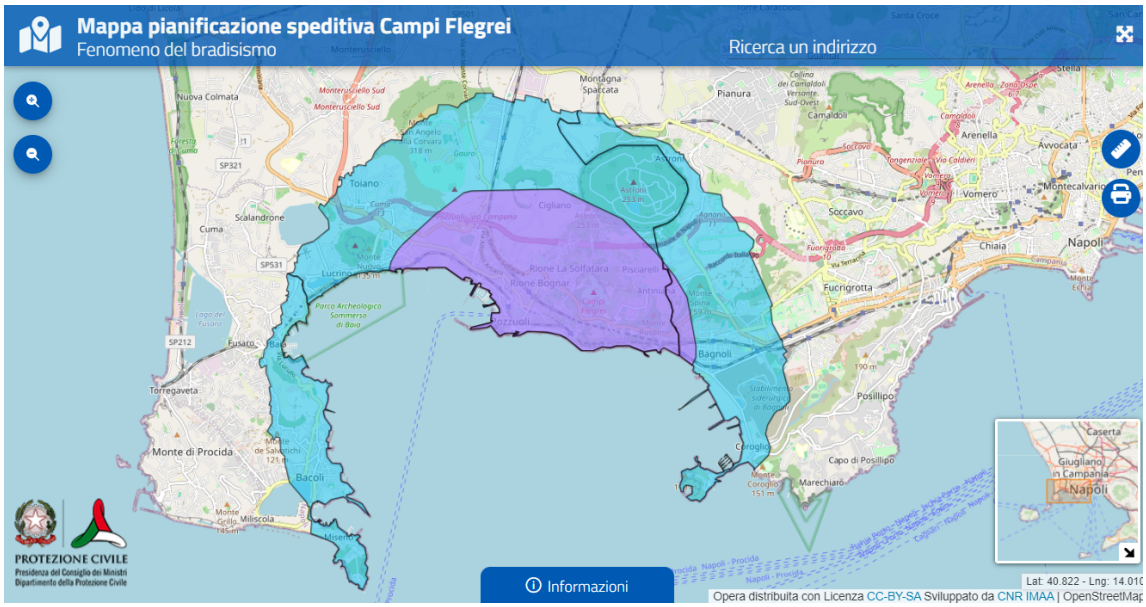

Fig.8 The Emergency Expeditive Plan map of the Campi Flegrei with the Intervention Zone (blue) and the Restricted Intervention Zone (purple)

As part of the Emergency Expeditive Plan a zone of intervention has been identified within the Municipalities of Pozzuoli, Bacoli, and Naples (specifically, the Bagnoli district and parts of the Soccavo/Pianura and Posillipo municipalities) that are most affected by the bradyseismic phenomenon and consequently by seismic activity and ground deformation. This "zone of intervention" was delineated based on the following criteria:

- The location of earthquake epicenters with a magnitude duration equal to or greater than 2, which have occurred in the Phlegraean area since 1983;
- Ground uplift equal to or greater than 10 cm since 2015 (corresponding to approximately 20 cm since 2006). The zone includes a total population of 84,961 people and an estimated 15,516 residential buildings.

Within this zone, a more "restricted intervention zone" has been identified, where the most significant effects could be widespread if the bradyseismic phenomenon continues or intensifies. This restricted zone was identified based on:

- The location of earthquake epicenters with a magnitude duration equal to or greater than 2 which have occurred in the Phlegraean area since 1983;
- Ground uplift equal to or greater than 30 cm since 2015 (approximately 45 cm since 2006), and it includes parts of the municipalities of Pozzuoli and Naples (specifically, the Bagnoli district). This area encompasses a total population of 33,653 people and an estimated 6,929 residential buildings.

Within the intervention zone, specific activities are carried out as outlined in article 2 of Law 183/2023 which mandates the implementation of an extraordinary plan for analyzing the vulnerability of both public and private buildings.

4. Coherence analysis and discussion

4.1 Methodology

The article aims to assess the effectiveness of the emergency plan for the Campi Flegrei by relating it to insights derived from scientific research and regulatory guidelines. To this end, a base sample considered

significant for comparison with the case study was selected. The methodology adopted is therefore comparative. This methodology is commonly applied to analyze and evaluate similarities and differences between two or more entities, phenomena, concepts, or groups, or to define possible analogies between a sample system of elements and an actual case. From operational perspective, the first step is to identify the sources to be used as a basis for determining the general elements of the emergency plan. From these sources, the elements deemed necessary for an emergency plan are extracted. The next phase involves analyzing the emergency plan of the case study. Finally, a comparative verification is conducted between the significant theoretical elements and the actual elements present in the emergency plan. The result is a qualitative coherence assessment that defines a potential effectiveness value of the plan based on parameters within the sources used as points of comparison.

4.2 Coherence analysis

After analyzing the fundamental elements of the emergency plans related to Vesuvio and the Campi Flegrei, it is considered useful to carry out a coherence analysis between these plans and some checklists that represent the state of the art at national and international levels.

Evaluating an emergency plan has very particular characteristics as it can only be done on the structure and predictions of the plan (ex-ante evaluation). As noted by some authors (Quarantelli, 1985), the effectiveness of an emergency plan can only be assessed (ex post) when it is actually implemented and produces, if it produces, the desired effects. For this reason, a coherence analysis is proposed rather than a true evaluation, while acknowledging that the subject deserves further in-depth study in a different specific context, also based on recent contributions from evaluative research (Núñez et al., 2015).

Previously, the criteria for the formation of an emergency plan were presented, and within the vast technical-scientific production, three systems of elements were examined in depth. The first proposed by Perry and Lindell (2003), the second by the United Nations (1985), and the third contained in the directive of the President of the Council of Ministers of 2021.

Each of these three documents proposes a structure of the emergency plan composed of a system of elements: 8 for the first, 14 for the second, and 4 for the third.

To provide a coherence assessment, the plans were evaluated based on three criteria: one general and two specifics to the emergency plan. The criteria are as follows:

- *Overall Relevance:* This criterion refers to the significant characteristics of importance, particularly concerning the achievement of the aims for which the plan was constructed. The relevance indicator pertains to the emergency plan as an object, specifying an overall and general condition.
- *Presence/Absence:* This criterion evaluates whether specific elements are included in the plan. It uses a binary scale (YES/NO) with the possibility of intermediate values.
- *Capacity/Effectiveness:* Closely linked to the presence/absence criterion, this evaluates the plan's ability to operate autonomously or in coordination with other actions. It measures both the suitability of actions to achieve the specified goals and their effectiveness in rendering the intended outcomes achievable up to a valid conclusion.

The coherence analysis is qualitative and derives from the analysis of the plan.

Tab.2 summarizes the assessment according to the factors considered by Perry and Lindell (2003). The analysis highlights that 5 out of 8 factors are absent, and among the other 3, only 1 has high capacity/effectiveness. Consequently, the two emergency plans do not meet the characteristics of Perry and Lindell's study.

Tab.3 presents the analysis of coherence with the model developed by the United Nations (UN, 1985), which requires the presence of 14 factors. In this case, the analysis shows that only 4 out of 14 factors are absent. Of the remaining 10 factors, only 3 are directly included in the plans, while the other 7 are present but in an

indirect manner (e.g., by referring to external elements not directly under the control of the two emergency plans). Regarding capacity/effectiveness, only in one case does it assume a high value, while in other cases, the assessment ranges from low to medium. Consequently, the two emergency plans only partially meet the characteristics contained in the United Nations model.

Tab.4 presents the analysis of coherence according to the factors contained in the 2021 Directive. The analysis highlights that, out of 4 factors, 3 are present in the plans with high capacity/effectiveness for two elements and medium for one. It follows that, in this case as well, there is a partial correspondence of the two plans with the guidelines contained in the Directive, despite a higher level of affinity.

Factors	Overall relevance	Presence/ Absence	Capacity/ Effectiveness
1. Accurate knowledge of threats	High	No	Zero
2. Effective planning of actions	High	No	Zero
3. Recognition of the dynamism of natural phenomena	Medium	No	Zero
4. Coordination between organizations	High	Yes	High
5. In-depth training activities	High	Yes	Medium low
6. Forecasting of testing phases	High	Yes	Medium low
7. Awareness of conflict and resistance created	High	No	Zero
8. Emergency planning and emergency management differences	High	No	Zero

Tab.2 Vesuvio and Campi Flegrei Emergency plans Relevance, presence and effectiveness of the necessary elements for Perry and Lindell (2003 § 2)

Factors	Overall relevance	Presence/ Absence	Capacity/ Effectiveness
1. Identification and mapping of dangerous areas	High	Yes - Direct	High
2. List of valuable movable property	Medium	No	Zero
3. Identification of safe territories that can serve as asylum	High	Yes – Direct	Medium
4. Identification of evacuation routes	High	Yes – Indirect	Low
5. Identification of collection points for people	High	Yes – Direct	Medium low
6. Vehicles and traffic control	High	Yes – Indirect	Medium low
7. Arrangement of asylum areas	High	Yes – Indirect	Zero
8. Inventory of personnel and equipment	High	Yes – Indirect	Zero
9. Hospital and health services	High	No	Zero
10. Safety of evacuated areas	Medium	No	Zero
11. Notice procedures	High	Yes – Indirect	Medium low
12. Procedures for drafting and disseminating public notices	Medium	No	Zero
13. Emergency communications	High	Yes – Indirect	Low
14. Provisions for updating the plan	Medium	Yes – Indirect	Low

Tab.3 Emergency plans of Vesuvio and Campi Flegrei. Relevance, presence and effectiveness of the necessary elements for UN (1985) (§ 2)

Factors	Overall relevance	Presence/ Absence	Capacity/ Effectiveness
1. Introductory elements	Medium	Yes	Medium
2. Territorial framework	High	No	Zero
3. Definition of hazard and risk scenarios	High	Yes	High
4. Intervention model and strategic elements	High	Yes	High

Tab.4 Vesuvio and Campi Flegrei Emergency plans Relevance, presence and effectiveness of the necessary elements for Directive of the Prime Minister of 2021 (DPC, 2021 § 2)

4.3 Discussion

The results obtained provide a basis for proposing several discussion points – some specific, others more general – while also addressing the limitations encountered in applying the methodology.

A first point of discussion concerns mobility. The intervention strategy for the Red Zones involves the precautionary evacuation of most of the population outside the Campania Region because, according to the most probable scenarios, the devastation within the zones, although not quantifiable in advance, poses a very serious risk to the population.

This means that the mobility network (Fig.9) could experience an inevitable surge in usage during the emergency phase, when it will need to evacuate an exceptional number of people within a 72-hour period, all of whom will likely be affected by the peak. The consequences of such a surge are foreseeable, though not desirable. Adding to this is the fact that pre-eruptive events (such as seismic swarms) could be equally disastrous, substantially compromising the network infrastructure. The issue of the number and type of disruptions to road and rail connections is vaguely mentioned in the plan.

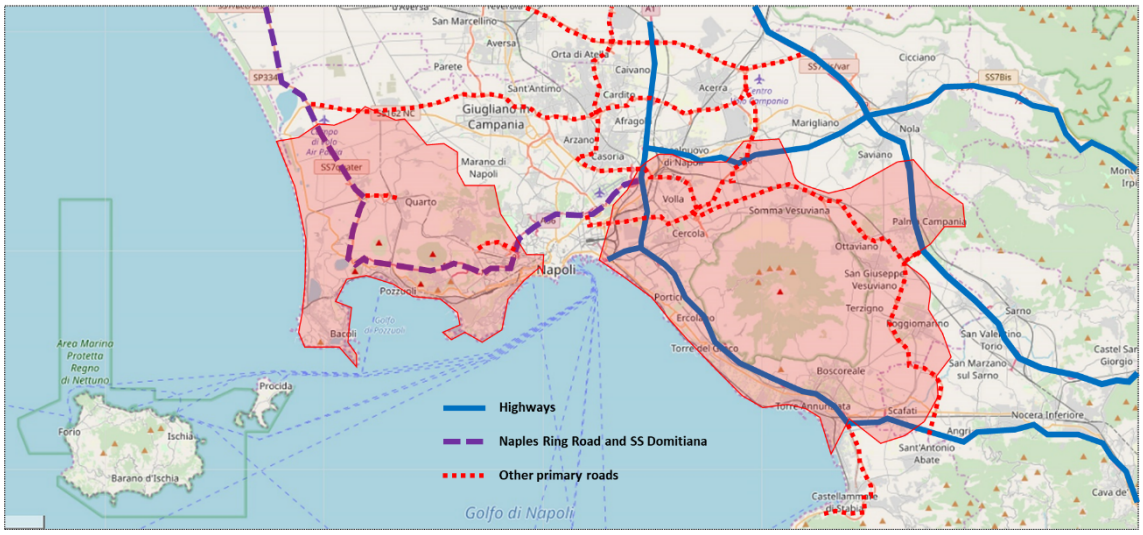

Fig.9 The primary road network of Metropolitan area of Naples as strategical network for the precautionary evacuation

A second issue is that the plan do not mention the damage that people might suffer during the activation phase, should the primary phenomenon be accompanied by other equally harmful events for the population and property. The mention of pre-eruption seismic vulnerability is not followed by any indication of its potential impacts. Obviously, the potential damage is correlated with the magnitude of probable earthquakes, but also with the high level of vulnerability of the building stock, characterized by old age and poor quality of materials and construction techniques.

A third issue is that the plan say nothing about the phase following the end of the emergency. This phase should involve a careful assessment of damage and the identification of areas where a substantial portion of the population can return, while ensuring that the twin-site facilities continue to function until all displaced persons have returned. However, nothing is said about the environmental conditions that these people might face, in terms of the lack of services, infrastructure, and the quality of water, air, and soil.

A fourth point of discussion concerns behavioral and psychological considerations. A significant attitude of fatalism is prevalent and seems to be a defining trait of the population living in the area. This is reflected in a clear sense of indifference, driven by the belief that volcanic risk is unmanageable and secondary to other, more pressing concerns (Ricci et al., 2013). While this attitude can be seen as both understandable and surprising, it highlights an inherent fatalism, a generalized distrust of scientific knowledge, and a persistent adherence to a system of rules rooted in the awareness of living in a high-risk environment.

In addition to this attitude, it should be noted that the necessity of setting up evacuation measures for such a large number of people, to be implemented at an uncertain point in time, seems objectively beyond the strategic vision of a national leadership class that bases its institutional and administrative decisions on much shorter time horizons and views the preparation of long-term tools aimed at managing territorial risk as an absurdity in itself.

Finally, the plan must work to build more prepared communities, given the fundamental role of the local community in constructing urban resilience (City of Chicago, 2019; Tira, 2021). The community must be able to access resources, utilize services and communicate easily even during an emergency. Residents need to be equipped with relationships, skills, and knowledge base to anticipate and -if necessary- face challenging situations.

5. Synergy between the Emergency Plan and the Metropolitan Plan of the Municipality of Naples

A specific point of discussion in the coherence analysis of Campi Flegrei's Emergency Plan concerns the very concept of the plan itself. If a "plan" is a complex structure that guides a multi-year transformation process (Alexander, 1997), in civil protection it becomes a low-complexity tool aimed at the evacuation and accommodation of a significant number of people affected by a disastrous event. In a systemic view of the territory, it can be hypothesized that even emergency plans could evolve to become complex tools, both strategic and operational in nature (Di Lodovico & Di Ludovico, 2018; Bojanić Obad Šćitaroci et al., 2021).

The strategic aspect lies in the fact that these plans involve an extensive system of stakeholders and institutions working toward a precise aim to be achieved through a series of actions that are refined over time and implemented only once, when needed, with the aim of completing the tasks within a limited number of hours. At the same time, they have the potential to guide a process of territorial decongestion over time. This would involve reducing the urban load (number of inhabitants), the scale of existing buildings, and, overall, the vulnerability of the territory through specific redevelopment programs.

The operational aspect of the plan lies in its function as a tool for monitoring and acting on potential crisis points within the territory during an emergency. Road and rail segments, interchange nodes, and urban areas with highly vulnerable buildings are all territorial elements that need to be continuously monitored and upgraded with the goal of increasing resilience (Fox-Lent et al., 2015), eliminating vulnerabilities, and improving the quality of both the building stock and infrastructure. These activities can also lead to updated scenarios for the use of the network in the event of an emergency (e.g., load testing), aimed at assessing the time required to transfer citizens from the area to internal gathering points and, subsequently, to external exit points.

In general, emergency planning is more efficient in a territory with a low value of exposed elements. Given that the territory in question has extremely high exposure values, it can be asserted that its activation could face critical conditions that might compromise its effectiveness.

Reducing the level of vulnerability is the task of ordinary planning, in accordance with the provisions of emergency planning. This crucial activity should be entrusted to ordinary planning through actions such as the improvement of the building stock, relocation actions (Mileti & Passerini, 1996), or flexible functional change actions (De Lotto et al., 2013). In the area this issue is mentioned as a contextual condition but not as a constraint from which obligations and provisions derive.

The Territorial Coordination Plan of the Metropolitan City addresses volcanic risk in the section on territorial risks, although with indications now outdated by the evolution of emergency tools. It notes that the territory is affected by the volcanic complexes of Vesuvius and the Campi Flegrei and, regarding operational aspects, states that "the [Plan] develops guidelines coordinated with the Operational Strategic Plan for the Red Zone of Vesuvius (...) and defines guidelines for the absolute containment of settlement increases in the highest

risk area of the Phlegraean caldera (Municipalities of Monte di Procida, Bacoli, and Pozzuoli)" (Città Metropolitana di Napoli, 2008). In the Strategic Plan of the Metropolitan City of Naples, the issue is present in the "Environmental Safeguarding" guideline, "Safe City" axis, "Civil Protection Interventions" action, without other indications (Metropolitan City of Naples, 2018).
From what has been mentioned, it follows that the metropolitan planning tools are, as of now, clearly inadequate in supporting and facilitating critical processes, such as the activation of emergency planning tools.

6. Conclusions

This paper aimed to delve into the topic of emergency planning in the specific context of volcanic risk.
To this end, the study explored some fundamental aspects of this type of risk and its significance for a territory. It then reviewed contributions from international literature on the development of emergency plans, expanding the analysis to include institutional inputs (such as those from the United Nations) and the latest regulatory developments in Italy. A key outcome of this section was the identification of a set of elements that various sources deem essential in the formulation of emergency plans.
The analysis of the form and content of the national emergency plan for Campi Flegrei serves as the link to the final section of the paper, which focuses on evaluating the plan's coherence using checklists and evaluation criteria. This part of the study highlighted the extent to which the plan aligns with what could be considered potential international standards. The overall result is insufficient, indicating a need to revise the plan to enhance its effectiveness, bearing in mind that this analysis was conducted ex ante.
From the examination of Tab.s 2, 3, and 4, the situation appears far from positive. Despite the recognized high hazard and the extreme vulnerability of people and property, the emergency plan for Campi Flegrei seem to consist of weak and generic guidelines, given the potentially catastrophic scale of the events.
Specifically, the plan raises questions regarding the clear definition of emergency management, the feasibility of evacuating the entire potentially affected population within a short timeframe, the functionality of the road and rail networks, and the lack of projections concerning the scale of probable (or acceptable) human losses. Analyzing the plan, another fundamental shortcoming for its success becomes evident: the knowledge of the territory on which they operate (Di Ludovico et al., 2021).
Earlier, the question was raised about whether emergency planning tools should also include this content. Even if the answer were negative, the need for such knowledge remains undeniable. For instance, it can be assumed that an external urban planning tool could monitor the condition of networks, levels of service and efficiency, critical points, and the state of structures useful in an emergency, planning the necessary upgrades in close coordination with emergency planning.
While the analysis acknowledges the efforts made by Civil Protection in this area, it also underscores the need to align the plan with best international practices, as recognized by the latest national regulations. Most importantly, it highlights the necessity for such planning to recognize the importance of having a foundational knowledge of the territory and being able to act proactively to improve its overall resilience. This aims to reduce the evocative burden highlighted by Heiken in 2013, namely, that there are too many volcanoes for too many people in that part of Italy.

References

Alexander, D.E. (2003). Towards the Development of Standards in Emergency Management Training and Education. *Disaster Prevention and Management, 12* (2), 113-123. https://doi.org/10.1108/09653560310474223

Alexander, E.R. (1997). *Introduzione alla pianificazione. Teorie, concetti e problemi attuali*. Napoli: CLEAN

Aspinall, W. & Blong, R. (2015). Chapter 70 - Volcanic Risk Assessment. In H. Sigurdsson (Ed.). *The Encyclopedia of Volcanoes*. Academic Press, 1215-1231. https://doi.org/10.1016/B978-0-12-385938-9.00070-5

Baxter P.J., Aspinall W.P., Neri A., Zuccaro G., Spence R.J.S., Cioni R. and Woo G. (2008). Emergency planning and mitigation at Vesuvius: A new evidence-based approach. *Journal of Volcanology and Geothermal Research. 178* (3), 454-473. https://doi.org/10.1016/j.jvolgeores.2008.08.015

Bojanić Obad Šćitaroci, B., Pierantoni, I., Sargolini, M. & Sopina, A. (2021). Fostering holistic natural-risk resilience in spatial planning. *TeMA - Journal of Land Use, Mobility and Environment*, 155-179. https://doi.org/10.6093/1970-9870/7427

Bonadonna, C., Frischknecht, C., Menoni, S., Romerio, F., Gregg, C.H., Rosi, M., Biass, S., Asgary, A., Pistolesi, M., Guobadia, D., Gattuso, A., Ricciardi, A. & Cristiani C. (2021). Integrating hazard, exposure, vulnerability and resilience for risk and emergency management in a volcanic context: the ADVISE model. *Journal of Applied Volcanology, 10* (7). https://doi.org/10.1186/s13617-021-00108-5

Brown, C.O., Hayes, J.L. & Milke, M. W. (2021). Planning to adapt: identifying key decision drivers in disaster response planning. *Civil Engineering and Environmental Systems, 38* (1), 20-35. https://doi.org/10.1080/10286608.2021.1887155

Carlino, S. (2018). Volcanoes and Risk. In Carlino S. (Ed.), *Neapolitan Volcanoes. A Trip Around Vesuvius, Campi Flegrei and Ischia*. Cham: Springer

Carreño, M.L., Cardona, O.D. & Barbat, A.H. (2007). Urban Seismic Risk Evaluation: A Holistic Approach. *Natural Hazards, 40*, 137-172. https://doi.org/10.1007/s11069-006-0008-8

Cascetta, E. (2001). *Transportation Systems Engineering: Theory and Methods*. Dordrecht: Kluwer Academic Publishers

Cashman, K.V. & Giordano, G. (2008). Volcanoes and human history. *Journal of Volcanology and Geothermal Research, 176*(3), 325-329. https://doi.org/10.1016/j.jvolgeores.2008.01.036

Cheng, C.Y. & Qian, X. (2010). Evaluation of Emergency Planning for Water Pollution Incidents in Reservoir Based on Fuzzy Comprehensive Assessment. *Procedia Environmental Sciences, 2*, 566-570. https://doi.org/10.1016/j.proenv.2010.10.061

Chester, D.K., Degg, M., Duncan, A.M. & Guest, J.E. (2000). The increasing exposure of cities to the effects of volcanic eruptions: a global survey. *Global Environmental Change Part B: Environmental Hazards, 2* (3), 89-103. https://doi.org/10.3763/ehaz.2000.0214

Città Metropolitana di Napoli (2008). *PTC Napoli - Relazione, N01-0*. Napoli: Città Metropolitana di Napoli.

Città Metropolitana di Napoli (2018). *Linee di indirizzo per la predisposizione del Piano Strategico metropolitano triennale e identificazione delle Zone Omogenee.* DCM 184, 27/11/2018

City of Chicago (2019). *Resilient Chicago. A Plan for Inclusive Growth and a Connected City*. Retrieved from: https://resilient.chicago.gov/download/Resilient%20Chicago.pdf. 3/09/2024

Di Lodovico L. & Di Ludovico D. (2018). Limit Condition for the Intermunicipal Emergency. *TeMA - Journal of Land Use, Mobility and Environment, 11* (3), 305-322. https://doi.org/10.6092/1970-9870/5845

Di Ludovico D., Di Lodovico L. & Basi M. (2021). Spatial knowledge for risks prevention and mitigation. The civil protection planning of the Abruzzo Region. *TeMA - Journal of Land Use, Mobility and Environment*, 39-51. https://doi.org/10.6093/1970-9870/7404

Civil Protection Department (2019a). *Campi Flegrei*. Retrieved from: https://rischi.protezionecivile.gov.it/it/vulcanico/vulcani-italia/campi-flegrei/

Civil Protection Department (2019b). *Io non rischio*. Retrieved from: http://iononrischio.protezionecivile.it/. 23/09/2024

De Lotto, R., Morelli di Popolo, C., Morettini, S. & Venco, E.M. (2013), La valutazione di scenari flessibili per la riduzione del rischio naturale. *Planum, The Journal of Urbanism*, 27

DPC (2021). *Direttiva del Presidente del Consiglio dei Ministri del 30 aprile 2021, Indirizzi per la predisposizione dei piani di protezione civile ai diversi livelli territoriali*

Emergency Management Australia (1998). *Australian Emergency Manuals, Part 1: Planning Fundamentals*. Canberra: Commonwealth of Australia

FEMA – Federal Emergency Management Agency (2020). *Volcanoes*. Retrieved from: https://www.ready.gov/volcanoes. 3/9/2024

Fox-Lent, C., Bates, M.E. & Linkov, I. (2015). A matrix approach to community resilience assessment: an illustrative case at Rockaway Peninsula. *Environment System Decision, 35*, 209-218. https://doi.org/10.1007/s10669-015-9555-4

Galderisi A., Guida G. & Limongi G. (2021). Emergency and spatial planning towards cooperative approaches. Challenges and opportunities in the multi-risk area of Campi Flegrei. *TeMA - Journal of Land Use, Mobility and Environment*, 73-92. https://doi.org/10.6093/1970-9870/7417

Garau, C., Desogus, G. & Stratigea, A. (2023). Digitalisation process and sustainable development of vulnerable territories. Assessment of equity potentials of major Mediterranean Islands. *TeMA - Journal of Land Use, Mobility and Environment*, *16* (3), 565-594. https://doi.org/10.6093/1970-9870/9910

Gugg, G. (2018). Anthropology of the Vesuvius Emergency Plan: history, perspectives and limits of a dispositive for volcanic risk government. In L. Antronico, F. Marincioni (Eds). *Natural Hazards and Disaster Risk Reduction Policies*. 105-123. Rende, Il Sileno Edizioni

Heiken, G. (2013). Too many people and too many volcanoes - Naples, Italy. In: G. Heiken, *Dangerous Neighbors. Volcanoes and Cities*. Cambridge: Cambridge University Press

Hervás, J. (Ed.) (2003). *Lessons Learned from Landslide Disasters in Europe*. NEDIES Project, EUR 20558 EN. S.l.: European Communities

Hicks, A., Barclay, J., Simmons, P. & Loughlin, S. (2014). An interdisciplinary approach to volcanic risk reduction under conditions of uncertainty: a case study of Tristan da Cunha. *Natural Hazards and Earth System Sciences*, 14, 1871-1887. https://doi.org/10.5194/nhess-14-1871-2014

Iervolino, I., Cito, P., De Falco, M., Festa, G., Herrmann, M., Lomax, A., Marzocchi, W., Santo, A., Strumia, C., Massaro, L., Scala, A., Scotto di Uccio, F. & Zollo, A. (2024). Seismic risk mitigation at Campi Flegrei in volcanic unrest. *Nature communications*, 15:10474. https://doi.org/10.1038/s41467-024-55023-1

INGV (2024). *Vesuvio. Storia eruttiva*. Retrieved from: https://www.ov.ingv.it/index.php/monitoraggio-sismico-e-vulcanico/vesuvio/vesuvio-storia-eruttiva. 5/9/2024

Lindell, M.K. & Perry, R.W. (1992). *Behavioral Foundations of Community Emergency Planning*. Washington: Hemisphere Publishing

Mazzeo, G. (2009). Naples. *Cities, 26* (6), 363-376. https://doi.org/10.1016/j.cities.2009.06.001

Mazzeo, G. & Polverino, S. (2023). Nature-based solution for climate change adaptation and mitigation in urban areas with high natural risk. *TeMA - Journal of Land Use, Mobility and Environment*, *16* (1), 47-65. https://doi.org/10.6093/1970-9870/9736

Mela, A., Mugnano S. & Olori, D. (2017). *Territori vulnerabili: Verso una nuova sociologia dei disastri italiana*. Milano: FrancoAngeli

Menoni, S. & Pesaro, G. (2008). Is relocation a good answer to prevent risk? Criteria to help decision makers choose candidates for relocation in areas exposed to high hydrogeological hazards. *Disaster Prevention and Management, 17*, 33-53. https://doi.org/10.1108/09653560810855865

Mileti, D.S. & Passerini, E. (1996). A social explanation of urban relocation after earthquakes. *International Journal of Mass Emergencies and Disasters, 14* (1), 97-110

Moraci, F., Bevilacqua, C. & Pizzimenti, P. (2024). Planning the transition of cities. Innovative research approaches and trajectories. *TeMA - Journal of Land Use, Mobility and Environment*, *17* (1), 109-127. https://doi.org/10.6093/1970-9870/10430

New Zealand Government (2002). *Civil Defence Emergency Management*. Wellington: Government of New Zealand

Norton, J., Atun, F. & Dandoulaki, M. (2015). Exploring Issues Limiting the Use of Knowledge in Disaster Risk Reduction. *TeMA - Journal of Land Use, Mobility and Environment*, 135-154. https://doi.org/10.6092/1970-9870/3032

Núñez, A.G., Penadés, M.A., Canós, J.H. & Borges M.R.S. (2015). Towards a Total Quality Framework for the Evaluation and Improvement of Emergency Plans Management. Short Paper. *Planning, Foresight and Risk Analysis Proceedings of the ISCRAM 2015 Conference*. Kristiansand, May 24-27, 2015

Papa, R. & Mazzeo, G. (2014). Characteristics of sprawl in the Naples Metropolitan Area. Indications for Controlling and Monitoring Urban Transformations. Computational Science and Its Applications - ICCSA 2014. 14th International Conference. Guimarães, Portugal, June 30 - July 3, 2014, Proceedings, Part II. *Lecture Notes in Computer Science, 8580*: 520-531. https://doi.org/10.1007/978-3-319-09129-7_38

Pareschi, M.T., Cavarra, L., Favalli, M., Giannini, F. & Meriggi, A. (2000). GIS and Volcanic Risk Management. In G.A. Papadopoulos, T. Murty, S. Venkatesh, R. Blong (Eds). *Natural Hazards*. Springer, Dordrecht. https://doi.org/10.1007/978-94-017-2386-2_16

Perry, W. & Lindell, M. (2003). Preparedness for emergency response: guidelines for the emergency planning process. *Disasters, 27* (4), 336-350. https://doi.org/10.1111/j.0361-3666.2003.00237.x

Poudel, S., Shahnawaz, S., & Shrestha, H. L. (2023). Suitable sites for built-up area expansion in Kamalamai municipality, Sindhuli district, Nepal. *TeMA-Journal of Land Use, Mobility and Environment*, *16* (2), 279-305. https://doi.org/10.6093/1970-9870/9968

Quarantelli, E.L. (1982). Ten Research-derived Principles of Disaster Planning. *Disaster Management, 2*, 23-25

Quarantelli, E.L. (1985). *Emergent Citizens Groups in Disaster Preparedness and Recovery Activities*. Newark: University of Delaware Disaster Research Center

Ricci, T., Nave, R. & Barberi, F. (2013). Vesuvio civil protection exercise MESIMEX: survey on volcanic risk perception. *Annals of Geophysics, 56* (4): S0452-6. https://doi.org/10.4401/ag-6458

Rockett, J.D. (1994). A Constructive Critique of United Kingdom Emergency Planning. *Disaster Prevention and Management, 3* (1): 47-60. https://doi.org/10.1108/09653569410049667

Rolandi, G. (2010). Volcanic hazard at Vesuvius: An analysis for the revision of the current emergency plan. *Journal of Volcanology and Geothermal Research, 189* (3-4). 347-362. https://doi.org/10.1016/j.jvolgeores.2009.08.007

Tira M. (2021). Planning to prevent disasters. *TeMA - Journal of Land Use, Mobility and Environment*, 191-202. https://doi.org/10.6093/1970-9870/7890

Tomasone M., Avvisati G., Cirillo F., Colucci O., Marotta E., Fiorenza E., Vertechi E. & Simonetti B. (2022). Risk management planning on a volcanic island: fear and loathing in Ischia (Italy). *Geological Society, London, Special Publications, 519*, 147-165. https://doi.org/10.1144/SP519-2021-183

Troise, C., De Natale, G., Somma, R., Buscema, M., Maurelli, G. Giannola, A., Petrazzuoli, S. (2022). Mitigating the highest volcanic risk in the World: a multidisciplinary strategy for the Neapolitan area. *EGU22, the 24th EGU General Assembly*, 23-27 May, Wien.

UN (1985). *Volcanic Emergency Management*. Office of the United Nations Disaster Relief Coordinator (UNDRO), United Nations Educational Scientific and Cultural Organization (UNESCO). New York: United Nations. Retrieved at: https://unesdoc.unesco.org/ark:/48223/pf0000080351. 2/9/2024

Wei H.L. (2021). Natural Hazards: Volcanic Eruptions. In L.R. Shapiro, M.-H. Maras (Eds.), *Encyclopedia of Security and Emergency Management*. 697-700. Springer Nature Switzerland AG 2021. https://doi.org/10.1007/978-3-319-70488-3

Sgambati, S. & Stiuso, T. (2023). The interventions of the Italian Recovery and Resilience Plan: digitalization in cities. *TeMA-Journal of Land Use, Mobility and Environment*, *16* (1), 245-250. https://doi.org/10.6093/1970-9870/9814

Image sources

Fig.1, 9: From Author on OpenStreet Map;

Fig.2, 3, 8: Department of Civil Protection;

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Fig.5: INGV, http://www.ov.ingv.it/ov/bollettini-campi-flegrei/Bollettino_Flegrei_2020_07_28.pdf;

Fig.6: INGV, https://ingvvulcani.com/2024/02/19/ speciale-vulcani-2023/;

Fig.7: INGV, Surveillance Bulletin, Campi Flegrei, June 2024.

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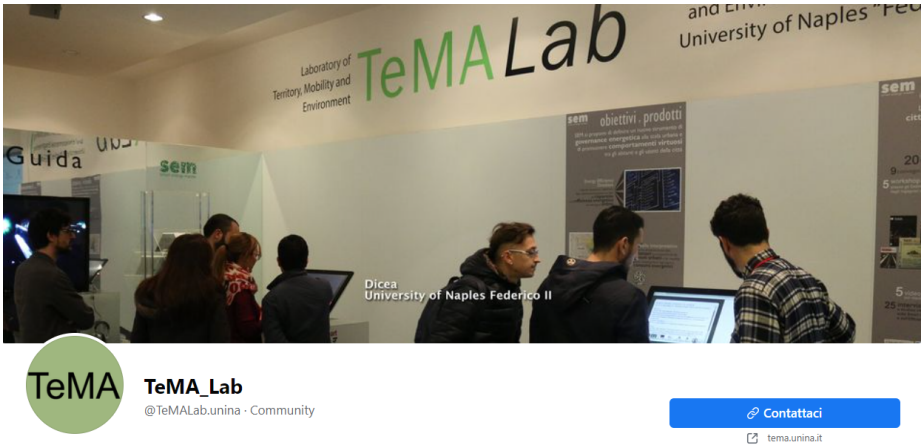

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Mobilising equity. Emerging evidence for integrating vulnerable communities

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Abstract
The transition towards sustainable cities is progressing, with numerous smart city technologies and innovative concepts being implemented. However, these advancements have predominantly focused on urban areas, often overlooking the critical need for integrating transportation systems with surrounding rural regions. Equitable access for vulnerable populations in peripheral areas remains underexplored, with most research focusing on the elderly while neglecting other vulnerable groups such as ethnic and gender minorities, women, young people, and individuals with serious health conditions. Empirical evidence shows that many rely on private transportation or are confined to small, localized areas. This article, through a literature review, analyses emerging research evidence on transportation for vulnerable groups, emphasizing the need to integrate technological solutions for individuals with reduced mobility (e.g. such as the visually impaired) into digital mobility platforms and land-use planning. The study highlights the lack of focus on rural regions and diverse vulnerable groups, stressing the importance of better integrating technology and land-use planning to improve transportation accessibility.

Keywords
Vulnerable groups; Accessibility; Mobility inclusive; Sustainable mobility; Policies.

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1. Introduction

The connection between transportation systems, land use, and mobility is fundamental for fostering social inclusion and well-being (Preston & Rajé, 2007). Efficient transportation access is essential for participation in key daily activities, such as healthcare, employment, and recreation (Gatrell, 2013; Papagiannidis et al., 2017). However, approximately 16% of the global population, including individuals with physical, sensory, or cognitive impairments, economically disadvantaged groups, and ethnic minorities, face restricted mobility options, limiting their ability to access essential services (WHO, 2021). This issue is expected to intensify with demographic changes, including aging populations and rising non-communicable diseases (He et al., 2020).

Accessibility challenges persist, particularly in low-income and underserved areas (Martens, 2019), where infrastructure investments are minimal, leading to high travel costs and extended commute times (El-Geneidy et al., 2016). Despite technological advancements (Oguz & Tanyas, 2024), marginalized groups continue to face systemic barriers, including financial limitations, physical inaccessibility (Soltani et al., 2012), and discriminatory practices. Technologies such as Intelligent Control Technology "ICT" and Augmented Reality "AR" offer promising tools, but their adoption often fails to address the specific needs of diverse vulnerable populations, especially in rural contexts (Nixon & Schwanen, 2018; Ma et al., 2018). Moreover, the COVID-19 pandemic further exposed the vulnerability of transportation systems, particularly for the elderly (LaPlante, 2014), immunocompromised, and those experiencing intersecting forms of marginalization (Beck & Hensher, 2020). This highlights the urgent need for resilient and inclusive infrastructure that caters to diverse user needs.

Understanding mobility vulnerabilities requires an intersectional approach to examine how social identities like gender, race, disability, and economic status intersect, creating compounded barriers to transportation access (Crenshaw, 1991; Sheller, 2018). For example, low-income women may face financial, cultural, and safety challenges, while ethnic minorities or individuals with disabilities may encounter discrimination limiting their mobility. Addressing these inequalities demands targeted strategies that consider these overlapping factors. (D'Agostino et al., 2024).

However, empirical studies lack comprehensive evaluations of technology adoption rates among economically disadvantaged or elderly users. Yet, evidence on how new design changes have tangibly improved daily mobility outcomes for vulnerable populations remains limited. Globally, policy innovations and best practices (BPs) offer valuable lessons for addressing mobility challenges, yet their impacts remain underexplored. The selected examples stand out for their integration of inclusivity and technological innovation, demonstrating measurable outcomes while addressing physical and digital barriers to mobility. In Finland, the Whim app integrates diverse transport modes into a seamless, multi-modal platform with flexible fare structures, reducing travel barriers and enhancing convenience. However, scalability and affordability remain challenges. Barcelona's accessible metro system exemplifies universal design principles, improving accessibility for mobility-impaired users, though long-term maintenance remains critical. In Medellín, the Metrocable system connects low-income hillside communities with central hubs, reducing travel times and improving access to education and healthcare. However, questions about subsidy sustainability persist.

São Paulo's community-led BRT system emphasizes participatory planning, fostering community ownership and localized solutions, though consistent institutional commitment is essential. In London, the contactless payment system enhances efficiency and reduces boarding times but lacks comprehensive analysis of its impact on low-income users (Moore et al., 2013). Similarly, Los Angeles' electric bus initiative offers environmental benefits but requires deeper evaluation of equity outcomes.

These cases reveal key lessons: inclusivity must be embedded from the outset, technology serves as an enabler but must remain accessible, and long-term financial sustainability is essential. Additionally, community participation strengthens adoption and trust. While these BPs are context-specific, they offer adaptable

frameworks for designing equitable, efficient, and sustainable mobility systems. Future research should focus on evaluating these dimensions to ensure broader applicability and long-term impact.

While these examples highlight promising interventions, they are often presented in fragmented narratives, lacking systematic evaluation frameworks to assess their long-term impacts on accessibility, social inclusion, and resilience. This paper addresses this analytical gap through a comprehensive literature review, incorporating academic and grey literature, including policy documents and case studies that explicitly focus on these dimensions but remain underexplored empirically.

The analysis focuses on three key dimensions (Litman, 2022; Lucas, 2011):

a) Equity-focused policies addressing disparities related to age, health, gender, and economic status to ensure fair mobility access;
b) Community engagement frameworks that align mobility solutions with the lived experiences of vulnerable groups, fostering trust and sustainable adoption;
c) Technology adoption strategies designed to bridge urban-rural divides and promote inclusive digital accessibility.

This study contributes to a deeper understanding of how transportation systems can reduce mobility inequalities and enhance social inclusion, advocating for further empirical research to validate these insights across diverse geographical and socio-economic contexts.

The central research question (RQ) guiding this study is: "How can technological and digital mobility solutions for users with reduced mobility be integrated into transportation systems to enhance accessibility for vulnerable populations, particularly in underserved urban and rural areas?".

The study structure is as follows. After this introduction, Section 2 describes the empirical background on current trends. Section 3 outlines the methodology. Section 4 discusses the results and discussion. Section 5 concludes with recommendations for policymakers, urban planners, and stakeholders to create equitable, inclusive, and sustainable mobility systems.

2. Background

The concept of social vulnerability includes not only "vulnerable populations" but also fragile individuals, such as the elderly with reduced mobility, the visually impaired, and the immunocompromised. Addressing their needs relies on technologies like Mobility-as-a-Service (MaaS), Artificial Intelligence (AI), and machine learning, which offer tailored navigation tools. However, these technologies remain only partially integrated into transportation systems, limiting their accessibility and effectiveness.

Despite advances in digital route assistance, elderly and visually impaired users still face significant barriers, especially in areas with poor technological infrastructure. Public transport systems often fail to accommodate immunocompromised individuals, pushing them to rely on private vehicles. In rural areas, and highlighted by O'Neill & O'Mahony (2005) for Ireland, the limited deployment of transport technologies further restricts mobility options and access to essential services.

While mobility planning increasingly prioritizes accessibility and equity, integrating trends such as ecological mobility and active transportation remains challenging for fragile groups. The adoption of ICT, MaaS, and Big Data technologies is still limited, preventing scalable and inclusive solutions.

The condition of mobility poverty reflects a lack of reliable, affordable, and sustainable transportation options, constrained by spatial, economic, technological, and cultural barriers (Kuttler & Moraglio, 2023). Overcoming these barriers requires integrated, equity-focused strategies to ensure accessible mobility for all.

From a spatial and geographic perspective, mobility barriers are distributed unevenly, with rural and peri-urban areas suffering from inadequate infrastructure and unreliable transit networks (O'Neill & O'Mahony, 2005). These deficits often force residents to rely on private vehicles, increasing financial burdens and

environmental degradation. In contrast, urban centers face different but equally challenging issues, including overcrowded networks and limited last-mile connectivity.

The economic dimension highlights the burden of transportation costs on low-income populations, who often cannot afford private vehicles or costly urban transit fares. Maintenance expenses, combined with the financial pressures of transit access, exacerbate existing inequalities (Lucas, 2011). These economic barriers frequently overlap with spatial disparities, intensifying social exclusion (Ignaccolo et al., 2016).

In the technological sphere, innovations like Mobility-as-a-Service (MaaS) and AI-driven mobility tools offer solutions for optimizing transit routes, improving flexibility, and enabling adaptive services. Multiple transport services into a single platform, simplifying travel for users (Sen et al., 2022). However, challenges such as digital literacy gaps, limited infrastructure readiness, and financial barriers prevent widespread adoption, especially in rural and underserved areas (Park et al., 2022).

The environmental dimension focuses on the sustainability challenges associated with mobility poverty. In regions where public transport is sparse or unreliable, dependency on private vehicles leads to increased carbon emissions and worsened air quality. At the same time, sustainable infrastructure—such as cycling lanes and pedestrian pathways—remains underdeveloped in vulnerable regions, further limiting accessible options (Titheridge et al., 2014).

The social and cultural dimension reflects barriers rooted in discrimination, safety concerns, and cultural exclusion, particularly for women, ethnic minorities, and migrants. Poorly lit transit stops, limited language assistance, and systemic biases in planning disproportionately impact these groups, reinforcing their exclusion from mobility networks. According to D'Agostino et al. (2024) women in advanced countries tend to travel shorter distances, make more daily trips, use cars less frequently, and are more willing to adopt sustainable travel behaviours than men.

To address these interconnected barriers, land-use planning and transportation systems must be integrated effectively. Mixed-use development reduces travel distances to essential services, while Transit-Oriented Development (TOD) enhances connectivity and encourages reliance on sustainable transit options. Cerdá et al. (2012) describing Medellín's Metrocable system, demonstrate the potential of TOD policies to improve spatial connectivity and inclusion. However, without complementary housing and affordability policies, TOD strategies risk triggering gentrification and displacement, ultimately excluding the very populations they aim to serve (Vecchio & Martens, 2021).

Technological advancements like MaaS platforms and AI tools offer additional opportunities to bridge mobility gaps. For individuals with motor, sensory, or cognitive impairments, MaaS platforms provide real-time updates on accessible routes, while AI-driven systems optimize service delivery and route planning to accommodate demand fluctuations (Park et al., 2022). However, these technologies remain underutilized in rural and marginalized areas, where affordability and digital literacy gaps persist. Evidence in European cities (e.g., Toronto and Barcelona) shows how policy initiatives can reduce financial and infrastructure barriers. Toronto's fare subsidy has notably improved transit affordability for low-income users (Barri et al., 2021), while Barcelona's station redesigns increased transit usability for individuals with mobility impairments by 27% (Comim, 2008). Nevertheless, both cases emphasize the importance of sustained investment and community engagement to ensure long-term success. Examples like London's contactless payment system and Los Angeles' electric bus initiative highlight how technology and environmental goals can intersect with social equity, albeit with limitations in reaching marginalized communities (Bezbradica & Ruskin, 2019; Allen & Farber, 2020).

Addressing mobility poverty requires a multi-faceted strategy that combines targeted technological integration, policy alignment, and sustained infrastructure investment. The next section will build upon these insights,

presenting evidence-based findings from the literature to highlight effective strategies for overcoming mobility barriers and fostering inclusive transportation systems.

Building on the earlier discussion, social vulnerability and mobility poverty are deeply interconnected, as limited transportation access amplifies exclusion from economic, social, and cultural activities. Vulnerable groups, including older adults, individuals with physical, sensory, or cognitive impairments, economically disadvantaged populations, women (D'Agostino et al., 2024), youth, and ethnic minorities, face compounded barriers due to inadequate infrastructure, affordability constraints, and systemic exclusion (Battarra et al., 2018; Park & Chowdhury, 2018).

Globally, well-planned transportation systems have shown potential to improve access to employment, healthcare, and education, fostering social inclusion and economic growth (Cerdá et al., 2012; Vecchio & Martens, 2021). Investments in accessible metro systems and fare equity programs demonstrate positive outcomes, but their scalability remains limited (Comim, 2008; Barri et al., 2021).

Technological innovations, including Mobility-as-a-Service (MaaS) and digital payment systems, offer promising solutions. However, while affluent users benefit from seamless integration, low-income populations often face financial barriers, limiting their accessibility and equity impact (Arai et al., 2022).

Addressing these challenges requires integrated strategies that bridge spatial, economic, and technological divides to ensure inclusive, accessible, and resilient mobility systems. Further empirical research is essential to validate these approaches and assess their effectiveness across diverse contexts.

3. Methodology

3.1 Identification of target groups

In line with the literature review methodology described, this section identifies the key vulnerable groups facing mobility barriers and transport poverty, drawing from established literature (Hine & Mitchell, 2016; Lucas et al., 2016; Van Wee & Geurs, 2011). These studies emphasize how systemic inequalities, infrastructural limitations, and socio-economic disparities create persistent mobility challenges for marginalized populations.

The specific user groups analysed include:

1. Individuals with Disabilities: People with mobility, sensory, or cognitive impairments who encounter physical and infrastructural barriers within transportation systems (Currie et al., 2010);
2. Economically Disadvantaged Populations: Communities with limited financial resources, often disproportionately affected by high transport costs and underfunded infrastructure (Lucas, 2012);
3. Elderly Populations: Older adults whose physical and cognitive limitations, coupled with transport design barriers, restrict their independent mobility (Shergold & Parkhurst, 2012);
4. Women and Youth: Groups facing social and cultural barriers, including safety concerns, caregiving responsibilities, and financial dependence (Uteng & Cresswell, 2008);
5. Ethnic Minorities and Marginalized Communities: Populations experiencing systemic discrimination and cultural exclusion in accessing transportation services (Soja, 2013; Oviedo & Sabogal, 2020);
6. Residents in Rural or Remote Areas: Individuals in low-density regions where public transport services are often unreliable, sparse, or economically unfeasible (Nutley, 2003).

As shown in Tab.1, these user groups were selected based on their documented vulnerabilities in global policy discussions on mobility justice, their prominence in academic research, and their alignment with sustainable transport strategies (Jones et al., 2018; Lucas, 2012). These references highlight the interconnected nature of social equity, mobility access, and transport infrastructure investment, providing a robust foundation for

this analysis. These groups represent the focus of the reviewed studies and provide a foundation for analyzing mobility-related social exclusion and accessibility challenges. Tab.1 summarizes their barriers, spatial contexts, and rationales:

1. Low-income and Unemployed Individuals:
- Barrier. High transportation costs, limited public transport access;
- Spatial Context. Urban reliance on public transit; rural dependence on car ownership;
- Rationale. Transport costs exacerbate poverty and reliance on inefficient systems (Lucas et al., 2016). In 2022, 21.7% of the EU population faced poverty risk (Eurostat, 2022).

2. Elderly Persons, Women, and Gender-Diverse Groups:
- Barrier. Physical infrastructure issues, safety concerns, limited services;
- Spatial Context. Urban and rural areas, with acute challenges in low-density zones;
- Rationale. Women face safety concerns, while elderly individuals encounter physical barriers. In 2021, 22.7% of women in the EU faced poverty risk (Eurostat, 2022).

3. Young People (16-24 years):
- Barrier. Financial dependence, restricted access to transport options;
- Spatial Context. Urban and suburban areas with infrequent transit services;
- Rationale. Limited financial independence hinders youth mobility (Eurostat, 2022).

4. Migrants and Ethnic Minorities:
- Barrier. Language barriers, financial constraints, cultural discrimination;
- Spatial Context. Predominantly urban areas with uneven transport access;
- Rationale. Reduced access due to financial and language challenges. In 2021, 5.3% of the EU population were non-EU citizens (Eurostat, 2022).

5. People with Reduced Mobility:
- Barrier. Inadequate infrastructure, lack of adapted services, technological exclusion;
- Spatial Context. Urban architectural barriers; poor rural services;
- Rationale. Specially adapted services are essential for equitable mobility. In 2021, 29.7% of disabled individuals in the EU faced poverty risk (Eurostat, 2022).

6. Residents of Rural, Disadvantaged, and Marginal Urban Areas:
- Barrier. Sparse networks, low transit frequency, long travel times;
- Spatial Context. Rural and peripheral areas with limited services;
- Rationale. Poor infrastructure limits access to essential services. In 2018, 29.1% of EU residents lived in rural areas (Eurostat, 2022).

7. Immunocompromised Individuals:
- Barrier. Safety and hygiene concerns in shared transport systems;
- Spatial Context. Urban and rural environments, with higher risks in crowded settings;
- Rationale. Safe travel conditions are essential but often unmet (Pezzagno & Richiedei, 2022).

These groups highlight the multifaceted barriers to mobility, emphasizing the need for targeted strategies to address their unique challenges across urban, suburban, and rural contexts.

4. Results and discussion

This section describes the results of the methodology, highlighting the role of policy-driven mobility solutions in overcoming barriers faced by older adults, individuals with impairments, economically disadvantaged populations, women, youth, and ethnic minorities.

Keyword Sector	Target Groups	Area of Interest	Quantitative Methods	Qualitative Methods	Focus of Vulnerability	Data Collection Method	Example References	No. of Papers Reviewed
Land-Use Integration	Economically disadvantaged groups	Transport policies, geography	✓	✓	Socio-economic exclusion	Travel survey, GIS	El-Geneidy et al., 2016; Welch & Mishra, 2013	12
Gender and Youth Mobility	Women, Youth	Behavioral science	✓	✓	Gender-specific barriers, safety	GPS tracking, Interviews	Vecchio & Martens, 2021; Park et al., 2022	10
Assistive Transport Tools	Individuals with impairments	Health, accessibility	✓	✓	Mobility, cognitive, sensory barriers	Questionnaire, Interviews	Li & Loo, 2017; Park & Chowdhury, 2018	8
Marginalized Communities	Ethnic minorities	Co-design, urban planning	✓	✓	Systemic and cultural exclusion	Travel survey, Focus groups	Nixon & Schwanen, 2018; Hananel & Berechman, 2016	9
Spatial Accessibility	Rural and remote communities	Regional geography	✓	✓	Infrastructure and distance barriers	Travel survey, GIS	Combs et al., 2016; Papa et al., 2018	7
Inclusive Policy Frameworks	Elderly	Social inclusion policies	✓	✓	Age-related accessibility barriers	Community workshops	Battarra et al., 2018; Shareck et al., 2014	6
Regulatory Policies	Cross-cutting (multiple groups)	Regulation, urban policy	✓	✓	Institutional and policy gaps	Document analysis	Di Ciommo & Shiftan, 2017; Allen & Farber, 2020	13

✓: Indicates that studies within the category utilized the specified methodological approach.

Tab.1 Overview of Reviewed Studies by Keyword Sector, Target Groups, and Methodologies (Elaboration of author)

The key findings of this research align with the five thematic dimensions (4.1–4.5) and offer an integrated framework for addressing mobility challenges:

1. Equitable transportation systems are essential for improving access to social, economic, and cultural opportunities. This aligns with Section 4.1: Policy-Oriented Mobility Targeting Vulnerable Groups, which emphasizes the role of targeted policy interventions, and Section 4.2: Accessibility and Proximity in Smart Cities, which focuses on spatial planning and urban design to minimize mobility barriers;
2. Active community participation ensures mobility solutions are aligned with the lived experiences and needs of end users. Section 4.5: Technology and Community Engagement explores participatory approaches to policymaking, while Section 4.4: Spatial and Infrastructure Resilience underscores how community input strengthens adaptability and responsiveness in infrastructure development;
3. Innovations such as Mobility-as-a-Service (MaaS) and ICT platforms offer scalable solutions to bridge mobility gaps. Section 4.3: Mobility Technologies for Vulnerable Groups examines these technologies' role in improving transport efficiency and inclusivity, while Section 4.4: Spatial and Infrastructure Resilience highlights the importance of context-specific implementation to address rural-urban disparities.

Together, these dimensions—policy frameworks (4.1), spatial planning (4.2), technological integration (4.3), infrastructure resilience (4.4), and community engagement (4.5) - form an interconnected strategy for combating mobility poverty. Each dimension contributes uniquely: policy provides direction, spatial planning ensures physical accessibility, technology drives innovation, resilient infrastructure sustains long-term access, and community engagement guarantees inclusivity and relevance. The following section builds on these insights, offering specific recommendations and actionable pathways to implement inclusive mobility solutions effectively. Lastly, the discussion proposes also an evaluation of different challenges across the types of regions, and the future development for research (4.7).

4.1 Policy oriented mobility targeting for vulnerable groups

Policy-oriented mobility focuses on tailored transport policies designed to address the unique needs of vulnerable groups. For instance, Toronto's Fair Pass program subsidizes public transit for low-income users,

reducing financial barriers (Barri et al., 2021), while Barcelona's metro upgrades improved usability for individuals with impairments by 27% (Comim, 2008).

However, policy effectiveness depends on clear metrics for accessibility and ongoing evaluation. Initiatives like Finland's Whim app demonstrate how MaaS platforms can offer integrated services, but questions remain about who drives these initiatives and how accessibility outcomes are measured (Sen et al., 2022).

Emerging trends in urban mobility, as outlined in the "POLIS Report" (Polis, 2021) and the EIT Report (EIT Urban Mobility, 2021), emphasize integrating resilience into sustainable urban mobility planning. These reports explore strategies for post-COVID mobility systems, highlighting best practices from European cities (Budd & Ison, 2020; Pan & He, 2022; Beck & Hensher, 2020). A key focus is on inclusiveness and integration, ensuring vulnerable groups are considered in urban and rural transport planning. Public transport remains vital for people with special needs, providing access to jobs, education, and social opportunities in disadvantaged areas. The MaaS sector is exploring accessibility measures, such as the Urban Mobility Index and Deloitte's City Mobility Index (Dixon et al., 2019), but these have yet to fully address the needs of vulnerable users. EU guidelines (2014) emphasize accessibility through user-centered design, including digital devices, audible/visual announcements, and affordability. The co-creation approach encourages civic participation, allowing communities to co-identify needs, co-develop solutions, and co-evaluate outcomes (EU, 2019). Community policies focus on reducing digital exclusion by improving access to technology, enhancing digital literacy, and ensuring adequate infrastructure. The European Accessibility Act (Directive (EU) 2019/882 (European Union - Regulation 2019) and the Regulation on Technical Specifications for Interoperability (EU, 2014) further support accessibility in transportation for people with disabilities.

4.2 Accessibility and proximity of smart cities

In smart city planning, accessibility serves as a core metric for evaluating the connection between people, territories, and transportation systems, while proximity, mobility, and connectivity represent the tools and processes enabling access. Accessibility, often considered an end goal, reflects the ability of individuals to reach essential services and opportunities efficiently and equitably, whereas mobility represents the movement itself, and proximity indicates the spatial arrangement of services relative to users.

Successful accessibility planning requires a shift from mobility-centered approaches to access-oriented frameworks, where the emphasis is placed on the capacity of transportation systems to meet social equity objectives. For example, Bocarejo & Oviedo (2012) developed a tool to analyze transport accessibility and social inequities, demonstrating how infrastructure and costs often limit access despite geographical proximity. Similarly, Sochor (2015) highlighted access deprivation through semi-structured interviews with disadvantaged populations, emphasizing the need to address both physical and economic barriers to access.

At the urban scale, Transit-Oriented Development (TOD) remains a widely adopted strategy to improve proximity and spatial accessibility by clustering housing, employment, and services around transit hubs. Medellín's Metrocable system stands as a notable example, successfully connecting marginalized neighborhoods with central urban areas (Xia et al., 2016) and significantly reducing travel times (Cerdá et al., 2012). However, TOD strategies can unintentionally lead to gentrification and displacement if not paired with complementary housing affordability policies (Vecchio & Martens, 2021). This highlights the necessity of cross-sectoral integration between transport, housing, and urban planning policies to ensure that improved accessibility translates into long-term inclusivity.

A critical issue in accessibility studies lies in the gap between theoretical proximity and real-world access. Pucci et al. (2019) note that even when facilities are geographically nearby, infrastructure quality, service availability, and costs often create significant barriers for vulnerable populations. To address these gaps, Paiva et al. (2022) argue for a social justice-oriented approach to accessibility, prioritizing equitable access across diverse socio-economic and demographic groups.

Measuring accessibility remains a persistent challenge, with methodologies varying significantly across studies. For instance, Ryan & Pereira (2021) and Sabella & Bezyak (2019) highlight the complexity of quantifying access deprivation, particularly for individuals with disabilities. Wong (2018) explores how social factors influence mobility among visually impaired individuals, while Boisjoly and El-Geneidy (2017) reviewed metropolitan transport plans, observing a trend towards integrating accessibility objectives. However, the practical application of accessibility-based indicators remains limited in many cities.

In terms of operational strategies, Cheng & Chen (2015) propose a multidimensional measure combining accessibility, mobility, and connectivity to evaluate public transport systems. Similarly, Guzman (Guzman et al., 2017; Guzman & Oviedo, 2018) examined 'pro-poor' public transport subsidies in Bogotá, showing how well-targeted financial measures can reduce access inequalities. Hidayati et al. (2019) report similar findings in Indonesia, underscoring the importance of context-specific policies in addressing affordability gaps.

In cities facing ageing population dynamics, accessibility becomes increasingly vital to support active ageing and continued participation in social and economic activities. Urban mobility systems must be designed to accommodate the specific needs of older adults, including considerations for safety, affordability, and physical accessibility. Initiatives integrating Smart City solutions, ICT technologies, and mobility services show promise in enhancing accessibility while addressing systemic vulnerabilities (Guida et al., 2020; Battarra et al., 2018; Pezzagno & Richiedei, 2022).

4.3 Mobility technologies for vulnerable groups

Technological innovations, including Mobility-as-a-Service (MaaS) platforms and AI-driven systems, hold significant potential to enhance accessibility, adaptability, and efficiency in transportation networks for vulnerable groups. MaaS platforms, such as Finland's Whim app, integrate multiple transportation modes—public transit, bike-sharing, and ride-hailing—into a single digital interface, simplifying travel planning and fare payments while offering flexible mobility options (Sen et al., 2022). Similarly, AI-powered tools enable demand-responsive transit services, optimizing routes and schedules based on real-time travel patterns and user demand, improving service availability in underserved areas (Park et al., 2022). However, despite these advancements, technological adoption remains uneven, particularly in rural and marginalized areas, where affordability, infrastructure gaps, and digital literacy barriers persist.

The limited success of MaaS in rural regions often stems from low population densities, making it economically unviable for private operators to deploy large-scale services. In contrast, urban environments with higher user volumes have seen more successful MaaS adoption, as demonstrated by Vienna's Smile app, which integrates multimodal travel and offers tailored options for elderly and disabled users. Similarly, in China (Niehaus et al., 2016) and in Singapore, AI technologies have been embedded in public transit systems to predict congestion, optimize routes, and ensure accessibility for users with limited mobility. These examples highlight the need for context-specific implementation strategies that address geographic, infrastructural, and socio-economic barriers.

For elderly individuals, technology offers both opportunities and challenges. While ICT tools can improve independence and enable real-time route planning, older adults often face digital literacy barriers and struggle with interfaces designed without their needs in mind. Moreover, outdated infrastructure—such as poorly designed bus stops, uneven sidewalks, and inadequate signage—further undermines the potential benefits of mobility technologies (Pretty et al., 2002). Research by Riazi et al. (2016) underscores these challenges, identifying outdoor navigation difficulties for visually impaired individuals, including unreadable signs, disorientation, and safety hazards.

For individuals with disabilities, paratransit services remain a critical, albeit often limited, option. Studies by Egger et al. (2022) in Switzerland highlight the barriers and facilitators affecting paratransit adoption, including poor scheduling reliability, limited coverage, and inadequate integration with broader transit networks. Addressing these issues requires infrastructure improvements alongside technological advancements, such as

real-time scheduling apps and accessible payment systems, which have shown success in cities like Berlin and Zurich.

The digital divide is another significant barrier, particularly in rural areas, where access to affordable mobile devices and stable internet connections is limited. Programs like India's Common Service Centers (CSCs) demonstrate how localized ICT hubs can address digital literacy gaps, providing community-based access to digital transportation services.

Integration between technological solutions and urban planning remains a critical gap in both research and practice. Technologies like MaaS and AI-based mobility platforms are often implemented as isolated solutions rather than being embedded into broader transportation and land-use strategies. For example, while MaaS platforms in cities like Helsinki and Vienna offer flexible urban mobility options, their success relies on integrated land-use policies that ensure equitable coverage across diverse neighborhoods.

To maximize the benefits of mobility technologies for vulnerable populations, a holistic approach is essential. This includes affordable and context-specific digital solutions, inclusive design principles, infrastructure readiness, and community involvement in the design and deployment phases. Cities must not only invest in cutting-edge technologies but also ensure these systems are user-friendly, widely accessible, and tailored to the unique challenges faced by vulnerable populations.

4.4 Spatial and infrastructure resilience

Resilient infrastructure ensures long-term, adaptive transit networks that respond to economic, environmental, and social challenges. Initiatives like Los Angeles' electric bus fleet showcase environmental sustainability but face challenges in reaching peripheral neighborhoods (Allen & Farber, 2020).

Similarly, São Paulo's community-led BRT systems highlight how local participation can improve infrastructure relevance and adoption (Cordoba et al., 2014). Success depends on sustained investment and adaptive planning.

Recent focus on resilience in urban transportation emphasizes reducing impacts and maintaining mobility, particularly for vulnerable populations (Wan et al., 2018; Mattsson & Jenelius, 2015). Resilience is closely tied to vulnerability and has gained attention in transportation studies, especially regarding reduced mobility for the elderly and visually impaired. Muller et al. (2021) identified mobility indices for MaaS, using heat maps to evaluate accessibility and performance. Van Dülmen et al. (2022) examined transportation poverty through GPS tracking in rural Czech and German regions, finding that social disadvantage often outweighs regional differences in mobility. Compagnucci & Morettini (2020) proposed a space-equity approach for equal access to services in inner regions, emphasizing the need for integrated systems, as in rural areas (Vitale Brovarone, 2021). Universal public transportation design often neglects vulnerable users, leading to unnecessary detours and collision risks, particularly for wheelchair users (Velho, 2019), the elderly, and women with strollers. Hranický et al. (2021) addressed rail transport for people with disabilities, focusing on specialized train cars. Arai et al. (2022) used network analysis to evaluate wheelchair accessibility at train stations, highlighting proximity, reachable times, and collision risks on designated paths.

4.5 Technology and community engagement

Community engagement bridges policy intent with user needs, ensuring mobility solutions reflect lived experiences. Participatory initiatives, as seen in Barcelona's inclusive mobility plans and Medellín's community-driven transit projects, demonstrate how local involvement fosters trust and alignment (Comim, 2008; Cerdá, et al., 2012).

However, engagement must go beyond consultation, requiring active citizen participation in planning, monitoring, and evaluation processes.

Research by Lee et al. (2022) in South-Corea identified a strong link between life satisfaction and perceived mobility environments among wheelchair users, highlighting the importance of social initiatives to boost mobility and social interaction (Dennis et al., 2016). European policies, such as those examined by Chiscano & Darcy (2022) in Barcelona, advocate for inclusive public transport co-designed with input from people with disabilities. Technologies can also address more nuanced factors like perceptions of accessibility, safety, and communication, all of which influence mobility decisions (Sochor, 2014). Though digitization has been slow among the elderly, the increasing use of ICT and Big Data supports a shift towards green, multimodal mobility solutions (Sochor, 2015). Navigation assistance for visually impaired individuals, such as the DeepNAVI system, shows potential for promoting independent living (Kuriakose et al., 2020). However, digital solutions sometimes introduce biases that restrict accessibility for vulnerable populations, including people with disabilities (Kwakye, 2022). Common barriers include administrative restrictions, negative driver attitudes, and difficulties in securing wheelchairs in vehicles (Hezam et al., 2022; Bezyak et al., 2019). Mora et al. (2017) emphasize the importance of involving vulnerable citizens as active participants in shaping more accessible urban environments (Ferrari et al., 2014). Cities can adopt a framework that combines urban planning, mobility strategies, and governance approaches (Martinelli, 2024) to enhance urban accessibility for the elderly (D'Amico, 2024), promoting an active, inclusive, and age-friendly urban environment (Gargiulo et al., 2018).

4.6 Investigation of ICT solutions across regions

This section explores regional differences in the adoption and effectiveness of ICT-based mobility solutions for vulnerable groups, highlighting distinct challenges and opportunities in urban and rural contexts as identified in the literature. In urban areas, ICT tools such as Mobility-as-a-Service (MaaS) platforms, AI-powered route optimization, and digital payment systems have shown significant potential to improve accessibility and reduce mobility barriers. For example, Finland's Whim app integrates multiple transport modes into a single platform, offering flexibility and convenience (Sen et al., 2022). Similarly, Singapore employs AI-driven systems to predict congestion and optimize routes, enhancing accessibility for vulnerable users (Arai et al., 2022; Zhou et al., 2012). Research by Battarra et al. (2018) emphasizes how smart mobility technologies, when paired with inclusive urban planning, can support accessibility for the elderly and people with disabilities. However, Wong (2018) and Bezyak et al. (2019) highlight persistent challenges, including digital literacy gaps and interface design shortcomings, which often exclude older adults and visually impaired individuals. In rural regions, ICT adoption faces systemic barriers, including low population density, poor digital infrastructure, and limited financial sustainability (Combs et al., 2016; Milbourne & Kitchen, 2014). Studies by Egger et al. (2022) reveal that paratransit services, often supported by ICT scheduling tools, struggle with limited coverage and operational inefficiencies. Additionally, the digital divide remains a critical obstacle, as access to affordable mobile devices and reliable internet connections is often restricted (AbuJarour, 2022; Pezzagno & Richiedei, 2022). Cross-regional analysis reveals that affordability and user-centered design are central to the effectiveness of ICT solutions. Research by Chiscano & Darcy (2022) stresses the importance of co-creation approaches in developing accessible transport technologies, while Busco et al. (2023) argue that financial barriers often prevent low-income populations from fully benefiting from subscription-based MaaS platforms. Holistic strategies integrating ICT solutions with broader transport policies and community engagement frameworks are essential. Allen & Farber (2020) propose an accessibility-activity participation model to evaluate social inclusion outcomes, while Bantis & Haworth (2020) suggest adopting a capabilities-based approach to assess ICT interventions' impacts on equity. Additionally, Gargiulo et al. (2018) emphasize the need for smart city frameworks that prioritize social justice and ensure that technological advancements do not exacerbate existing inequalities. In conclusion, while ICT-based mobility solutions offer transformative potential, their success depends on affordable digital tools, localized infrastructure investments, inclusive design, and active community participation to address disparities across urban and rural contexts (Boisjoly & El-Geneidy, 2017; Hananel & Berechman, 2016).

4.7 Further research directions

Equitable and accessible transportation systems must address the physical, economic, and social barriers faced by vulnerable groups, including the elderly, disabled, and economically disadvantaged (Stanley & Stanley, 2017; Stanley et al., 2011, 2012, 2019, 2022). Infrastructure improvements, such as ramps, accessible vehicles, and ICT tools for journey planning, are essential for enhancing mobility equity. Technologies like Mobility-as-a-Service (MaaS) must be user-friendly and tailored to accommodate diverse abilities (Battarra et al., 2018).

In rural areas, where mobility barriers are more pronounced, specific investments are needed to reduce isolation and improve access to essential services such as healthcare and education (Di Ruocco, 2022a,b, 2024; Combs et al., 2016). Integration between land use planning and transport systems can minimize travel distances and improve accessibility (Lucas, 2012; Kuttler & Moraglio, 2023). Transit-Oriented Development (TOD) principles, typically urban-focused, should be adapted for rural hubs to create better connectivity.

Technological solutions, including MaaS and ICT platforms, have potential but require adaptability and scalability to overcome rural infrastructure limitations (Arai et al., 2022; Zhou et al., 2012). Additionally, digital literacy programs and affordable digital tools must accompany these solutions to bridge existing divides (AbuJarour, 2022; Bezyak et al., 2019).

Community engagement is critical for developing transport solutions that reflect local needs. Inclusive participatory planning fosters trust and aligns infrastructure with social equity goals (Chiscano & Darcy, 2022; Papa et al., 2018). Coordinated approaches involving governments, private sectors, and NGOs can ensure sustained implementation and policy alignment (Allen & Farber, 2020; Bantis & Haworth, 2020).

On this premise, this study proposes future research directions:

- Comparative Regional Analysis: Assess how urban and rural settings respond differently to MaaS and ICT adoption, focusing on factors such as infrastructure readiness, financial barriers, and cultural acceptance;
- Spatial Integration Studies: Examine how land use policies and transportation networks can be better aligned to improve accessibility across diverse geographic contexts;
- Technological Inclusivity: Investigate how digital tools can be optimized for elderly and disabled users, addressing challenges in interface design and usability;
- Affordability and Financial Models: Explore sustainable funding mechanisms, including fare subsidies and public-private partnerships, to ensure equitable access to mobility services;
- Case Study Evaluation: Deep dive into best practices from successful transport initiatives, such as Toronto's Fair Pass program or Medellín's Metrocable system, to identify replicable strategies (Cordoba et al., 2014; Dharmowijoyo & Joewono, 2019).

Policy Effectiveness Metrics: Develop measurable indicators to evaluate the social, economic, and environmental impacts of transport interventions in underserved areas.

5 Conclusions

The findings suggest that while technologies like Mobility-as-a-Service (MaaS) and ICT offer significant potential for enhancing mobility, their effectiveness is constrained without the support of well-integrated land use planning and inclusive policies (Shliselberg & Givoni, 2017). Addressing mobility poverty requires a comprehensive approach that includes technological innovations, sustainable land use strategies, and policies that promote inclusion and equity. This integrated approach will help reduce transportation disparities and improve access to essential services, particularly for vulnerable populations in both urban and rural areas. Expanding on these strategies can foster a more equitable transportation system that prioritizes social inclusion and sustainability (Pezzagno & Richiedei, 2022). However, limitations include an urban-centric focus in the literature, limited insights from rural areas, and a lack of longitudinal data to measure long-term impacts.

Despite these gaps, the study distinguishes disability-specific barriers from broader socio-economic challenges, ensuring a clear analysis of mobility inequities (Remillard et al., 2022). It highlights the need for affordable digital tools, context-specific policies, and community engagement to bridge gaps in accessibility.

Future research will refine these insights, focusing on successful case studies and developing measurable indicators for evaluating policy effectiveness. This study offers a foundation for inclusive, resilient, and equitable transportation systems, providing actionable insights for policymakers and stakeholders

References

AbuJarour, S. (2022). Integration through education: Using ICT in education to promote the social inclusion of refugees in Germany. *Journal of Information Systems Education, 33* (1), 51-60. https://aisel.aisnet.org/jise/vol33/iss1/7

Allen, J. & Farber, S. (2020). Planning transport for social inclusion: An accessibility-activity participation approach. *Transportation Research Part D: Transport and Environment, 78*, 102212. https://doi.org/10.1016/j.trd.2019.102212

Arai, Y., Kusakabe, T., Niwa, Y. & Honma, K. (2022). Evaluation of wheelchair accessibility in train stations using a spatial network. *Asian Transport Studies, 8*, 100067. https://doi.org/10.1016/j.eastsj.2022.100067

Bantis, T. & Haworth, J. (2020). Assessing transport-related social exclusion using a capabilities approach to accessibility framework: A dynamic Bayesian network approach. *Journal of Transport Geography, 84*, 102673. https://doi.org/10.1016/j.jtrangeo.2020.102673

Barri, E. Y., Farber, S., Kramer, A., Jahanshahi, H., Allen, J. & Beyazit, E. (2021). Can transit investments in low-income neighbourhoods increase transit use? Exploring the nexus of income, car-ownership, and transit accessibility in Toronto. Transportation Research Part D: Transport and Environment, 95, 102849. https://doi.org/10.1016/j.trd.2021.102849

Battarra, R., Zucaro, F. & Tremiterra, M. (2018). Smart mobility and elderly people. Can ICT make the city more accessible for everybody?. *TeMA - Journal of Land Use, Mobility and Environment*, 23-42. https://doi.org/10.6092/1970-9870/5768

Beck, M. J. & Hensher, D. A. (2020). Insights into the impact of COVID-19 on household travel and activities in Australia–The early days under restrictions. *Transport Policy, 96*, 76-93. https://doi.org/10.1016/j.tranpol.2020.07.001

Bezbradica, M. & Ruskin, H. J. (2019). Understanding urban mobility and pedestrian movement. In V. Bobek (Ed.), *Smart Urban Development*, 149. IntechOpen eBooks. https://doi.org/10.5772/intechopen.86801

Bezyak, J. L., Sabella, S., Hammel, J., McDonald, K., Jones, R. A. & Barton, D. (2019). Community participation and public transportation barriers experienced by people with disabilities. *Disability and Rehabilitation, 42* (23), 3275-3283. https://psycnet.apa.org/doi/10.1080/09638288.2019.1590469

Bocarejo S., J. P. & Oviedo H., D. R. (2012). Transport accessibility and social inequities: A tool for identification of mobility needs and evaluation of transport investments. *Journal of Transport Geography, 24*, 142–154. https://doi.org/10.1016/j.jtrangeo.2011.12.004

Boisjoly, G. & El-Geneidy, A. M. (2017). How to get there? A critical assessment of accessibility objectives and indicators in metropolitan transportation plans. *Transport Policy, 55*, 38-50. http://dx.doi.org/10.1016/j.tranpol.2016.12.011

Budd, L. & Ison, S. (2020). Responsible transport: A post-COVID agenda for transport policy and practice. *Transportation Research Interdisciplinary Perspectives, 6*, 100151. http://dx.doi.org/10.1016/j.trip.2020.100151

Busco, C., González, F., Carmona, P., Cancino, A. & Alonso, B. (2023). Social exclusion and the public bus system in Santiago, Chile. *Cities, 132*, 104092. http://dx.doi.org/10.1016/j.cities.2022.104092

Cerdá, M., Morenoff, J. D., Hansen, B. B., Tessari Hicks, K. J., Duque, L. F., Restrepo, A. & Diez-Roux, A. V. (2012). Reducing violence by transforming neighborhoods: a natural experiment in Medellín, Colombia. *American journal of epidemiology*, *175*(10), 1045-1053. https://doi.org/10.1093/aje/kwr428

Cheng, Y. & Chen, S. (2015). Perceived accessibility, mobility, and connectivity of public transportation systems. *Transportation Research Part A: Policy and Practice, 77*, 386-403. https://doi.org/10.1016/j.tra.2015.05.003

Chiscano, M. C. & Darcy, S. (2022). An accessible and inclusive public transportation management response to COVID-19 through a co-creation process with people with disability. The case of Metro Barcelona. *Research in Transportation Business & Management, 45*, 100880. https://doi.org/10.1016/j.rtbm.2022.100880

Combs, T. S., Shay, E., Salvesen, D., Kolosna, C. & Madeley, M. (2016). Understanding the multiple dimensions of transportation disadvantage: The case of rural North Carolina. *Case Studies on Transport Policy, 4* (2), 68-77. http://dx.doi.org/10.1016/j.cstp.2016.02.004

Comim, F. (2008). Measuring capabilities. In F. Comim, M. Qizilbash & S. Alkire (Eds.), *The Capability Approach: Concepts, measures and applications*. Cambridge University Press.

Compagnucci, F. & Morettini, G. (2020). Improving resilience at the local level: The location of essential services within inner areas. Three case studies in the Italian Marche region. *Regional Science Policy & Practice, 12* (5), 767-793. https://doi.org/10.1111/rsp3.12343

Cordoba, D. Z., Stanley, J. & Stanley, J. R. (2014). Reducing social exclusion in highly disadvantaged districts in Medellín, Colombia, through the provision of a cable-car. *Social Inclusion, 2* (4), 1-13. https://doi.org/10.17645/si.v2i4.127

Crenshaw, K. (1991). Race, gender, and sexual harassment. *Southern California Law Review, 65*, 1467-1496. https://doi.org/10.2139/ssrn.1434678

Currie, G., Richardson, T., Smyth, P., Vella-Brodrick, D., Hine, J., Lucas, K., ... & Stanley, J. (2010). Investigating links between transport disadvantage, social exclusion and well-being in Melbourne–Updated results. *Research in transportation economics*, *29*(1), 287-295. https://doi.org/10.1016/j.retrec.2010.07.036

D'Agostino, C., Piva, E., Pucci, P. & Rossi, C. (2024). A systematic literature review on women's daily mobility in the Global North. *Transport Reviews, 44* (5), 1016-1044. http://dx.doi.org/10.1080/01441647.2024.2350613

D'Amico A. (2024). Strategies and instruments for active mobility: the main Italian policies. *TeMA - Journal of Land Use, Mobility and Environment*, *17* (3), 509-515. https://doi.org/10.6093/1970-9870/11166

Dennis, C., Alamanos, E., Papagiannidis, S. & Bourlakis, M. (2016). Does social exclusion influence multiple channel use? The interconnections with community, happiness, and well-being. *Journal of Business Research, 69* (3), 1061-1070. https://doi.org/10.1016/j.jbusres.2015.08.019

Dharmowijoyo, D. B. E. & Joewono, T. B. (2019). Mobility and health: The interaction of activity-travel patterns, overall well-being, transport-related social exclusion on health parameters. In *Energy Efficiency in Mobility Systems*, 53-83. https://doi.org/10.1007/978-981-15-0102-9_4

Di Ciommo, F. & Shiftan, Y. (2017). Transport equity analysis. *Transport Reviews, 37* (2), 139-151. https://doi.org/10.1080/01441647.2017.1278647

Di Ruocco, I. (2022a). Resilient marginal cities by encouraging intermodality strategies. *TeMA - Journal of Land Use, Mobility and Environment, 15* (3), 377-396. https://doi.org/10.6092/1970-9870/9031

Di Ruocco, I. (2022b). Ripensare gli spazi urbani con l'integrazione di politiche di MaaS. Un incubatore sociale per promuovere la mobilità dei soggetti fragili. In *Dare valore ai valori in urbanistica – Worthing values for urban planning, XXIV Conference 2022*, Brescia, 23rd-24th June 2022. Planum Publisher.

Di Ruocco, I. (2024). Eco-mobility justice in the ecological transition. An analysis for possible directions in mobility and transport equity. *TeMA - Journal of Land Use, Mobility and Environment (2),* 97-111. https://doi.org/10.6093/1970-9870/10162

Dixon, S., Irshad, H., Pankratz, D. M. & Bornstein, J. (2019). *The 2019 Deloitte City Mobility Index: Gauging Global Readiness for the Future of Mobility.* Deloitte Insights. Retrieved from: https://www2.deloitte.com/content/dam/insights/us/articles/4331_Deloitte-City-Mobility-Index/4331_city-mobility-index_OVERVIEW.pdf

Egger, S. M., Gemperli, A., Filippo, M., Liechti, R. & Gantschnig, B. E. (2022). The experiences and needs of persons with disabilities in using paratransit services. *Disability and Health Journal, 15* (4), 101365. https://doi.org/10.1016/j.dhjo.2022.101365

EIT Urban Mobility. (2021). *Full report: Urban mobility strategies during COVID-19.* Retrieved from https://www.eiturbanmobility.eu/wp-content/uploads/2021/03/Urban-mobility-strategies-during-COVID-19_long-1.pdf

El-Geneidy, A., Levinson, D., Diab, E., Boisjoly, G., Verbich, D. & Loong, C. (2016). The cost of equity: Assessing transit accessibility and social disparity using total travel cost. *Transportation Research Part A: Policy and Practice, 91*, 302-316. https://doi.org/10.1016/j.tra.2016.07.003

European Union: EU (2014). *Commission Regulation (EU) No 1300/2014 of 18 November 2014 on the technical specifications for interoperability relating to accessibility of the Union's rail system for persons with disabilities and persons with reduced mobility.* Retrieved from https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32014R1300

European Union: EU (2019). *Directive (EU) 2019/882 of the European Parliament and of the Council of 17 April 2019 on the accessibility requirements for products and services.* Retrieved from https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32019L0882

Eurostat (2022). Living conditions in Europe - poverty and social exclusion. Retrieved from https://ec.europa.eu/eurostat/data/database

Ferrari, L., Berlingerio, M., Calabrese, F. & Reades, J. (2014). Improving the accessibility of urban transportation networks for people with disabilities. *Transportation Research Part C: Emerging Technologies, 45*, 27-40. https://doi.org/10.1016/j.trc.2013.10.005

Gargiulo, C., Zucaro, F. & Gaglione, F. (2018). A set of variables for the elderly accessibility in urban areas. *TeMA - Journal of Land Use, Mobility and Environment*, 53-66. https://doi.org/10.6092/1970-9870/5738

Gatrell, A. C. (2013). Therapeutic mobilities: Walking and 'steps' to wellbeing and health. *Health & Place, 22*, 98-106. https://doi.org/10.1016/j.healthplace.2013.04.002

Guida, C., Angiello, G., Tulisi, A., Gaglione, F. & Morosini, R. (2020). Reviews pages: The city challenges and external agents. Methods, tools and best practices. *TeMA - Journal of Land Use, Mobility and Environment, 13* (1), 99-119. https://doi.org/10.6092/1970-9870/6793

Guzman, L. A., Oviedo, D. & Rivera, C. (2017). Assessing equity in transport accessibility to work and study: The Bogotá region. *Journal of Transport Geography, 58*, 236-246. http://dx.doi.org/10.1016/j.jtrangeo.2016.12.016

Guzman, L. A. & Oviedo, D. (2018). Accessibility, affordability and equity: Assessing 'pro-poor' public transport subsidies in Bogotá. *Transport Policy, 68*, 37-51. https://doi.org/10.1016/j.tranpol.2018.04.012

Hananel, R. & Berechman, J. (2016). Justice and transportation decision-making: The capabilities approach. *Transport Policy, 49*, 78-85. https://doi.org/10.1016/j.tranpol.2016.04.005

He, S. Y., Thøgersen, J., Cheung, Y. H. Y. & Yu, A. H. Y. (2020). Ageing in a transit-oriented city: Satisfaction with transport, social inclusion and wellbeing. *Transport Policy, 97*, 85-94. https://doi.org/10.1016/j.tranpol.2020.06.016

Hezam, I. M., Mishra, A. R., Rani, P. & Alshamrani, A. (2022). Assessing the barriers of digitally sustainable transportation system for persons with disabilities using Fermatean fuzzy double normalization-based multiple aggregation method. *Applied Soft Computing, 133*, 109910. http://dx.doi.org/10.1016/j.asoc.2022.109910

Hidayati, I., Yamu, C. & Tan, W. (2019). The emergence of mobility inequality in greater Jakarta, Indonesia: A socio-spatial analysis of path dependencies in transport–land use policies. *Sustainability, 11* (18), 5115. https://doi.org/10.3390/su11185115

Hine, J. & Mitchell, F. (2016). *Transport disadvantage and social exclusion: Exclusionary mechanisms in transport in urban Scotland.* Routledge.

Hranický, M. P., Nedeliaková, E. & Kuka, A. (2021). Innovations in the process of transporting the disabled. *Transportation Research Procedia, 55*, 450-457. http://dx.doi.org/10.1016/j.trpro.2021.07.008

Ignaccolo, M., Inturri, G., Giuffrida, N. & Torrisi, V. (2016). Public transport accessibility and social exclusion: Making the connections. In *Proceedings of the Third International Conference on Traffic and Transport Engineering (ICTTE),* Belgrade, Serbia, 24-25. https://www.researchgate.net/publication/311589366_PUBLIC_TRANSPORT_ACCESSIBILITY_AND_SOCIAL_EXCLUSION_MAKING_THE_CONNECTIONS

Kuriakose, B., Shrestha, R. & Sandnes, F. E. (2020). Smartphone navigation support for blind and visually impaired people: A comprehensive analysis of potentials and opportunities. In *Universal Access in Human-Computer Interaction. Applications and Practice: 14th International Conference, UAHCI 2020, Held as Part of the 22nd HCI International Conference, HCII 2020, Copenhagen, Denmark, July 19-24, 2020, Proceedings, Part II*, 568-583. Springer International Publishing. https://doi.org/10.1007/978-3-030-49108-6_41

Kuttler, T. & Moraglio, M. (Eds.). (2023). *Re-thinking mobility poverty: Understanding users' geographies, backgrounds and aptitudes.* Routledge.

Kwakye, K. (2022). Social responsibility considerations for autonomous vehicles implementation: Design and legislature for equity towards vulnerable groups. *SSRN Electronic Journal*. https://dx.doi.org/10.2139/ssrn.4175764

Jones, M., Morris, J. & Deruyter, F. (2018). Mobile healthcare and people with disabilities: current state and future needs. *International journal of environmental research and public health*, *15* (3), 515. https://doi.org/10.3390/ijerph15030515

LaPlante, M. P. (2014). Key goals and indicators for successful aging of adults with early-onset disability. *Disability and Health Journal, 7* (1), S44-S50. https://doi.org/10.1016/j.dhjo.2013.08.005

Lee, Y., Oh, S., Cha, J., Kim, K., Lee, S. Y. & Kim, H. (2022). Mobility and life satisfaction among wheelchair users: A study using mobile phone data in Seoul, South Korea. *International Journal of Social Welfare, 31* (3), 368-381. https://doi.org/10.1111/ijsw.12529

Li, L. & Loo, B. P. Y. (2017). Mobility impairment, social engagement, and life satisfaction among the older population in China: A structural equation modeling analysis. *Quality of Life Research, 26*, 1273-1282. https://doi.org/10.1007/s11136-016-1444-x

Litman, T. (2022). *Evaluating transportation equity: Guidance for incorporating distributional impacts in transportation planning.* Victoria Transport Policy Institute. https://vtpi.org/Litman_ITEJ_Equity_Apr2022.pdf

Lucas, K. (2011). Making the connections between transport disadvantage and the social exclusion of low-income populations in the Tshwane Region of South Africa. *Journal of Transport Geography, 19* (6), 1320-1334. https://doi.org/10.1016/j.jtrangeo.2011.02.007

Lucas, K. (2012). Transport and social exclusion: Where are we now? *Transport Policy, 20*, 105-113. https://doi.org/10.1016/j.tranpol.2012.01.013

Lucas, K., Mattioli, G., Verlinghieri, E. & Guzman, A. (2016). Transport poverty and its adverse social consequences. In *Proceedings of the Institution of Civil Engineers-Transport, 169* (6), 353-365. Thomas Telford Ltd. https://doi.org/10.1680/jtran.15.00073

Ma, L., Kent, J. & Mulley, C. (2018). Transport disadvantage, social exclusion, and subjective well-being: The role of the neighborhood environment—evidence from Sydney, Australia. *Journal of Transport and Land Use, 11* (1), 31-47. https://doi.org/10.5198/jtlu.2018.1008

Martens, K. (2019). Why accessibility measurement is not merely an option, but an absolute necessity. In *Designing Accessibility Instruments* (pp. 37-51). Routledge. http://dx.doi.org/10.4324/9781315463612-4

Martinelli V. (2024). Governance of the energy transition: the role of local authorities in Italy. *TeMA - Journal of Land Use, Mobility and Environment*, *17* (3), 503-507. https://doi.org/10.6093/1970-9870/11168

Mattsson, L. & Jenelius, E. (2015). Vulnerability and resilience of transport systems–A discussion of recent research. *Transportation Research Part A: Policy and Practice, 81*, 16-34. https://doi.org/10.1016/j.tra.2015.06.002

Milbourne, P. & Kitchen, L. (2014). Rural mobilities: Connecting movement and fixity in rural places. *Journal of Rural Studies, 34*, 326-336. https://doi.org/10.1016/j.jrurstud.2014.01.004

Moore, J., Lucas, K. & Bates, J. (2013). *Social disadvantage and transport in the UK: A trip-based approach.* Retrieved from https://www.tsu.ox.ac.uk/pubs/1063-moore-lucas-bates.pdf

Mora, H., Gilart-Iglesias, V., Pérez-del Hoyo, R. & Andújar-Montoya, M. D. (2017). A comprehensive system for monitoring urban accessibility in smart cities. *Sensors (Basel, Switzerland), 17* (8), 1834. https://doi.org/10.3390/s17081834

Muller, M., Park, S., Lee, R., Fusco, B. & Correia, G. H. d. A. (2021). Review of whole system simulation methodologies for assessing mobility as a service (MaaS) as an enabler for sustainable urban mobility. *Sustainability, 13* (10), 5591. https://doi.org/10.3390/su13105591

Niehaus, M., Galilea, P. & Hurtubia, R. (2016). Accessibility and equity: An approach for wider transport project assessment in Chile. *Research in Transportation Economics, 59*, 412-422. https://doi.org/10.1016/j.retrec.2016.05.003

Nixon, D. V. & Schwanen, T. (2018). Emergent and integrated justice: Lessons from community initiatives to improve infrastructures for walking and cycling. In N. Cook & D. Butz (Eds.), *Mobilities, Mobility Justice and Social Justice*, 129-141. Routledge. http://dx.doi.org/10.4324/9780815377047

Nutley, S. (2003). *Bridging the policy/research divide: Reflections and lessons from the UK*. Research Unit for Research Utilisation. https://www.treasury.govt.nz/sites/default/files/2007-09/tgls-nutley.pdf

O'Neill, Y. & O'Mahony, M. (2005). Travel behavior and transportation needs of people with disabilities: Case study of some categories of disability in Dublin, Ireland. *Transportation Research Record: Journal of the Transportation Research Board, 1924*, 1-8. https://doi.org/10.3141/1924-01

OguzS. & TanyasM. (2024). Technological applications in sustainable urban logistics: a systematic review with bibliometric analysis. *TeMA - Journal of Land Use, Mobility and Environment*, *17* (3), 487-502. https://doi.org/10.6093/1970-9870/10844

Oviedo, D. & Sabogal, O. (2020). Unpacking the connections between transport and well-being in socially disadvantaged communities: Structural equations approach to low-income neighbourhoods in Nigeria. *Journal of Transport & Health, 19*, 100966. https://doi.org/10.1016/j.jth.2020.100966

Paiva, S., Amaral, A., Gonçalves, J., Lima, R. & Barreto, L. (2022). Image recognition-based architecture to enhance inclusive mobility of visually impaired people in smart and urban environments. *Sustainability, 14* (18), 11567. https://doi.org/10.3390/su141811567

Pan, Y. & He, S. Y. (2022). Analyzing COVID-19's impact on the travel mobility of various social groups in China's Greater Bay Area via mobile phone big data. *Transportation Research Part A: Policy and Practice, 159*, 263-281. https://doi.org/10.1016/j.tra.2022.03.015

Papa, E., Carpentieri, G. & Guida, C. (2018). Measuring walking accessibility to public transport for the elderly: The case of Naples. *TeMA - Journal of Land Use, Mobility and Environment*, 105-116. https://doi.org/10.6092/1970-9870/5766

Papagiannidis, S., Bourlakis, M., Alamanos, E. & Dennis, C. (2017). Preferences of smart shopping channels and their impact on perceived well-being and social inclusion. *Computers in Human Behavior, 77*, 396-405. https://doi.org/10.1016/j.chb.2017.04.029

Park, J. & Chowdhury, S. (2018). Investigating the barriers in a typical journey by public transport users with disabilities. *Journal of Transport & Health, 10*, 361-368. https://doi.org/10.1016/j.jth.2018.05.008

Park, K., Esfahani, H. N., Novack, V. L., Sheen, J., Hadayeghi, H., Song, Z. & Christensen, K. (2022). Impacts of disability on daily travel behaviour: A systematic review. *Transport Reviews*, *43* (2), 178-203. https://doi.org/10.1080/01441647.2022.2060371

Pezzagno, M. & Richiedei, A. (2022). New scenarios for safe mobility in urban areas: Emerging topics from an international debate. *TeMA - Journal of Land Use, Mobility and Environment*, 243-251. https://doi.org/10.6093/1970-9870/8649

POLIS & Rupprecht Consult - Forschung & Beratung GmbH (Eds.) (2021). *Topic guide: Planning for more resilient and robust urban mobility.* Retrieved from https://civitas.eu/sites/default/files/sump_topic-guide_planning_for_more_resilient_and_robust_urban_mobility.pdf

Preston, J. & Rajé, F. (2007). Accessibility, mobility and transport-related social exclusion. *Journal of Transport Geography, 15* (3), 151-160. https://doi.org/10.1016/j.jtrangeo.2006.05.002

Pretty, G., Rapley, M. & Bramston, P. (2002). Neighbourhood and community experience, and the quality of life of rural adolescents with and without an intellectual disability. *Journal of Intellectual and Developmental Disability, 27* (2), 106-116. https://doi.org/10.1080/13668250220135079-5

Pucci, P., Vecchio, G., Bocchimuzzi, L. & Lanza, G. (2019). Inequalities in job-related accessibility: Testing an evaluative approach and its policy relevance in Buenos Aires. *Applied Geography, 107*, 1-11. https://doi.org/10.1016/j.apgeog.2019.04.002

Remillard, E. T., Campbell, M. L., Koon, L. M. & Rogers, W. A. (2022). Transportation challenges for persons aging with mobility disability: Qualitative insights and policy implications. *Disability and Health Journal, 15* (1), 101209. https://doi.org/10.1016/j.dhjo.2021.101209

Riazi, A., Riazi, F., Yoosfi, R. & Bahmeei, F. (2016). Outdoor difficulties experienced by a group of visually impaired Iranian people. *Journal of Current Ophthalmology, 28 (2)*, 85–90. https://doi.org/10.1016/j.joco.2016.04.002

Ryan, J. & Pereira, R. H. (2021). What are we missing when we measure accessibility? Comparing calculated and self-reported accounts among older people. *Journal of Transport Geography, 93* (4), 103086. https://doi.org/10.1016/j.jtrangeo.2021.103086

Sabella, S. A. & Bezyak, J. L. (2019). Barriers to public transportation and employment: A national survey of individuals with disabilities. *Journal of Applied Rehabilitation Counseling, 50* (3), 174–185. https://doi.org/10.1891/0047-2220.50.3.174

Sen, S., Charles, M. B. & Harrison, J. L. (2022). Usage-based road pricing and potential equity issues: A study of commuters in South East Queensland, Australia. *Transport Policy, 118*, 33-43. https://doi.org/10.1016/j.tranpol.2022.01.006

Shareck, M., Frohlich, K. L. & Kestens, Y. (2014). Considering daily mobility for a more comprehensive understanding of contextual effects on social inequalities in health: A conceptual proposal. *Health & Place, 29*, 154-160. https://doi.org/10.1016/j.healthplace.2014.07.007

Sheller, M. (2018). *Mobility justice: The politics of movement in an age of extremes*. Verso Books.

Shergold, I. & Parkhurst, G. (2012). Transport-related social exclusion amongst older people in rural Southwest England and Wales. *Journal of Rural Studies, 28* (4), 412–421. https://doi.org/10.1016/j.jrurstud.2012.01.010

Shliselberg, R. & Givoni, M. (2017). Motility as a policy objective. *Transport Reviews, 38* (3), 279-297. https://doi.org/10.1080/01441647.2017.1355855

Sochor, J. (2014). The reassuring effects of ICT in public transportation: The perspectives of older adults. *Proceedings of the 93rd Annual Meeting of the Transportation Research Board, Washington, DC, USA.*

Sochor, J. (2015). Enhancing mobility and perceived safety via ICT: The case of a navigation system for visually impaired users. In V. Ceccato & A. Newton, (Eds.), *Safety and Security in Transit Environments: An Interdisciplinary Approach* (pp. 344-361). Springer Nature. https://doi.org/10.1057/9781137457653_19

Soja, E. W. (2013). *Seeking spatial justice*, 16. University of Minnesota Press.

Soltani, S. H. K., Sham, M., Awang, M. & Yaman, R. (2012). Accessibility for disabled in public transportation terminal. *Procedia - Social and Behavioral Sciences, 35*, 89-96. https://doi.org/10.1016/j.sbspro.2012.02.066

Stanley, J. K., Hensher, D. A., Stanley, J. R. & Vella-Brodrick, D. (2011). Mobility, social exclusion and well-being: Exploring the links. *Transportation Research Part A: Policy and Practice, 45* (8), 789-801. http://dx.doi.org/10.1016/j.tra.2011.06.007

Stanley, J., Stanley, J. & Hensher, D. (2012). Mobility, social capital and sense of community: What value? *Urban Studies, 49* (16), 3595-3609. http://dx.doi.org/10.1177/0042098012447002

Stanley, J. & Stanley, J. (2017). The importance of transport for social inclusion. *Social Inclusion, 5* (4), 108-115. http://dx.doi.org/10.17645/si.v5i4.1289

Stanley, J., Stanley, J., Balbontin, C. & Hensher, D. (2019). Social exclusion: The roles of mobility and bridging social capital in regional Australia. *Transportation Research Part A: Policy and Practice, 125*, 223-233. https://doi.org/10.1016/j.tra.2018.05.015

Stanley, J. K., Hensher, D. A. & Stanley, J. R. (2022). Place-based disadvantage, social exclusion and the value of mobility. *Transportation Research Part A: Policy and Practice, 160*, 101-113. https://doi.org/10.1016/j.tra.2022.04.005

Titheridge, H., Christie, N., Mackett, R., Oviedo Hernández, D. & Ye, R. (2014). *Transport and poverty: A review of the evidence.* Retrieved from https://www.ucl.ac.uk/transport/sites/transport/files/transport-poverty.pdf

Uteng, T. P. & Cresswell, T. (Eds.). (2008). *Gendered mobilities* (p. 270). Aldershot: Ashgate.

van Dülmen, C., Šimon, M. & Klärner, A. (2022). Transport poverty meets car dependency: A GPS tracking study of socially disadvantaged groups in European rural peripheries. *Journal of Transport Geography, 101*, 103351. https://doi.org/10.1016/j.jtrangeo.2022.103351

Van Wee, B. & Geurs, K. (2011). Discussing equity and social exclusion in accessibility evaluations. *European journal of transport and infrastructure research*, *11* (4). https://doi.org/10.18757/ejtir.2011.11.4.2940

Vecchio, G. & Martens, K. (2021). Accessibility and the capabilities approach: A review of the literature and proposal for conceptual advancements. *Transport Reviews*, *41* (6), 833–854. https://doi.org/10.1080/01441647.2021.1931551

Velho, R. (2019). Transport accessibility for wheelchair users: A qualitative analysis of inclusion and health. *International Journal of Transportation Science and Technology, 8* (2), 103–115. https://doi.org/10.1016/j.ijtst.2018.04.005

Vitale Brovarone, E. (2021). Accessibility and mobility in peripheral areas: A national place-based policy. *European Planning Studies, 30*(8), 1444-1463. https://doi.org/10.1080/09654313.2021.1894098

Wan, C., Yang, Z., Zhang, D., Yan, X. & Fan, S. (2018). Resilience in transportation systems: A systematic review and future directions. *Transport Reviews, 38* (4), 479-498. https://doi.org/10.1080/01441647.2017.1383532

Welch, T. F. & Mishra, S. (2013). A measure of equity for public transit connectivity. *Journal of Transport Geography, 33*, 29-41. https://doi.org/10.1016/j.jtrangeo.2013.09.007

Wong, S. (2018). Traveling with blindness: A qualitative space-time approach to understanding visual impairment and urban mobility. *Health & Place, 49*, 85-92. https://doi.org/10.1016/j.healthplace.2017.11.009

World Health Organization: WHO (2023). *Blindness and vision impairment.* Retrieved from https://www.who.int/news-room/fact-sheets/detail/blindness-and-visual-impairment

Xia, J. C., Nesbitt, J., Daley, R., Najnin, A., Litman, T. & Tiwari, S. P. (2016). A multi-dimensional view of transport-related social exclusion: A comparative study of Greater Perth and Sydney. *Transportation Research Part A: Policy and Practice, 94*, 205-221. https://doi.org/10.1016/j.tra.2016.09.009

Zhou, H., Hou, K., Zuo, D. & Li, J. (2012). Intelligent urban public transportation for accessibility dedicated to people with disabilities. *Sensors, 12* (8), 10678-10692. https://doi.org/10.3390/s120810678

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Multilevel governance approach to adaptation. The construction of the Italian mid-Adriatic green infrastructure

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Abstract
There is a persistent discrepancy between the climate adaptation measures advocated by European and international bodies and the actual implementation of such measures. While implementation frequently occurs at the municipal level, which makes municipalities pivotal actors, this is insufficient. Indeed, the involvement of other levels of governance and the private sector is essential, as are adaptation actions that permeate all plans, programs, and projects of a public entity. An approach to adaptation that refers to multilevel governance and mainstreaming strategies for implementation is pioneered in the Life+ A_GreeNet Project, which envisages the construction of the green infrastructure of the Italian mid-Adriatic city. This approach integrates adaptation actions into existing decision-making and policy processes, innovates the processes of construction of urban plans, and promotes the management and care of green with innovative and flexible tools.

Keywords
Climate adaptation, Multilevel governance, Horizontal and vertical planning.

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1. Introduction

Climate change is one of the most important challenges of our time, requiring rapid and effective responses at all levels of governance (De Waal et al., 2019; Di Gregorio et al., 2019) and robust collaboration among diverse public and private stakeholders (van den Ende, 2022; Termeer et al., 2013). The confluence of complexity, uncertainty, and conflicting values, coupled with the multitude of structural impediments inherent to the extant political system, renders the pursuit of adaptation policies a challenging endeavor (Eisenack et al., 2014; Tuhkanen et al., 2020; Moser & Ekstrom, 2010). The term "adaptation gap" (Eisenack et al., 2014) is used to describe this difficulty. It is primarily caused by a lack of political commitment, effective coordination, and cooperation between government departments involved at different levels (Persson et al., 2018), as well as the hierarchical, linear governance model employed (Lesnikowski, 2016; EEA, 2020; OECD, 2009; Keskitalo and Preston, 2019; Cha et al., 2024). The European Union has initiated an ambitious program to promote climate adaptation under the Green Deal (EC, 2019) and the new Adaptation Strategy 2021 (EC, 2021), emphasizing the necessity for involvement at all levels of governance (Clar, 2019), in particular at local level (Biesbroek et al., 2010; Pellizzaro, 2015). The latter is considered the most relevant for implementation (Zucaro et al., 2018), even if it occurs in collaboration with other levels (OECD, 2023). In the literature, the need to support local-level initiatives through a multilevel governance model (Adriazola et al., 2018; Birchall et al., 2022) takes on particular importance because it is recognized as having the capacity to avoid or resolve conflicts by different actors and at different levels of government (Ishtiaque, 2021; Gonzales-Iwanciw, et al., 2019).
This model appears:

- more suitable to overcome the same geographic boundaries that often make adaptation actions fragile on the local scale and thus more effectively implement strategies and projects that necessarily cross administrative boundaries and the limits of small and medium sized municipalities (Fila et al., 2024);
- more conducive to supporting a "place-based" (OECD, 2023) approach to adaptation on specific economic, environmental, and social contexts (Parks & Bertuzzi, 2022; Novalia et al., 2024);
- more capable in fostering the integration of national and subnational climate policies into urban and spatial development policies at all scales, avoiding watertight compartments and fragmentation of responsibilities and competencies (Candel & Biesbroek, 2018);
- more congenial to fostering polycentric governance arrangements (Ostrom, 2014) in which public and private actors engage in collective, simultaneous decision-making processes, prompting different actors to "learn, coordinate and cooperate" (Berardo & Lubell, 2019);
- more useful to exchange information and expertise between different levels, facilitating mutual learning (Bodin et al., 2017), encouraging the development of mixed-methods to coordinate actions, cooperating and resolving potential conflicts (Calliari et al., 2019).

A governance model with these characteristics may facilitate access to information and knowledge, enhance technical and financial capabilities, facilitate access to public funding, utilize private capital, and engage citizens and associations in the management of green spaces (Mattijssen, 2017). Casprini et al. (2021) posits that this model of governance will be fully operational by 2023. Additionally, in the event of a dearth of capacity and expertise among local authorities (especially smaller ones) on climate change issues, it may facilitate the creation of economies of scale (Blank & Niaounakis, 2021).
In a multilevel governance approach, the supra-local level of adaptation policies can play a pivotal role in guiding the process of implementation (Granberg et al., 2019). Indeed, subnational governments (regions and provinces) are expected to promote more coordinated planning and develop policy priorities than municipalities, which often lack staff and have scarce resources at their disposal (Fila et al., 2024). Planning tools at the supra-local (regional and provincial) scale can facilitate the integration of disparate policies, taking into account the multiplicity of goals (Kruse & Pütz, 2014) associated with adaptation, the diverse spheres and spatial levels (Ledda, 2020; Dupont & Jordan, 2021), and the multifarious public and private actors involved.

This article discusses the significance of an integrated approach, exemplified by the "Life+ A_GreeNet" project. This initiative represents one of the initial efforts to implement a multilevel policy in the Italian Adriatic coastal territories. Furthermore, it serves as a testing ground for the governance model proposed by the PNACC (National Climate Adaptation Plan), which was approved by Italy at the end of 2023 (PNACC, 2023). The Life+A_GreeNet project advocates the development of green infrastructure (Salata & Yiannakou, 2016) in the mid-Adriatic city-territory, spanning the cities of Ancona (Marche) and Pescara (Abruzzo). It addresses the challenges posed by rising temperatures, the importance of citizens' health, and the role of green areas. The project's objectives include establishing a unified governance structure, as proposed by Cittadino et al. (2022), which would integrate and enhance existing tools while coordinating the diverse competencies of various institutional levels, public and private actors, and partnership networks. Urban planning is of central importance to this path, as it plays a significant role in the implementation of many of the actions required to enhance urban resilience (Dabrowski et al., 2022).

The article aims to investigate:

- the enabling factors and obstacles of a multilevel approach in adaptation governance in the Life+A_GreeNet project territory, which, although characterized by unitary characters for environmental, settlement, climate and risk aspects, belong to different regions and provinces, with their own instruments and regulations regarding environmental and spatial planning;
- possible public and private strategies to be deployed to overcome the criticalities of possible integration and to enhance the potential of network governance at the territorial and urban scale, with possible forms of replicability in other Italian and European contexts (Gustavsson, 2009).

Ultimately, the objective of the article is to highlight potential improvements to the methodology employed to facilitate the implementation of the identified adaptation actions over time. This may prove beneficial in the replication of interventions in other territorial contexts.

2. Climate adaptation in the Italian framework and in the context of the mid-Adriatic Sea

According to the European Environment Agency's (EEA) first European Climate Risk Assessment, Europe is getting warmer twice as fast as the rest of the world, and current adaptation policies and actions are not keeping pace with the rapid growth in risk (EEA, 2024). The Italian territories are situated within the so-called "Mediterranean hot spot," rendering them particularly susceptible to the effects of climate change (Doblas-Reyes, 2021; EEA, 2016). Furthermore, the national territory is prone to a multitude of natural hazards, including landslides, floods, coastal erosion, and water shortages. These risks are exacerbated by rising temperatures and the intensification of extreme events related to climate change, such as droughts, heat waves, strong winds, and intense rainfall. These factors contribute to amplified economic, social, and environmental impacts (PNACC, 2023). The National Strategy for Adaptation to Climate Change (SNAC) (Castellari et al., 2014) was initiated in 2015 and provided a national strategic vision regarding the mitigation of impacts on the land. Subsequently, in 2023, the National Climate Change Adaptation Plan (PNACC) was introduced, following a period of eight years during which the strategy was developed in full. The PNACC serves as a planning document, delineating *climate change* adaptation measures to be implemented at the national level. The document presents a series of recommended actions for adaptation, classified into 18 sectors: aquaculture, geological, hydrological and hydraulic disruption, desertification, inland and transitional water ecosystems, marine ecosystems, energy, terrestrial ecosystems, forests, hazardous industries and infrastructure, urban settlements, cultural heritage, marine fisheries, agriculture, water resources, health, transportation, tourism, and coastal zones. The trans-scalar dimension of adaptation is afforded considerable attention in the regional and local contexts (Annex I and II), with the objective of furnishing methodological guidance for the formulation of adaptation plans at each level and for the assessment of the efficacy of the

respective actions. Accordingly, the PNACC is based on the principle of subsidiarity, whereby subnational entities are tasked with providing the most effective responses to local adaptation needs, albeit within a unified planning framework ensured by the national level. Despite the lively debate that this Plan has provoked, with some environmental associations, the National Institute of Urban Planning (INU), and a few trade associations distancing themselves from it, there has been a general recognition of its high scientific value. It is observed that the Plan lacks sufficient operational value. This issue has been brought to light through the analysis of the press releases and web pages of numerous Italian environmental associations. These associations have expressed concerns regarding the inability to identify actions that can effectively anticipate the changes caused by the climate crisis, as well as the insufficient funding allocated to address these issues[1]. Further aspects regarding the operability of the PNACC pertain to its minimal projected impact on the realms of public administration, as well as on citizens and businesses, due to its marked deficiencies in the domains of implementation and governance[2]. This is compounded by the deterministic approach, as opposed to the need for a systemic and inclusive approach that includes the participation of local authorities and associations as a strategic element[3]. Other concerns include the lack of integration with other sectoral and territorial policies to maximize the effectiveness of adaptation measures, and coordination with other national strategies[4].

Nevertheless, it is evident that the Italian Ministry of the Environment (MASE) has endeavored to integrate climate change adaptation into the country's social and economic planning and to acknowledge the pivotal role of regions and local authorities in the formulation and execution of adaptation strategies. In order to achieve this objective, the PNACC requires subnational entities to develop their own adaptation strategies and/or plans. These entities must then proceed to "mainstreaming," as defined by Runhaar et al. (2018) and Baack (2024), in spatial and sectoral planning. Finally, they must provide themselves with the means to implement adaptation in practice. This entails integrating adaptation into existing development programs, policies, or management strategies, rather than relying on the development of new, separate adaptation initiatives (Runhaar, 2018; ten Brinke et al., 2022). This approach is pursued by the Life+A_GreeNet Project, which is based on the central Italian Adriatic regions (Marche e Abruzzo). It implements an adaptation strategy that engages existing spatial planning tools and multiple levels of institutional expertise, with a particular emphasis on the involvement of local communities and stakeholders.

3. Materials and methods

The Life A_GreeNet Project is a project co-funded by the European Union through the LIFE program. Its objective is to enhance the resilience of the Italian Mid-Adriatic coastline (between Ancona and Pescara) to the impacts of climate change, particularly rising temperatures and heat waves, through the creation of green infrastructure (Pantaloni et al., 2024; Kumar et al., 2024; Azmeer et al., 2024; Delgado Capel et al., 2023). In addition to addressing the environmental consequences of climate change, the green infrastructure project also aims to mitigate its economic and social impacts, including the potential effects on the local economy (Moboraki, 2023), the environment and biodiversity (Garmendia et al., 2016; Lazzarini et al., 2024); human health and the quality of life (Climate Adapt, 2023; Palermo et al., 2024).

To effect this transformation, the project aims to develop multilevel and multi-actor governance, thereby strengthening the administrative capacity for climate adaptation of all levels involved in land planning and management (region, province, municipalities) (Ronchi et al., 2020; Monteiro, 2022; Marot, 2024), involving

1 See: https://www.wwf.it/area-stampa/piano-nazionale-di-adattamento-tanto-rumore-per-nulla/; https://asvis.it/editoriali/3257-19920/il-pnacc-da-solo-non-basta-servono-risorse-e-politiche-coerenti-con-ladattamento

2 See: https://www.renewablematter.eu/arriva-pnacc-piano-nazionale-adattamento-cambiamenti-climatici-delude-tutti

3 See: https://hubzineitalia.com/2023/05/16/pubblicazione-commenti-al-piano-nazionale-di-adattamento-ai-cambiamenti-climatici/

4 See: https://www.agendadigitale.eu/smart-city/politiche-climatiche-ambizioni-e-limiti-dei-piani-pnac-e-pniec-del-governo/

local actors (Scheiber & Mifsud, 2024). It is imperative that public and private actors collaborate in green management and design, thereby increasing their responsibility and awareness of adaptation measures. Furthermore, there is a need to integrate adaptation measures, namely mainstreaming (Ten Brinke et al., 2022), into ordinary urban practices (Storbjörk & Uggla, 2015; Uittenbroek et al., 2012; Newman, 2008). The Life+ A_GreeNet Territory includes a population of 400,000 inhabitants, the territories of two municipalities in the Marche Region: Ancona and San Benedetto del Tronto, and 8 municipalities in the Abruzzo Region (the 7 coastal municipalities of the ATS city of the Coast of the Province of Teramo) and the Municipality of Pescara (Fig.1). The results of the indicators utilized by Ispra (Istituto Superiore per la Protezione e la Ricerca Ambientale), consistent with the indicator implemented by the European Environment Agency, "Landscape fragmentation indicator effective mesh density (Seff)," indicate that a very high level of fragmentation is present in the coastal area of the mid-Adriatic Sea in Italy (coastal areas of Marche and Abruzzo) (Ispra, 2022; Munafò, 2023). This level of fragmentation, which is equivalent to an effective mesh density greater than 250 meshes per 1,000 km2, is indicative of the extensive reduction in ecological connectivity that has resulted from phenomena such as urban expansion and infrastructure network development (Ispra, 2024).

These areas are characterized by a degraded forest heritage, a lack of quality in green spaces, and a dearth of attention devoted to adaptation policies at various levels of planning. Additionally, they are home to a significant proportion of vulnerable populations (approximately 40%), who are particularly susceptible to increases in mortality and the need for emergency medical care due to the adverse effects of high nighttime temperatures. With reference to this project, which is in progress and will end in 2025 (https://www.lifeagreenet.eu/site/), except for the After LIFE activities, the keys used to verify the correspondences and criticalities towards effective multilevel planning involved the development of two particular areas of investigation: vertical cooperation and mainstreaming, in this case between Region, Province and local authorities, and horizontal cooperation and mainstreaming (between municipalities).

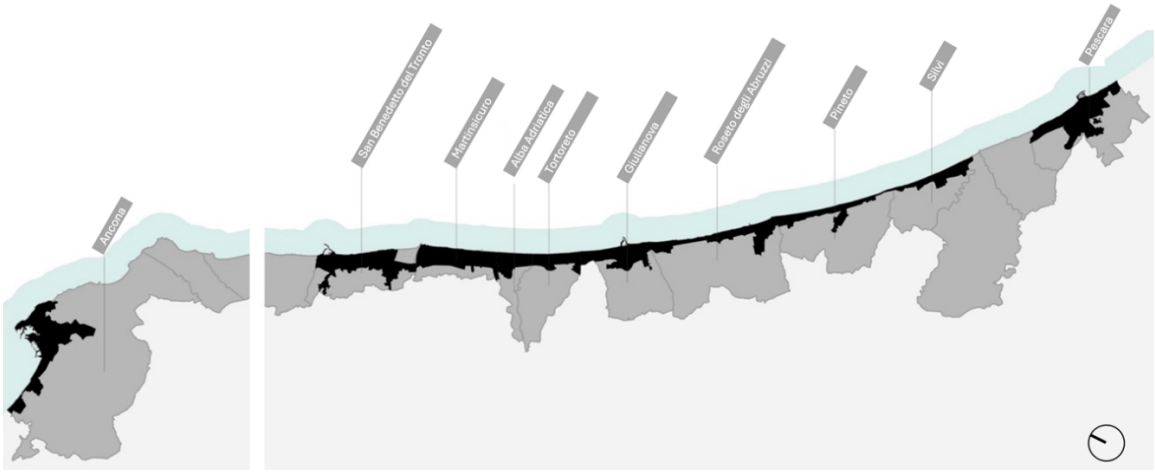

Fig.1 The territory of the Life+ A_GreeNet project

The former was investigated with the objective of evaluating the efficacy of the regions' role in providing guidance and support to local authorities, with specific reference to certain aspects identified by the PNACC as requiring priority attention, including organizational, financial and technical aspects. In terms of *organizational aspects*, the PNACC identifies the need to ascertain the relevant stakeholders and select the most suitable methods for engaging them in project activities. The *financial aspects* pertain to the potential for allocating resources from a range of sources, commencing with the regional budget and subsequently targeting other available resources, such as European funds. In particular, Regions are able to establish dedicated funding for local authorities through the utilization of ERDF (European Regional Development Fund) allocations. The *technical aspects* pertain to the feasibility of streamlining the development of adaptation

measures through the formulation of incentive regulations, the creation of specialized instruments for the aggregation and examination of climate inventories, and the provision of assistance in the identification of projected potential consequences and prospective adaptation strategies.

In examining horizontal cooperation and mainstreaming, the investigations concentrated on pivotal mechanisms that local governments can leverage to advance territorial cooperation objectives, as delineated in the NACCP guidelines. These mechanisms were examined in light of the following considerations: new "place-based" *planning approache*s that shape a novel perspective on the quality of public action necessitate the promotion of synergies and the adoption of co-design and "stewardship" processes with local communities. The objective is to mobilize the resources and capabilities of the territory in order to implement climate resilience measures. The remaining aspects under investigation are *inter-municipal cooperation* for the "activation of the provision of shared services for the community" and the partnership of local government with social organizations, businesses, and technical professionals from various public or private entities. This potential influence can be leveraged to disseminate integrated models of intervention in projects and investments pertaining to homogeneous territorial areas, thereby fostering collective responses from the provincial or regional community to climate change. The investigation of these dimensions of multilevel governance should enable the verification of the effectiveness of the adaptation strategy envisaged by the "Life+A_GreeNet" project, the critical aspects to be solved, and the possible possibility of its replicability in other contexts envisaged by the same project.

4. Vertical Dimension: aspects of cooperation and mainstreaming

4.1 Organizational aspects

The Life+ A_GreeNet Project included an experience-sharing phase that enabled the involvement of institutional stakeholders at various levels and associations with the aim of improving the transparency and effectiveness of projects and processes, thereby fostering collective awareness and shared intent. Stakeholder involvement in the project was structured around several key phases, including the dissemination of information and experiences, the formulation of the "Interregional Forestry Contract," the development of a regulatory document for green infrastructure design, and the establishment of an observatory for climate change, urban green infrastructure, and health.

The knowledge-sharing phase was attended by technicians from public administrations at various levels, professional associations, and local administrators. The objective was to enhance collective understanding through collaborative, multifunctional, and multiscalar planning; innovative urban planning techniques (urban and spatial equalization, pre-greening, environmental offsets, etc.); and the targeted use of vegetation to construct livable and healthy urban environments. To gain insight into these subjects, a review was conducted of select national and international projects that exemplify best practices. The selection permitted the organization of two workshops and three focus groups, which were attended by planners and technicians from public administrations promoting best practices. This introductory phase permitted the researchers to become acquainted with local stakeholders, particularly public administration technicians and policymakers, and to ascertain their familiarity with adaptation issues.

A pivotal stage of the project entailed the formulation of a "CIdFU Interregional Forest Contract" and a prototype coastal pine forest management plan. The CIdF was developed and implemented through an open and inclusive participatory process. A series of eight plenary meetings were convened with relevant stakeholders and participants in the Interregional Contract formation process, predominantly held remotely to foster widespread engagement. The meetings saw the participation of over 80 entities, primarily from the public administration sector (24%), followed by associations dedicated to socio-environmental issues (20%), research and professional bodies (17%), including various universities and the Professional Orders of

Agronomists, Forestry, and Architects. Individual businesses or the representations of businesses accounted for 17% of the participants, freelancers constituted 17%, and finally, other public bodies such as various regional agencies, the forest ranger, and consumer advocacy associations accounted for 5%. The CIdFU was concluded in December 2023 with the underwriting by 39 parties. The signatories of the contract included public and private entities, such as several universities, a province, a regional environmental agency, numerous environmental associations, three social cooperatives involved in green maintenance, and a number of municipalities that were not members of the project partners. The execution of the Forestry Contract obligates the signatories to incorporate the principles and actions stipulated within the Project into their respective programs, plans, and projects, and it shall:

- facilitate the implementation of the Green Infrastructure Project for Climate Change Adaptation and Community Health in the programs and policies under its jurisdiction, such as: the Regional Climate Change Adaptation Plan and the Regional Prevention Plan, giving priority to municipalities adhering to the Covenant of Mayors and municipalities affected by forestation contracts;
- prepare regulations (throughout the region) so that the implementation of green infrastructure becomes a founding principle of local urban planning, identifying useful methods and techniques for its implementation. It is also stipulated that regulations should contain a performance checklist for the purposes of health and welfare of urban plans and projects;
- carrying out activities to promote and involve the Marche Region so that it initiates the implementation of green infrastructure in its regional territory.

Another vertical activity involved the activation of the Climate Change and Health Observatory, which will be managed by the Abruzzo Region, to monitor the evolution over time of climate change effects on city dwellers.

4.2 Financial aspects

The project encompasses three categories of demonstration actions: coastal forest restoration (Pinewoods), soil regeneration interventions, and urban microforestry interventions. Pine forest restoration interventions are designed to ensure the preservation and enhancement of biophysical and qualitative-quantitative attributes, thereby optimizing the forest's resilience to climate change and its capacity to sustain the well-being of local communities and visitors. Additional demonstration actions entail microforestry and soil regeneration interventions. In conclusion, during the After LIFE period, the Abruzzo Region has pledged to provide financial support for the most suitable measures for the design and implementation of green infrastructure within the context of European and national programming funds, in accordance with its authority and responsibility for managing and programming the use of these funds at the regional level.

4.3 Technical aspects

The initial step in achieving mainstreaming is to gain an understanding of the territory, society, and the dynamics that shape places, transcending municipal boundaries. This involves both organizing existing information and acquiring new and updated data with the support of a single directorate. Consequently, the Life A-GreeNet Project initiated an initial assessment of the natural and semi-natural green assets of all the municipalities in the network (Fig.2). The assessment entailed evaluating the quality of these green assets using the SAVI index, which was clustered into four classes. This was followed by point analyses of sample areas and an assessment of the ecosystem services provided by green areas. The green area surveys were cross-read with climate maps, and the UTCI (Universal Thermal Climate Index) was calculated for the years 2019 to 2030 and 2050 (Fig.3). This analysis identified the most critical areas for hydrogeological disruption, spatialization of population fragility (children and the elderly), and health risks due to rising temperatures

(emergency room accesses and daily mortality during the hottest days over the past few years were investigated), allowed us to identify the present and future risks of the mid-Adriatic city in a large-scale view.

Fig.2 Classification of green areas. Municipalities of San Benedetto del Tronto and Ancona

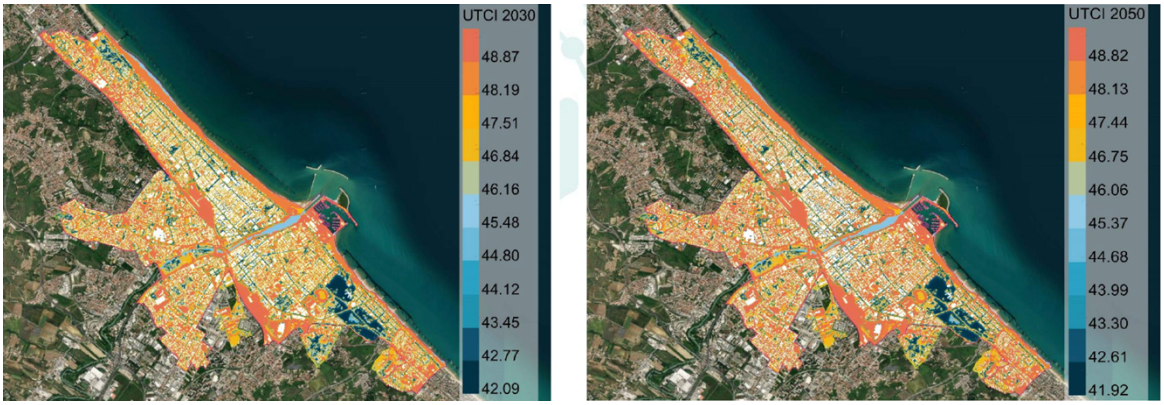

Fig.3 Map of the _UTCI forecast of Pescara to 2030 and 2050. The column on the right shows the degrees of temperature perceived by people in different areas of the city in a time forecast to 2030 and 2050

The subsequent phase entailed the interrogation of prevailing urban planning forecasts and the function of green spaces within the urban planning instruments of partner municipalities. This investigation led to the identification of homogeneous types across diverse urban planning instruments with regard to their prevailing functions, roles in the urban context, permitted interventions, ownership structures, and design interventions. The aggregation of this information enabled the identification of design opportunities for adapting to climate change within the frequently incomplete system of green areas in local urban plans. The analysis of the city's diverse settlement fabrics, informed by the voids, led to the identification of two distinct systems: "Homogeneous Systems and Areas of the Mid-Adriatic City". This identification was accompanied by the formulation of planning scenarios extending into the future, with projections extending to the year 2030 and 2050.These scenarios offer valuable direction for municipalities in their planning activities and interventions for adapting to climate change, both in the immediate and long-term future, with a view that extends beyond municipal boundaries. The integration of various geospatial information layers has facilitated the identification of critical areas in terms of climate and social vulnerability. These areas must be prioritized during the detailed planning phase, during which the objectives and actions to be implemented will be delineated. The development of a unified methodology for the analysis and evaluation of climate data, as well as the planning tools for all municipalities within the study area, employs a WebGIS platform for data storage and monitoring. This platform provides valuable information for future planning. The establishment of this platform and the

dissemination of information and planning forecasts on both a large and local scale represent a novel undertaking in this region.

4.4 Critical issues, opportunities and suggestions

The vertical dimension of the project has brought to light several critical issues that must be addressed and resolved. Many of these difficulties, as anticipated in the previous section, stem from the challenge of municipalities participating in the network, which belong to different provinces and regions, sharing experiences and project proposals despite their similarity in geography, socioeconomics, and the presence of risks. This difficulty manifested, for example, in the construction of the cognitive framework on green areas. The Life+A_GreeNet Project aspires to propose a shared methodology for the cataloguing of green areas; however, it faced challenges due to the lack of homogeneous information among the different technical offices of the municipalities involved. Furthermore, there was a shortage of personnel capable of managing and archiving spatial data. Another difficulty related to the inadequacy of current urban planning tools to conceptualize the green area system as spatial infrastructure and the inability to ensure the quality of green spaces. Urban standards, legally mandated, govern only the "quantity" of green spaces, frequently resulting in oversupply.

In addition to the aforementioned objective difficulties, which complicate the operational development of green infrastructure in the mid-Adriatic city, a cultural challenge must also be considered. Focus groups and workshops conducted during the initial phase of the project revealed a pervasive lack of knowledge regarding the impact of climate change among technicians and administrators. A survey of administrators, technicians, and citizen representatives revealed that only a few of them were aware of studies and research on the impact of environmental and climate change on the quality of life in cities and the application of Nature Based Solutions (NBS) (Mazzeo & Polverino, 2023; Santoro et al., 2024). The aforementioned challenges notwithstanding, the relationships cultivated with local stakeholders, as evidenced by the workshops, focus groups, and capacity-building activities that preceded the Forestation Contract, initiated a process of sharing and awareness concerning some fundamental aspects that form the basis for implementing the construction of green infrastructure in the coming years. The culmination of this journey, marked by the signing of the Forestation Contract, signified the signatories' commitment to a comprehensive spatial vision encompassing coastal green infrastructure, including the network of green areas and the facilitation of urban ecosystem development. This vision transcends the confines of municipal boundaries, proposing solutions on a larger scale. This shared vision is further complemented by a collective awareness and commitment to a unified approach in the retrieval of cognitive and evaluative data, their dissemination, and the involvement of all stakeholders. In this context, the strategic role of regions becomes evident, as they are called upon to assume full political responsibility for promoting and facilitating the integration of adaptation into overall processes. This will necessitate active engagement with stakeholders and local governments, as well as the various sectors of public administration.

5. Horizontal dimension: aspects of cooperation and mainstreaming

5.1 New planning approaches at the local scale

The construction of a Design Framework shared among network partners for the realization of the green infrastructure of the City of the Middle Adriatic has led to the identification of environmental, climatic, socio-anagrammatic characters and recurring risk scenarios at the local scale. The project also includes operational tools that facilitate the realization of the green infrastructure at the local scale. Primarily, this involves the establishment of a Directory of urban planning techniques (e.g., urban equalization and compensation, ecological compensation, etc.) to facilitate the implementation of green areas in compliance with the provisions

of current PRGs, through forms of involvement of private operators and innovative financing measures. Additionally, the dissemination of these techniques among various municipalities is accompanied by the integration of "nature-based" design for building codes, which is based on the utilization of a Nature Based Directory (Fig.4) and the application of the "Green Suite A_GreeNet Explorer"[5]. The latter is configured as a "Friendly" platform that, on the basis of a map that identifies a 500x500 m grid, returns a series of climatic, sociodemographic parameters, urban planning and design forecasts to 2030 and 2050 for each "tile" into which the Middle Adriatic city is divided. This interactive map fosters an in-depth and multidimensional understanding of the urban environment, offering a comprehensive perspective on the challenges and opportunities in the Middle Adriatic city. It thereby facilitates the formulation of more effective urban policies and projects that can enhance the quality of urban life and mitigate the adverse impacts of climate change. Each of the "tiles" is associated with a "type" design solution, which contains references to NBS solutions and their integration within settlement systems. Each "type" design solution is associated with behaviors/performances that recur within the Mid-Adriatic territory; it can be applied to multiple areas/sub-environments, where similar conditions occur, including in the territory of other municipalities. The parameters provided and the suggested typological design solution constitute the "materials" to be brought to the attention of planners and public administrations to guide the construction of green infrastructure. These tools serve as an exploratory mechanism, facilitating the identification of potential typological design solutions. These solutions are subsequently investigated and verified through a comprehensive analysis of the Life+A_GreeNet Project databases, which are accessible via the WEB Platform. The "friendly platform" offers design recommendations at the local scale, providing a valuable resource for decision-making regarding the interventions to be implemented (Fig.7). It also enables the comparison of design solutions proposed in other territorial contexts with similar characteristics. This methodological approach fosters collaboration among diverse municipal administrations and facilitates periodic reviews, information exchange, and suggestions for the development of green infrastructure.

Fig.5 Strategic scenario of the municipality of San Benedetto del Tronto

[5] See: https://lifeagreenet-explorer.eu/

Fig.6 Typological solutions and identification of NBS: typological solutions for different homogeneous areas of the mid-Adriatic city, with reference to the NBSs to be used

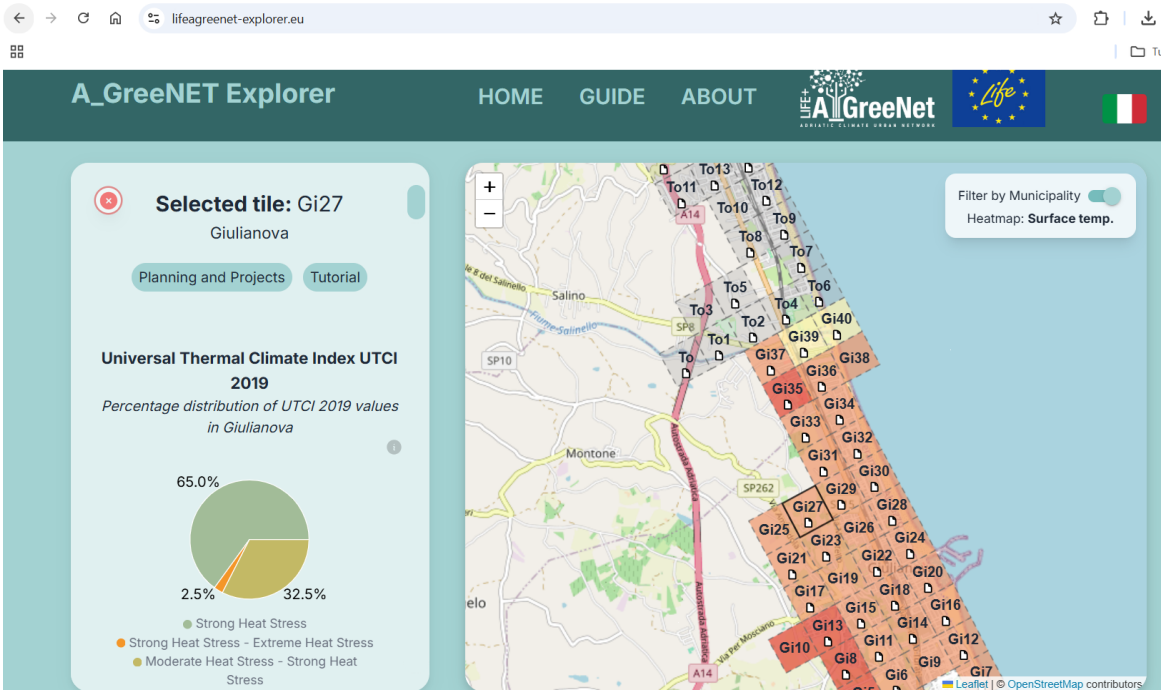

Fig.7 Home Page Friendly platform (https://lifeagreenet-explorer.eu/)

5.2 Local actions supported by open calls

Top-down interventions, in the form of demonstration actions aimed at selecting optimal design solutions, are complemented by bottom-up interventions. The latter involve private projects financed by municipalities and regions through open calls. Demonstration projects funded directly by the Life Project have been joined by projects co-funded by partners through "open calls." This type of call for proposals is characterized by the possibility of continuous application until the available resources are exhausted. In contrast to "ranked" calls, where all applications are evaluated and ranked after a predetermined deadline, over-the-counter calls adhere to the principle of "first come, first served," meaning that applications are processed in the order in which they are received and meet the specified criteria. These mechanisms facilitate the allocation of resources for micro-forestry interventions within the urban landscape, in alignment with the Action Program of the Forestation Contract, with the financial participation of the beneficiaries. The total budget allocated for this initiative is €300,000, with €50,000 designated for each municipality, €50,000 allocated for ATS Cities of the Coast, and €100,000 set aside for the Abruzzo Region. The call is open to both public and private entities, including management entities of protected natural areas, third sector operators (i.e., social and environmental

associations), and economic entities (e.g., construction companies, businesses). Each project proposal includes a share of co-financing guaranteed by the beneficiary entity of at least 50-20% of the total project cost depending on whether the beneficiary is an economic entity or a park entity/third sector entity, respectively. The verification of eligibility for funding is based on several technical evaluation criteria: contributions to the forestation contract strategy (consistency with the lines of intervention of the Strategic Document integration of the proposal with the interventions indicated in the Action Program); governance of the project (presence in support of microforestation interventions of community education and awareness activities, completeness and heterogeneity of the partnership and presence of partners subscribing to the forestation contract, sustainability of the project in environmental and economic terms, commitment to the management and maintenance of the intervention for example by signing a collaboration pact, co-financing share greater than the maximum percentage required); quality of the project proposal (technical quality and completeness of the proposed project consistent with the technical indications of the NBS abacus developed by the Project).

5.3 Intermunicipal cooperation with social organizations, business and local professionalism

The municipalities participating in the project have committed to integrating the tenets of the Green Infrastructure Regulations into their urban planning instruments, building regulations, and public works specifications over the course of the "AfterLIfe" initiative. Furthermore, the project encompasses the construction of a "Model Management Plan for Coastal Pine Forests," which will be disseminated among the participating municipalities. This plan will encompass all agronomic, cultivation, and phytosanitary interventions necessary to enhance the bio-static characteristics of each pine forest. The activation of the "Network of Pine Forest Management Plans" will enable the different municipal managers to share data and knowledge. It is of paramount importance to facilitate integration and information sharing, as this will prove instrumental in preventing and containing the potential spread of diseases. In order to encourage citizen participation in the implementation of green infrastructure and to relieve administrative bodies of the onerous task of management, it is also planned to draft a "Model Collaboration Pact" for urban green spaces. This is a tool that encourages citizen participation in the care of public green spaces. It can be used by citizens in individual or associated form, or directly by municipal administrations. The agreement, which is of a provisional nature, may provide for a range of maintenance tasks, including the upkeep of green spaces, the cleaning of premises, and the routine maintenance of recreational facilities and equipment.

5.4 Critical issues, opportunities and suggestions

Some of the planned activities are currently being implemented, including the open calls. Consequently, it is premature to conduct a review of the efficacy of horizontal cooperation and mainstreaming. Nevertheless, some preliminary observations can be made regarding the innovative aspects of the methodology employed in the design of green areas. This methodology introduces a number of relatively unexplored concepts, including the option of selecting potential design solutions, with a particular focus on the most critical areas. A selection was made by integrating the needs that emerged from analyses and assessments of social and climate impacts with the needs/opportunities for funding by local governments.

The friendly platform offers the possibility of selecting the best performing project solutions through the sharing of a working method that constitutes an effective decision support tool, which can also be transferred to replication territories. Concurrently, several pivotal concerns have been brought to light due to the lack of familiarity among municipalities in addressing the ramifications of climate change. This has resulted in a dearth of involvement in the construction of knowledge and the formulation of potential project solutions.

In this regard, the recently enacted regional legislation governing territorial government, together with the regulations and guidelines of the LifeA-GreeNet Project, offers a promising foundation for advancing the project's objectives.

7. Debate and conclusions

The effects of climate change will continue to manifest in a variety of ways, including a deterioration in living standards, an inability of urban areas to withstand external shocks and stresses, a decline in the resilience of territories, and a reduction in the conservation of natural areas. Nevertheless, the measures taken by the array of institutions and the private sector to address these challenges and prepare for them are, as yet, insufficient (EEA, 2024). Despite the existence of numerous agreements and efforts over the past decades aimed at raising awareness of the risks posed by disruptions in the climate environment, these have unfortunately not had a significant impact on policies. In order for adaptation to climate change to become more sustainable, it is essential that these concepts be incorporated and integrated into the policies (plans, strategies, and programs) with which administrations of different levels are or have been equipped. This is a priority for the present moment. The Life+A_GreeNet project proposes a comprehensive strategy for adaptation that is not confined to a single, comprehensive instrument. Rather, it employs a more inclusive, collaborative, and agile approach that transcends the limitations of a single administrative level or sector (Cáceres et al., 2024). In lieu of incorporating climate change adaptation as an additional policy, this project endeavors to integrate it into existing policy and decision-making processes.

Working on existing urban plans, modifying existing actions with an adaptive perspective and inserting new adaptive actions, is a choice of this project, which anticipated first and accommodated later both the determinations of the new PNACC and the new Spatial Government Laws of the two regions involved in the project. There are risks, however, as reflected in the project itself: the difficulty of coordination, poor collaboration or even divergence on the part of some public actors (Biesbroek et al., 2017). To overcome these obstacles, a key condition is to have strong political support within different level entities at any step of the adaptation journey and agile governance (Janssen, 2020). Without these, the process cannot be developed. On this point, the partners of the Life+ A_GreeNet Project will have a lot of work to do in the terminal phase of the project and in the AfterLife. In an effort to implement mainstreaming more effectively and efficiently, some corrective/additional measures are suggested to be implemented:

- The creation of a territorial coordination unit. This could take different forms, depending on the resources and capacities of the entities involved, but also on their willingness to invest in the issue. This coordinating office could be tasked with organizing, providing and coordinating data collection, climate tools and services at the local level, providing decision makers, policy makers, administrators and local authorities with the necessary tools to make informed decisions (Pörtner, 2022). Thus, a robust scientific database is needed because unfamiliarity with globally accessible climate data contributes significantly to slow progress in local climate change adaptation planning and decision-making (Lorenz et al., 2017);
- Improve, integrate and implement more climate data within routine urban planning and increase adaptation actions in urban planning documents (Hurlimann et al., 2021);
- The eventual definition of a shared "Strategy for Adaptation" document that can make comprehensible and organized in a single document the objectives that all the public administrations concerned set themselves and that is matched by an institutional commitment to finance adaptation actions at any level. This commitment would mean to make more explicit precise goals and actions, to be simultaneously flexible and adaptable according to the renewed needs of the entities concerned and by the sensitivities of the administrations of the super-ordinate as well as the sub-ordinate levels;
- The development of synergies between short-term sectoral benefits and long-term adaptation benefits represents a significant challenge. Frequently, greater emphasis is placed on short-term sectoral goals,

which can act as a barrier to progress. However, this can be overcome to achieve both immediate goals and enhance long-term resilience.

At all levels, the overarching objective should be to create win-win situations. In this regard, local governments could consider introducing reward systems and tax breaks in certain areas to encourage investment and innovation in adaptation (Adriázola et al., 2018). Finally, the project entails the replicability of the methodology in other Italian and European coastal areas. Specifically, the project involves four Italian coastal areas: the Province of Latina (municipalities of Gaeta and Formia); the Province of Salerno (Eboli, Capaccio-Paestum); the Province of Grosseto (Marina di Grosseto, Marina di Alberese, Talamone-Orbetello); and the Province of Barletta, Andria, Trani (Barletta, Trani, Bisceglie). Additionally, the project encompasses the Croatian city of Poreč. With respect to these cities, the project entails the signing of a transferability memorandum for the application of the methodology and the creation of a manual for the design and implementation of the Green Infrastructure. This manual will be instrumental in providing step-by-step guidance to the municipalities during the experimentation phase. The project will also involve mentoring actions by the project partners, ensuring the effective and comprehensive support of the municipalities throughout the process. To verify the outcomes of the project over time and possibly propose corrective actions, it is planned to select environmental and socioeconomic impact indicators that will monitor the project after its conclusion (After Life). The goal is to steer the implementation of the project after the projected deadline of September 2025, in the hope that public and private administrations will be able to live up to their commitments and test the project in their territories. Indeed, the risk is that the multilevel governance tested in this project, which aims to standardize environmental policies to a high and effective level of protection, will find resistance and inaction in the local and regional spheres. In the face of this risk, advantages should always be kept in mind. Among them: the ability to adapt and tailor adaptation measures to local needs and their characteristics; improved interaction with civil society, increasing the contribution of private individuals, as well as their adherence to the change process. To all this is added the dissemination of good practices and virtuous competition among the different actors in the process.

References

Adriázola, P., Dellas, E. & Tänzler, D. (2018). *Multi-Level Climate Governance Supporting Local Action*, GIZ. Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH Retrived from: https://www.researchgate.net/publication/356760091

Azmeer, A., Tahir, F. & Al-Ghamdi, S.G. (2024). Progress on green infrastructure for urban cooling: Evaluating techniques, design strategies, and benefits. *Urban Climate, 56*, 102077, ISSN 2212-0955, https://doi.org/10.1016/j.uclim.2024.102077

Baack, F., Özerol, G., Vinke-de Kruijf, J., et al. (2024). Implementing climate change adaptation through mainstreaming at the local level—a comparative case study of two municipalities in the Netherlands. *Reg Environ Change, 24*, 49. https://doi.org/10.1007/s10113-024-02214-7

Berardo R. & Lubell M. (2019). The ecology of games as a theory of polycentricity: recent advances and future challenges. *Policy Stud J., 47* (1), 6-26. https://doi.org/10.1111/psj.12313

Biesbroek, G.R., Swart R. J., Carter, T.R., Cowan, C., Henrichs, T., Mela, H., Morecroft, M.D. & Rey, D. (2010). Europe Adapts to Climate Change: Comparing National Adaptation Strategies. *Global Environmental Change, 20* (3), 440-450. https://doi.org/10.1016/j.gloenvcha.2010.03.005

Birchall, S.J., Bonnett, N. & Kehler, S. (2023). The influence of governance structure on local resilience: Enabling and constraining factors for climate change adaptation in practice. *Urban Climate*, *47*, 101348. https://doi.org/10.1016/j.uclim.2022.101348

Blank, J.L.T. & Niaounakis, T.K. (2021). Economies of Scale and Sustainability in Local Government: A Complex Issue. *Sustainability, 13*, 13262. https://doi.org/10.3390/ su132313262

Bodin, Ö., Sandström, A. & Crona, B. (2017). Collaborative networks for effective ecosystem-based management: a set of working hypotheses. *Policy Stud J., 45* (2), 289-314. https://doi.org/10.1111/psj.12146

Brinke, N.T., de Kruijf, J.V., Volker, L. & Prins, N. (2022). Mainstreaming Climate Adaptation into Urban Development Projects in the Netherlands: Private Sector Drivers and Municipal Policy Instruments. *Climate Policy, 22* (9-10), 1155-1168. https://doi.org/10.1080/14693062.2022.2111293

Cáceres, R., Wandel, J., Pittman, J. & Daedman, P. (2024). Insights intended to improve adaptation planning and reduce vulnerability at the local scale, *Front. Clim., Sec. Climate Adaptation, 6*. 2024. https://doi.org/10.3389/fclim.2024.1345921

Calliari, E., Michetti, M., Farnia, L. & Ramieri, E. (2019). A network approach for moving from planning to implementation in climate change adaptation: Evidence from southern Mexico*. Environmental Science & Policy, 93*, 146-157. https://doi.org/10.1016/j.envsci.2018.11.025

Candel, J.J.L. & Biesbroek, R. (2023). Toward a processual understanding of policy integration. *Policy Sciences, 49*, 211-231. https://doi.org/10.1007/s11077-016-9248-y

Casprini, D., Oppio, A., Rossi, G. & Bengo, I. (2023). Managing Urban Green Areas: The Benefits of Collaborative Governance for Green Spaces. *Land, 12*, 1872. https://doi.org/10.3390/land12101872

Castellari, S., Venturini, S., Giordano, F., Ballarin Denti, A., et al. (2014). *Elementi per una Strategia Nazionale di Adattamento ai Cambiamenti Climatici.* Ministero dell'Ambiente e della Tutela del Territorio e del Mare, Roma

Cha, Y., Donovan, K., Shackley, S. & van der Horst, D. (2024). Place-Based Adaptation through Network Governance. *Sustainability, 16*, 2155. https://doi.org/10.3390/su16052155

Cittadino, F., Parks, L., Bußjäger, P. & Rosignoli, F. (2022). Climate Change Integration in the Multilevel Governance of Italy and Austria Shaping Subnational Policies. *Transport, Energy, and Spatial Planning Sectors Series: Studies in Territorial and Cultural Diversity Governance,* 17. https://doi.org/10.1163/9789004513006

Clar, C. & Steurer, R. (2019). Climate change adaptation at different levels of government: Characteristics and conditions of policy change. *NRF, 43* (2), 121-131. https://doi.org/10.1111/1477-8947.12168

Climate ADAPT (2023). *Urban green infrastructure planning and nature-based solutions*. DG CLIMA Project Adaptation Strategies of European Cities (EU Cities Adapt). Retrieved from: https://climate-adapt.eea.europa.eu/en/metadata/adaptation-options/green-spaces-and-corridors-in-urban-areas

Dabrowski, M.M. (2022). Multi-Level and Multi-Actor Governance: Why it matters for spatial planning. In R. Rocco, G.B.C. Newton & M. Dabrowski (Eds.), *Teaching, Learning & Researching Spatial Planning*, 56-67. https://doi.org/10.34641/mg.50

Delgado-Capel, M.J., Cariñanos, P., Escudero-Viñolo, M. (2023). Capacity of Urban Green Infrastructure Spaces to Ameliorate Heat Wave Impacts in Mediterranean Compact Cities: Case Study of Granada (South-Eastern Spain). *Land, 12*, 1076. https://doi.org/10.3390/land12051076

De Waal, A. Weaver, M., Day, T. & van der Heijden, B. (2019). Silo-Busting: Overcoming the Greatest Threat to Organizational Performance. *Sustainability, 11*(23), 6680. https://doi.org/10.3390/su11236860

Di Gregorio, M., Fatorelli, L., Paoavola, J., et al. (2019). Multi-level Governance and Power in Climate Change Policy Networks, *Global Environmental Change, 54*, 64-77. https://doi.org/10.1016/j.gloenvcha.2018.10.003

Doblas-Reyes, F.J., Sörensson A.A., Almazroui M., Dosio A., Gutowski W.J., Haarsma R., Hamdi R., Hewitson B., Kwon W.-T., Lamptey B.L., Maraun D., Stephenson T.S., Takayabu I., Terray L., Turner A. & Zuo Z. (2021). Linking Global to Regional Climate Change. In Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press,* Cambridge, United Kingdom and New York, NY, USA, 1363–1512, https://doi.org/10.1017/9781009157896.012.

Dupont, C. & Jordan, A. (2021). Policy Integration, in Jordan A. & Gravey V. (eds.), *Environmental Policy in the EU*, 203-219. London: Routledge

EEA, European Environment Agency (2016). *Climate change, impacts and vulnerability in Europe 2016. An indicator-based report*. Copenhagen: EEA. https://doi.org/10.2800/534806

EEA, European Environment Agency (2020). *Monitoring and evaluation of national adaptation policies throughout the policy cycle*. Copenhagen: EEA. https://doi.org/10.2800/83221

EEA, European Environment Agency (2024). *European Climate Risk Assessment*. Copenhagen: EEA. https://doi.org/10.2800/204249

Eisenack, K., Moser, S.C., Hoffmann, E., Klein, R.J.T., Oberlack, C., Pechan, A., Rotter, M. & Termeer, C.J.A.M. (2014). Explaining and overcoming barriers to climate change adaptation. *Nature Climate Change, 4* (10), 867-872. https://doi.org/10.1038/nclimate2350

European Commission (2019). *Communication from the Commission to the European Parliamenti the European Council, The Council, The European Economic and Social Committee and the Committee of the Regions. The European Green Deal*. Retrieved from: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex:52019DC0640

European Commission (2021). *Communication from the Commission to the European parliament, the Council, the European economic and social committee and the committee of the regions forging a climate-resilient Europe - the new EU Strategy on Adaptation to Climate Change*. Retrieved from: https://eur-lex.europa.eu/legal-content/IT/TXT/?uri=COM%3A2021%3A82%3AFIN

Fila, D., Fünfgeld, H. & Dahlmann, H. (2024). Climate change adaptation with limited resources: adaptive capacity and action in small- and medium-sized municipalities. *Environ Dev Sustain, 26*, 5607-5627. https://doi.org/10.1007/s10668-023-02999-3

Garmendia E., Apostolopoulou E., Adams W.M., Bormpoudakis D. (2016). Biodiversity and green infrastructure in Europe: Boundary object or ecological trap? *Land Use Policy, 56*, 315-319. https://doi.org/10.1016/j.landusepol.2016.04.003

Granberg, M., Bosomworth, K., Moloney, S., Kristianssen, A.-C. & Fünfgeld, H. (2019). Can Regional-Scale Governance and Planning Support Transformative Adaptation? A Study of Two Places. *Sustainability, 11*, 6978. https://doi.org/10.3390/su11246978

Gonzales-Iwanciw, J., Dewulf, A. & Karlsson-Vinkhuyzen, S. (2019). Learning in multi-level governance of adaptation to climate change – a literature review. *Journal of Environmental Planning and Management, 63* (5), 779-797. https://doi.org/10.1080/09640568.2019.1594725

Gustavsson, E., Elander, I. & Lundmark, M. (2009). Multilevel Governance, Networking Cities, and the Geography of Climate-Change Mitigation: Two Swedish Examples. *Environment and Planning C: Government and Policy*, *27* (1), 59-74. https://doi.org/10.1068/c07109j

Hurlimann, A., Moosavi, S., Geoffrey R. & Browne, G.R. (2021). Urban planning policy must do more to integrate climate change adaptation and mitigation actions. *Land Use Policy, 101*, 105188. https://doi.org/10.1016/j.landusepol.2020.105188.

Ishtiaque, A. (2021). Chapter 10 - Multilevel governance in climate change adaptation: Conceptual clarification and future outlook. In Ali Fares (Ed.). *Climate Change and Extreme Events*. 171-185. Amsterdam: Elsevier. https://doi.org/10.1016/B978-0-12-822700-8.00009-3

Ispra (2022). *Distribuzione del valore ecologico secondo carta della natura.* Roma: ISPRA. Retrieved from: https://indicatoriambientali.isprambiente.it/it/biodiversita-stato-e-minacce/distribuzione-del-valore-ecologico-secondo-carta-della-natura

Ispra (2024). *Frammentazione del territorio naturale e agricolo.* Roma: ISPRA. Retrieved from: https://indicatoriambientali.isprambiente.it/it/biodiversita-stato-e-minacce/frammentazione-del-territorio-naturale-e-agricolo

Janssen, M. & van der Voort, H. (2020). Agile and adaptive governance in crisis response: Lessons from the COVID-19 pandemic. *Int. J. Inf. Manage, 55*, 102180. https://doi.org/10.1016/j.ijinfomgt.2020.102180

Kruse, S. & Pütz M. (2014). Adaptive Capacities of Spatial Planning in the Context of Climate Change in the European Alps. *European Planning Studies, 22* (12), 2620-2638. https://doi.org/10.1080/09654313.2013.860516

Kumar, P., Debele, S., Khalili, Soheila, K., Halios,C. H., Sahani, J., Aghamohammadi, N., de Fatima Andrade, M., Athanassiadou, M., Bhui, K., Calvillo, N., et al. (2024). Urban heat mitigation by green and blue infrastructure: drivers, effectiveness, and future needs. *The Innovation, 5* (2). 100588. https://doi.org/10.1016/j.xinn.2024

Lazzarini, L., Mahmoud, I.H. & Pastore, M.C. (2024). Urban Planning for Biodiversity. *TeMA - Journal of Land Use, Mobility and Environment, SI 1*, 45-60. http://dx.doi.org/10.6093/1970-9870/10197

Ledda, A., Di Cesare, E.A., Satta, G., Cocco, G., Calia, G., Arras, F., Congiu, A., Manca, E. & De Montis, A. (2020). Adaptation to Climate Change and Regional Planning: A Scrutiny of Sectoral Instruments. *Sustainability, 12*, 3804. https://doi.org/10.3390/su12093804

Lesnikowski, A., Ford, J., Biesbroek, R. et al. (2016). National-level progress on adaptation. *Nature Clim Change, 6*, 261-264. https://doi.org/10.1038/nclimate2863

Lorenz, S., Dessai, S., Forster, P.M. & Paavola, J. (2017). Adaptation planning and the use of climate change projections in local government in England and Germany. *Reg. Environ. Change, 17*, 425-435. https://doi.org/10.1007/s10113-016-1030-3

Marot, N., Kostanjšek, B., Penko Seidl, N. & Harfst, J. (2024). Implementing the green infrastructure concept in practice: an example of the EU-strategy for Alpine Region. *Journal of Environmental Policy & Planning, 26*(4), 325-338. https://doi.org/10.1080/1523908X.2024.238368

Mattijssen, T.J.M., van der Jagt, A.P.N., Buijs, A.E., Elands, B.H.M., Erlwein, S. & Lafortezza, R. (2017). The long-term prospects of citizens managing urban green space: From place making to place-keeping? *Urban Forestry & Urban Greening, 26*, 78-84. https://doi.org/10.1016/j.ufug.2017.05.015

Mazzeo, G. & Polverino, S. (2023). Nature-based solution for climate change adaptation and mitigation in urban areas with high natural risk. *TeMA - Journal of Land Use, Mobility and Environment*, *16* (1), 47-65. http://dx.doi.org/10.6093/1970-9870/9736

Mobaraki, O. (2023). Spatial analysis of green space use in Tabriz metropolis, Iran. TeMA - *Journal of Land Use, Mobility and Environment,* 55-73. http://dx.doi.org/10.6092/1970-9870/10117

Monteiro, R., Ferreira, J.C. & Antunes, P. (2022). Green infrastructure planning principles: Identification of priorities using analytic hierarchy process. *Sustainability*, *14* (9), 5170. https://doi.org/10.3390/su14095170

Moser, S.C. & Ekstrom, J.A., (2010). A Framework to Diagnose Barriers to Climate Change Adaptation. *Proc. Natl. Acad. Sci., 107*, 22026-22031. https://doi.org/10.1073/pnas.100788710

Munafò, M. (Ed.) (2023). *Consumo di suolo, dinamiche territoriali e servizi ecosistemici*. Report SNPA 37/23

Newman, P. (2008). Strategic Spatial Planning. *European Planning Studies, 16*, 1371-1383. https://doi.org/10.1080/09654310802420078

Novalia, W., Suwarso, R. & Nurdin, I. (2024). Connecting place and multilevel governance for urban river restoration. *Territory, Politics, Governance, 1-26*. https://doi.org/10.1080/21622671.2024.2336608

OECD (2023), Climate adaptation: Why local governments cannot do it alone, *OECD Environment Policy Papers*, No. 38, *OECD Publishing, Paris*, https://doi.org/10.1787/be90ac30-en

OECD (2009),Integrating Climate Change Adaptation into Development Co-operation: Policy Guidance, *OECD Publishing, Paris*, https://doi.org/10.1787/9789264054950-en.

Ostrom, E. (2014). A polycentric approach for coping with climate change. *Ann Econ Financ, 15* (1), 97-134. https://doi.org/10.2139/ssrn.1934353

Palermo, A., Chieffallo, L. & Virgilio, S. (2024). Re-generate resilience to deal with climate change. *TeMA - Journal of Land Use, Mobility and Environment, 1*, 11-28. https://doi.org/10.6093/1970-9870/9969

Pantaloni,M., Botticini,F. & Marinelli,G. (2024). Assessment of urban green spaces proximity to develop the green infrastructure strategy. An Italian case study. *TeMA - Journal of Land Use, Mobility and Environment, 3,* 67-81. https://doi.org/10.6093/1970-9870/10919

Parks, L.R. & Bertuzzi, N. (2023). *Climate Change Integration in the Multilevel Governance of Italy and Austria: Shaping Subnational Policies in the Transport, Energy, and Spatial Planning Sectors*. Boston: Brill. https://doi.org/10.1163/9789004513006

Pelizzaro, P. (2015). Public Private Partnerships for Resilient Communities. *TeMA - Journal of Land Use, Mobility and Environment*, 123-134. https://doi.org/10.6092/1970-9870/3657

Persson, Å., et al. (2018). Editorial: Environmental Policy Integration: Taking stock of policy practice in different contexts. *Environmental Science & Policy, 85*, 113-115. https://doi.org/10.1016/j.envsci.2018.03.029

Pörtner, H.-O et al. (2022). Technical Summary. Cambridge University Press, Cambridge, UK and New York, NY, USA, pp. 37–118, https://doi.org/10.1017/9781009325844.002.

Ronchi, S., Arcidiacono, A. & Pogliani,L. (2020). Integrating green infrastructure into spatial planning regulations to improve the performance of urban ecosystems. Insights from an Italian case study. *Sustainable Cities and Society, 53*, 101907. https://doi.org/10.1016/j.scs.2019.101907

Runhaar, H., Wilk, B., Persson, Å. et al. (2018). Mainstreaming climate adaptation: taking stock about "what works" from empirical research worldwide. *Reg Environ Change ,18*, 1201.1210. https://doi.org/10.1007/s10113-017-1259-5

Salata, K.D. & Yiannakou, A. (2016). Green Infrastructure and climate change adaptation. *TeMA - Journal of Land Use, Mobility and Environment, 9* (1), 7-24. https://doi.org/10.6092/1970-9870/3723

Scheiber, S. & Mifsud, W.J. (2024). Developing processes for the co-creation and co-governance of urban green space in dense urban areas: a Maltese case study. TeMA - *Journal of Land Use, Mobility and Environment, 2*, 65-79. http://dx.doi.org/10.6092/1970-9870/10273

Santoro, S., Mastrodonato, G. & Camarda, D. (2024). Managing local knowledge about NBS in spatial planning. A group model building approach. *TeMA - Journal of Land Use, Mobility and Environment, 17* (2), 265-283. https://doi.org/10.6093/1970-9870/10810

Storbjörk, S. & Uggla, Y. (2015). The practice of settling and enacting strategic guidelines for climate adaptation in spatial planning: lessons from ten Swedish municipalities. *Regional Environmental Change, 15* (6), 1133-1143. http://dx.doi.org/10.1007/s10113-014-0690-0

Ten Brinke, N., Vinke-de-Kruijf, J., Volker, L. & Prins, N. (2022), Mainstreaming climate adaptation into urban development projects in the Netherlands: private sector drivers and municipal policy instruments, *Climate policy, 22*, 1155-1168. https://doi.org/10.1080/14693062.2022.2111293

Termeer C., Dewulf A. & Breeman, G. (2013). Governance of Wicked Climate Adaptation Problems. In: J. Knieling, W. Leal Filho (Eds.) *Climate Change Governance. Climate Change Management*. Berlin, Heidelberg: Springer https://doi.org/10.1007/978-3-642-29831-8_3

Uittenbroek, C.J., Janssen-Jansen ,L.B. & Runhaar, H.A.C. (2012). Mainstreaming climate adaptation in urban planning. *Regional Environmental Change, 13*, 399-411. https://doi.org/10.1007/s10113-012-0348-8

van den Ende, M.A., Mees, H.L.P., Hegger, D.L.T. & Driessen, P.P.J. (2022). Mechanisms influencing mainstreaming of adaptation in spatial development: case studies in three Dutch municipalities. *Journal of Environmental Planning and Management, 66* (14), 2903-2921. https://doi.org/10.1080/09640568.2022.2092724

Zucaro, F. & Morosini R. (2018). Sustainable land use and climate adaptation: a review of European local plans. *TeMA - Journal of Land Use, Mobility and Environment, 11* (1), 7-26. https://doi.org/10.6092/1970-9870/5343

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REVIEW NOTES
International regulation and legislation for the energy transition

Urban energy transition between regulatory evolution and scientific production: a bibliometric analysis

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Abstract
Starting from the relationship between urban planning and mobility management, TeMA has gradually expanded the view of the covered topics, always remaining in the groove of rigorous scientific in-depth analysis. This section of the Journal, Review Notes, is the expression of continuously updating emerging topics concerning relationships between urban planning, mobility and environment, through a collection of short scientific papers written by young researchers. The Review Notes are made of four parts. Each section examines a specific aspect of the broader information storage within the main interests of TeMA Journal. This section, International Regulations and Legislation for the Energy Transition, explores the challenges and opportunities in the urban context to understand the evolving landscape of the global energy transition. The contribution explores how scientific research on urban energy transition has evolved alongside European climate policies. It highlights the role of urban governance and planning in supporting decarbonisation through tools like Positive Energy Districts and Renewable Energy Communities. These models integrate innovation with citizen engagement and local energy autonomy. The analysis also reveals how regulatory developments have shaped research priorities. Finally, it underscores the need for stronger coordination to overcome implementation gaps.

Keywords
Energy transition; Urban planning; Regulations; Bibliometric analysis.

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1. Introduction

The energy transition is one of the central challenges for contemporary cities in a context of increasing urbanisation and the pressing need to reduce greenhouse gas emissions. Urban areas, responsible for more than 70 % of global CO_2 emissions (EC, 2024), play a key role in the adoption of strategies for decarbonisation and integration of renewable energy. However, the urban energy transition is not only a technological issue, but also a social, economic and governance issue, requiring solutions that combine technical innovation with integrated planning and active citizen participation (Cruz et al., 2023). Over the last two decades, European energy-climate policies have provided a strong impetus for the development of energy transition in cities, triggering a parallel evolution in academic research. Each new policy framework - from the 20-20-20 targets for 2020 to the European Green Deal - has set ambitious goals that have stimulated studies aimed at supporting their achievement (ISPI, 2022). At the same time, scientific interest in urban sustainability has grown exponentially, especially after 2015, with a spike in publications in recent years correlated with the rise of urban decarbonisation targets. Initiatives such as the Green Deal (2019), the Fit for 55 package (2021) and the REPowerEU plan (2022) have stimulated research on energy communities, positive energy neighbourhoods, urban electrification and energy resilience. Considering this co-evolution between policy and science, the aim of this study is to analyse the evolution of scientific production on urban energy transition in relation to European regulatory developments. By means of a bibliometric analysis of the literature (2004-2024), we intend to highlight how changes in energy policies have influenced academic research trends and, reciprocally, how scientific evidence has helped guide strategies and interventions for energy transition in cities. Ultimately, the review highlights the dialogue between policy and academia and the implications for cities' future challenges towards climate neutrality.

2. Bibliometric analysis methodology

The bibliometric analysis was designed to offer a representative overview of the scientific literature on the energy transition in urban areas, following a multi-step structured approach:

1. Data collection - source and coverage: Scopus was chosen as the reference database for the bibliographic search, given its broad subject coverage and the possibility of exporting metadata in formats compatible with analysis software. This choice also allows integration with software tools such as VOSviewer and Bibliometrix, useful for subsequent data processing phases.

2. Search strategy: a specific query string was defined to intercept the relevant literature. In particular, the query used is TITLE-ABS-KEY (energy transition' AND 'urban'), applied to the title, abstract and keyword fields. The search initially covered a broad time span (1973-2024), excluding 2025 to avoid distortions due to incomplete data. To ensure an international perspective of scientific production, the analysis was limited to English-language papers.

3. Filters and selection criteria: in order to focus the analysis on the studies most relevant to our field of research, targeted filters were applied to the initial dataset:

- Time range: limited to the last 20 years (2004-2024), as the topic was previously only treated sporadically;
- Type of documents: inclusion of scientific articles, conference proceedings and books, excluding less relevant types to ensure the reliability of the results;
- Disciplinary areas: restricted selection to the fields of Energy, Environmental Science, Engineering and Social Sciences, i.e. the areas most closely related to the urban energy transition. Attention was also paid to Open Access documents to facilitate their consultation and dissemination.

The application of these criteria produced a final dataset consisting of 1,276 relevant documents, which was subsequently exported in CSV format for quantitative analysis.

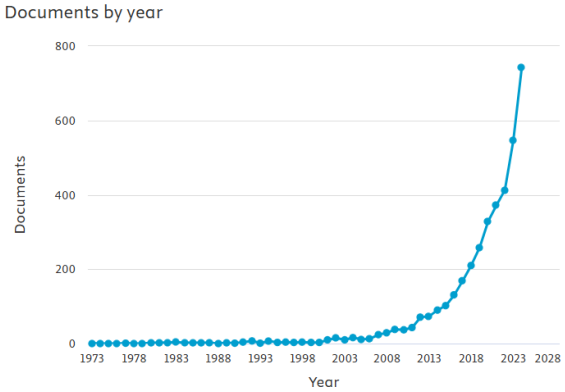
4. Bibliometric analysis and tools: the data collected were analysed using two main tools:

- VOSviewer used to construct the co-occurrence network of keywords and identify thematic clusters. All keywords associated with the articles were considered and, to focus on the most significant terms, a minimum threshold of 5 occurrences was set. This reduced the set from over 9,000 terms to approximately 688 relevant keywords. In addition, to obtain a clearer map, keywords directly derived from the main query (i.e. urban, energy, transition) were excluded from the network in order to better highlight links between specific topics. VOSviewer provided both a Network Visualisation (map of thematic clusters) and an Overlay Visualisation to observe the temporal evolution of the search topics;
- Bibliometrix (in R, via the Biblioshiny interface) - used to analyse general bibliometric metrics and the evolution of topic trends over time. In particular, the frequency of occurrence of the main keywords and topic trends per year were examined, as well as the word cloud of the most recurrent words.

Thanks to this articulated methodological approach, it was possible to obtain a clear view of the evolution of academic research on the subject, highlighting the main scientific trends and their relationship with the normative milestones.

3. Bibliometric analysis results

The literature analysis (period 2004-2024) shows a significant growth of academic interest in urban energy transition (Fig.1). The total number of publications identified is 1,276 papers, distributed across 378 academic sources, with a compound annual growth rate of 30.95%. This increase indicates that the field of study has gained increasing relevance in recent years. A strong international component is noticeable: more than 32% of the publications are the result of collaborations between several countries, confirming that the urban energy transition is a global challenge tackled with shared approaches. The degree of collaboration between authors is also high (an average of 3.91 co-authors per article), reflecting the interdisciplinary nature of the topic that requires contributions from experts in energy, urban planning, environmental policy, economics and engineering. Scientific production is not geographically homogeneous (Fig.2). Some countries emerge as predominant research poles on the topic, leading the scientific debate: the United Kingdom is the leading research centre on the urban energy transition (Brummer, 2018), followed by Italy, which has seen significant growth thanks to experiments on Renewable Energy Communities (RECs) (Musolino et al., 2023). China stands out for the volume of studies related to the environmental challenges of urbanisation (Quin, 2024). The Netherlands and Germany emerge for applied research on Positive Energy Districts and innovative models of urban energy governance (Mahzouni, 2017; Derkenbaeva et al., 2024).



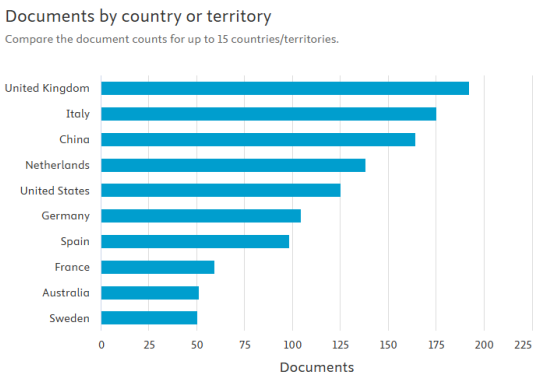


Fig.1 Documents by year; Fig.2 Documents by country or territory

The bibliometric network built on the co-occurrences of keywords offers a map of the main themes that have characterised research on urban energy transition (Fig.3). Analysis with VOSviewer reveals four predominant thematic clusters, each identified by a colour and a set of related key terms:

- Energy Transition & Smart Cities (red cluster): includes terms such as energy utilisation, renewable energies, energy efficiency, smart grid and positive energy districts (PEDs). This cluster reflects the focus on the integration of renewable energy sources and energy efficiency in smart cities, also highlighting the growing interest in positive energy districts and, in general, the active role of cities in producing more energy than they consume;
- Urban Planning & Sustainability (Green Cluster): links energy transition to spatial governance and planning processes. Key terms include urban area, sustainability, governance approach, urban transformation and socio-technical transition. The cluster emphasises how energy strategies are increasingly interlinked with urban planning and local sustainability, indicating the importance of integrated policies;
- Low Emission Mobility & Transport (Blue Cluster): highlights the relevance of the transport sector in the urban energy transition. Terms such as electric vehicle, hydrogen, charging infrastructure and fleet operations indicate a focus on sustainable mobility, from the electrification of transport (electric vehicles and charging infrastructure) to the use of hydrogen as an energy carrier to reduce emissions in public and private transport;
- Pollution & Environmental Impacts (Orange/Purple Cluster): represents the link between urban energy transition and local pollution mitigation. It includes keywords such as air pollution, carbon emissions, environmental policy and public health. This cluster draws attention to the fact that the decarbonisation of cities is also motivated by improving air quality and public health, in addition to combating climate change.

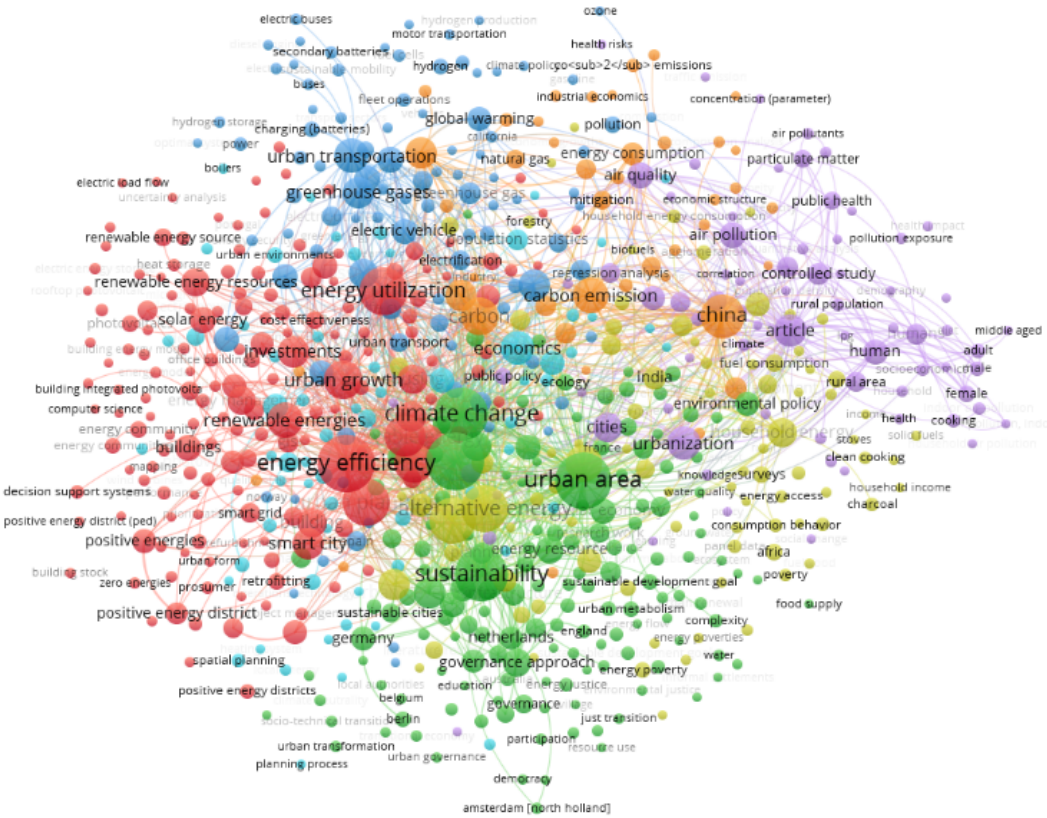


Fig.3 Network Visualisation of keywords

The time map (Overlay Visualization) of the keyword network clearly shows how research topics have evolved over time, following - and often anticipating - energy policy directions (Fig.4). As can be seen from the map marked in blue/purple in the visualisation, until 2018, studies focused on the core concepts of energy

efficiency, climate change and sustainable development, in line with the EU's early climate goals (e.g. Kyoto Protocol 2005). Words such as energy efficiency, climate change and sustainable development recurred frequently, highlighting the priority given to reducing emissions and optimising consumption. In contrast, in the more recent period from 2020 onwards - highlighted in yellow/light green - new and more advanced terms such as energy communities, prosumers, positive energy districts, smart grids and hydrogen mobility emerge. This reflects a shift in focus towards integrated models of urban decarbonisation, consistent with the entry into force of second-generation European policies (e.g. Clean Energy Packages) and the growing interest in innovative technologies in the urban context. The appearance of these concepts in the scientific lexicon marks the broadening of the research scope to include socio-technical and participatory dimensions of the energy transition, underlining the transition from a pioneering phase, focused mainly on energy efficiency and climate mitigation, to a more recent phase oriented towards complex strategies integrating governance, urban planning and sustainable mobility.

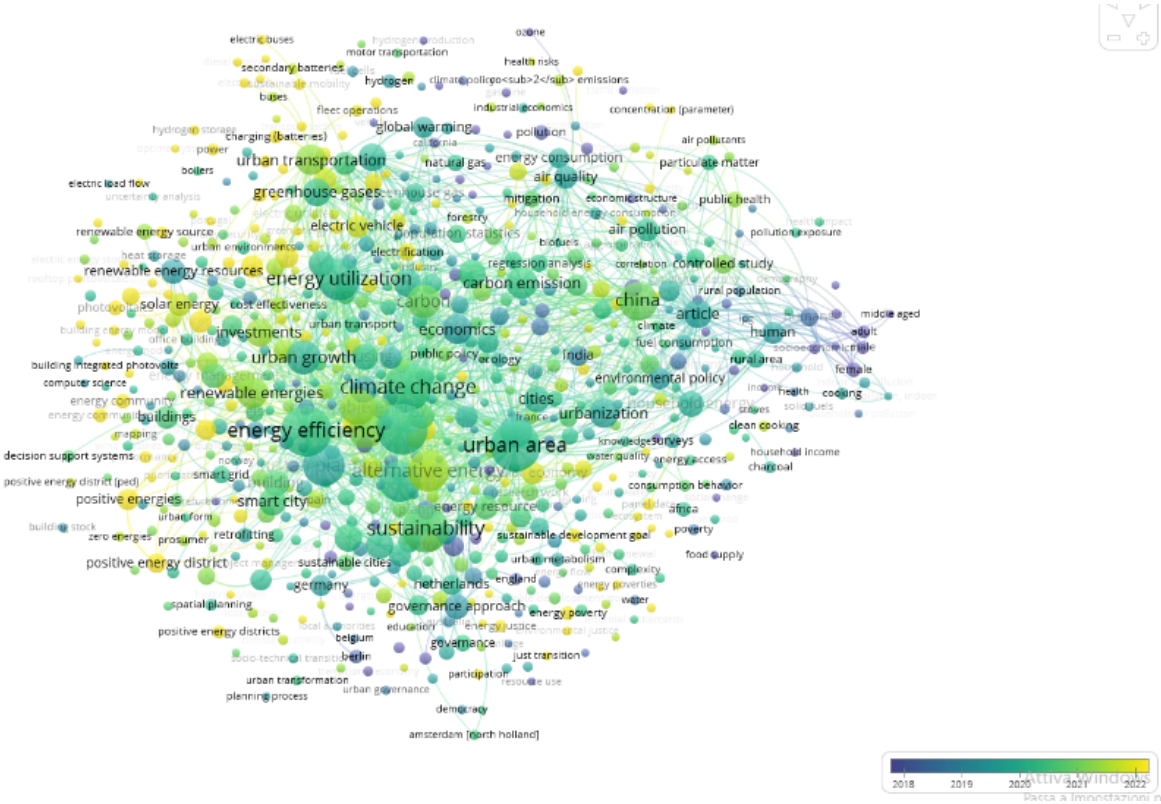


Fig.4 Overlay Visualization of keywords

In parallel, the analysis of keyword frequencies and temporal trends carried out in Biblioshiny (Fig.s 5, 6 and 7) provides further insights. The most recurrent keywords over the entire period (e.g. energy efficiency, sustainable development, urban area) confirm the constant focus on sustainability and emissions, while the presence of terms such as climate change and energy policy underline the link between energy transition and climate mitigation strategies. As of 2018, a marked increase in publications on decarbonisation, renewable energy and sustainable urban planning can be observed, with a further acceleration after 2020 in terms such as clean energy and urban politics, in line with the launch of the European Green Deal and the Fit for 55 packages. At the same time, new terms are emerging with greater emphasis: words such as decision making, governance approach and alternative energy indicate the growing interest in participatory decision-making processes and alternative energy solutions, in addition to the already established strands.

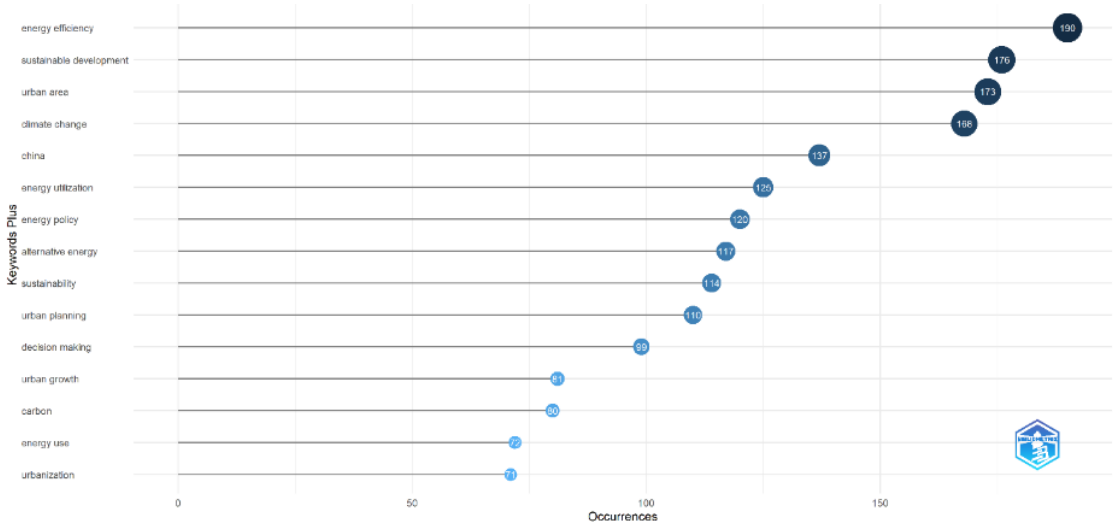


Fig.5 Most Relevant Words

Fig.6 Wordcloud of most relevant keywords

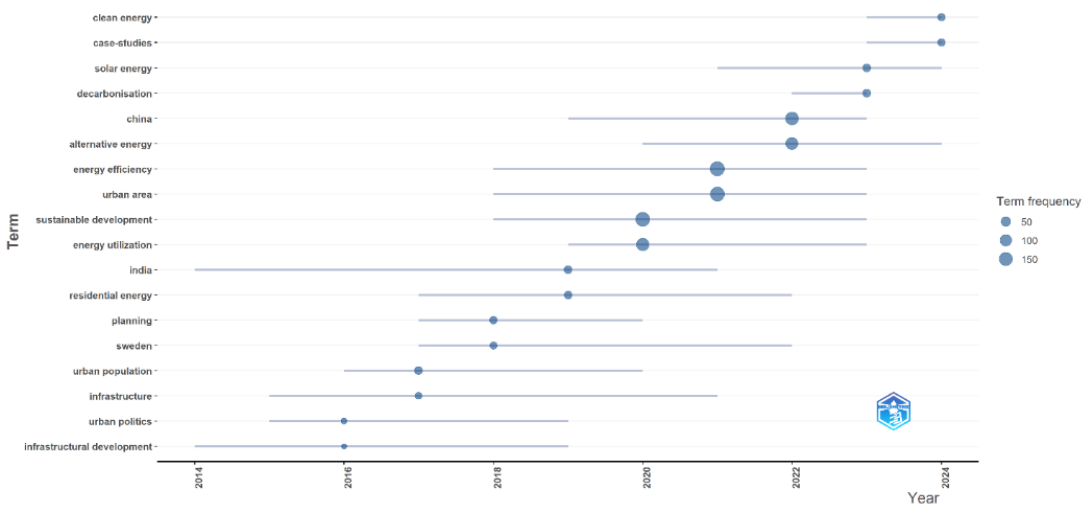


Fig.7 Trend Topics of the most frequent keywords over the years

In summary, the bibliometric results confirm that urban energy transition is a rapidly expanding and constantly evolving field of research. Over the last two decades, the horizon of studies has progressively broadened: from the classical themes of environmental sustainability, it has moved on to embrace aspects of governance, involvement of local actors and socio-technical innovation. The influence of European policies is evident in the spread of innovative concepts (think of the surge of studies on energy communities after 2018), while research is increasingly oriented towards integrated and holistic strategies, aimed at the goal of climate neutrality by 2050. This framework provides the context for understanding in detail, in the following section, how regulatory developments have marked and driven the main trends in scientific production.

4. Regulatory evolution and scientific production

Overall, the quantitative analysis suggests a close correlation between regulatory developments and scientific output. Spikes and accelerations in the number of publications often coincide with the adoption of new energy policy packages at the European level, signalling that the academic community actively responds to stimuli from policy makers. This link indicates the key role of research in supporting the development of strategies for urban energy transition. At the same time, there are signs of a time lag between theory and practice: the rapid development of knowledge and innovative solutions is not always immediately followed by an equally rapid implementation in cities, due to regulatory, institutional or financial obstacles (Good, 2017; Sæle et al., 2023). European and international energy-climate policies in recent decades have marked milestones that are reflected in the evolving scientific literature on urban energy transition. Below we retrace the salient phases of the dialogue between legislation and academic research, highlighting for each period the essential connections between the policy initiatives and the thematic trends that emerged.

- Until 2015 the European Union lays the foundations of its climate and energy strategy. With Directive 2001/77/EC and above all with Directive 2009/28/EC (Renewable Energy Directive - RED I), the ambitious 20-20-20 objectives for 2020 are introduced (20% emissions reduction, 20% renewable share, 20% more efficiency). These first regulations, aimed at promoting renewable sources and energy efficiency, immediately stimulated research on wind and solar technologies, on the efficiency of buildings and on the integration of sustainable energy in urban contexts (Newton & Newman, 2013). Key terms such as renewable energy, sustainable urban development and energy efficiency appear in the literature of the early 2000s, indicating the focus on local sustainability and efficient use of energy. The first concepts of local energy planning and intelligent networks (smart grids) also appear, a sign of a nascent attention to the advanced management of urban networks (Balta-Ozkan, 2015). An important impulse comes from the Covenant of Mayors initiative (2008), through which hundreds of European cities begin to develop Sustainable Energy Action Plans (SEAPs) sanctioning the active role of local communities in the transition (Grafakos, 2015). At the same time, the EU adopts measures aimed at sustainable mobility - Directive 2014/94/EU on alternative fuels dates back to 2014 - which lead to the development of studies on charging infrastructures for electric vehicles, on vehicle-to-grid integration and, in general, on the role of transport in the urban energy transition (Moore, 2015). A further impetus comes from the Paris Agreement (2015), which by setting global decarbonisation objectives shifts attention towards resilient and low-emission urban energy models. As a result, terms such as urban resilience and climate planning enter the scientific literature, and studies on the reduction of emissions in transport and on the potential of cities in contributing to global climate objectives are consolidated. It is also the period in which the awareness matures that urban governance and citizen participation are indispensable levers for implementing energy policies in the territory: research begins to explore participatory approaches and new models of multilevel governance for energy in the city (Berghi, 2016).
- In the second half of the 2010s there was an exponential growth in scientific production corresponding to the launch of the Clean Energy for All Europeans Package (2018). This package of directives and regulations which includes, among other things, RED II (Directive 2018/2001/EU) and Directive 2019/944 on the electricity

market for the first time officially recognizes and strengthens the active role of citizens and communities in the energy transition (Grignani et al., 2021). In fact, the concepts of renewables self-consumer and renewable energy community are formally introduced, guaranteeing prosumers and local communities new rights to produce, self-consume, share and sell renewable energy. The transposition of these rules has an immediate impact on research: after 2018 there is a boom in publications on topics such as energy communities, peer-to-peer energy trading, sharing economy models applied to energy and forms of collective involvement in distributed generation (Fichera et al., 2021). Terms that until a few years earlier were niche - prosumer, energy community - become mainstream in the scientific lexicon, often associated with studies on microgrids, digital platforms for energy exchange and new local energy business models. In parallel, the EU strengthens the integration between energy and territorial planning: cities are explicitly mentioned in post-2018 energy strategies, recognizing that objectives such as 32% renewables by 2030 (established by RED II) must also be pursued through bottom-up local initiatives. Consequently, attention for multilevel governance and integrated planning is spreading in scientific journals: numerous studies explore tools for coordinating urban policies and energy (Hunag et al., 2018; Oguz & Tanyas, 2024).

With the European Green Deal (end 2019) the EU adopts an all-encompassing strategy to achieve climate neutrality by 2050, integrating energy, climate and urban planning into a single synergistic framework. This new political horizon stimulates further changes of focus in academic research. The vision of "climate-neutral cities" promoted by the Green Deal encourages studies on local decarbonisation strategies, on the development of Urban Energy and Climate Plans and on the design of zero or positive emissions neighborhoods (Cumo et al., 2022). In particular, the concept of Positive Energy District (PED) - i.e. the positive energy urban neighborhood - receives great attention: supported by the European SET-Plan program, which envisages 100 of them by 2025, it becomes a central theme that requires integrated design approaches (Sassenou et al., 2023). At the same time, interest is growing in nearly zero-emission buildings (NZEB) and the energy requalification of existing building stock, in line with medium-long term objectives (Koutra, 2022). The Fit for 55 package (2021) further raises the bar to 2030 (requiring -55% of emissions compared to 1990) and emphasizes the principle of "energy efficiency first": this translates into an increase in studies on deep renovation of buildings, heat pumps, green district heating networks and on the electrification of heat consumption and transport (Margaritopoulos & Xenidis, 2023). In the same period, the theme of "just transition" forcefully enters the academic debate: key words such as just transition, energy justice and energy poverty signal a growing awareness of the socio-economic aspects of decarbonisation, reflecting the commitment of the Green Deal to "leave no one behind" (Knox et al., 2021). Finally, the REPowerEU plan (2022) - response to the energy crisis triggered by geopolitical shocks - gives a further direction to research, placing the emphasis on energy independence and diversification of sources. The need to reduce dependence on imported gas drives new studies on the hydrogen economy and green hydrogen, on the scalability of storage systems and on the network infrastructures necessary to integrate massive shares of intermittent renewables. In the urban context, this translates into research on distributed storage systems through neighborhood batteries and on the resilience of cities in the face of energy shocks (Proedrou, 2023).

Overall, the most recent European policies push the literature towards increasingly systemic and integrated approaches: the conceptual networks of academic studies today show a strong interconnection between technological, planning and social terms, reflecting the holistic nature of initiatives such as Fit for 55 and REPowerEU. This trend reflects the current orientation of EU policies, in which energy and territorial governance are now inseparable in designing the ecological transition of cities (Segales et al., 2023).

5. Conclusions

From the analysis carried out, it clearly emerges how regulatory evolution has had a decisive impact on academic research trends in the field of urban energy transition. Each major European directive or international

agreement has introduced new objectives and concepts which, in the space of a few years, have been assimilated by the scientific lexicon and explored in depth in numerous studies. We have moved from a pioneering phase, focused on renewables and energy efficiency (in the wake of the 2020 targets), to an era of strong interest for prosumers and energy communities (after the 2018 Clean Energy Package), up to more recent approaches that embrace the systemic dimension of urban decarbonisation (e.g. positive energy districts, sector integration, green hydrogen) in line with the Green Deal and post-2020 strategies. This process outlines a profound co-evolution: on the one hand, policies have oriented research towards areas considered priorities, on the other, scientific evidence has often provided bases and tools for the policies themselves, in a virtuous circle of mutual influence. Cities have emerged as absolute protagonists of the energy transition and are increasingly configured as innovation laboratories in which to experiment with advanced solutions. In fact, urban environments concentrate both the major critical issues (high energy consumption, polluting emissions, socio-environmental vulnerabilities) and the potential to intervene in an integrated way on energy, transport and territorial planning (Mauree et al., 2019). Numerous initiatives confirm the role of cities as "bridgeheads" of the transition: for example, the EU 100 Climate-Neutral Cities Mission (which aims for 100 climate-neutral cities by 2030) and the European Smart Cities & Communities projects finance pilot cities to act as examples and spread good practices (Natanian et al., 2024). Such experiences underline the importance of closely integrating energy policies with urban planning and local development strategies to ensure a sustainable and equitable transition. A truly holistic approach is fundamental: urban decarbonisation does not just concern systems and technologies, but involves the regeneration of neighbourhoods, mobility, waste management, the protection of vulnerable groups and the creation of new "green" employment opportunities. Only through this multilevel integration, in which energy solutions are linked to land use, housing, social inclusion and economic development policies, will the energy transition be able to advance in a fair and sustainable way, maximizing collective benefits and minimizing social costs (Derkenbaeva et al., 2022). Only through a balance between innovation, administrative capacity and social inclusion will it be possible to achieve a just, equitable and lasting urban energy transition, transforming cities into sustainable and resilient models.

References

Balta-Ozkan, N., Watson, T. & Mocca, E. (2015). Spatially uneven development and low carbon transitions: Insights from urban and regional planning. *Energy Policy*, 85, 500–510. https://doi.org/ 10.1016/j.enpol.2015.05.013

Berghi, S. (2016). Energy planning for Metropolitan Context: Potential and Perspectives of Sustainable Energy Action Plans (SEAPs) of three Italian big cities. *Energy Procedia*, 101, 1072–1078. https://doi.org/ 10.1016/j.egypro.2016.11.146

Brummer, V. (2018). Community energy – benefits and barriers: A comparative literature review of Community Energy in the UK, Germany and the USA, the benefits it provides for society and the barriers it faces. *Renewable and Sustainable Energy Reviews*, 94, 187–196. https://doi.org/10.1016/j.rser.2018.06.013

Cruz, C., Alskaif, T., Palomar, E. & Bravo, I. (2023). Prosumers integration in aggregated demand response systems. *Energy Policy*, 182, 113745. https://doi.org/10.1016/j.enpol.2023.113745

Cumo, F., Maurelli, P., Pennacchia, E. & Rosa, F. (2022). Urban Renewable Energy Communities and Energy Poverty: a proactive approach to energy transition with Sun4All project. IOP Conference Series Earth and Environmental Science, 1073 (1), 012011. https://doi.org/10.1088/1755-1315/1073/1/012011

Derkenbaeva, E., Yoo, H. K., Hofstede, G. J., Galanakis, K. & Ackrill, R. (2022). Positive Energy Districts in Europe: one size does not fit all. 2022 IEEE International Smart Cities Conference (ISC2), 1–6. https://doi.org/10.1109/ isc255366.2022.9921835

Derkenbaeva, E., Hofstede, G. J., Van Leeuwen, E., Vega, S. H. & Wolfers, J. (2024). ENERGY Pro: Spatially explicit agent-based model on achieving positive energy districts. MethodsX, 12, 102779. https://doi.org/10.1016/j.mex.2024.102779

European Commission. (2024). Renewable energy targets. U.S. Department of Energy. https://www.energy.gov/ sites/default/files/2024-06/076.%20European%20Commission%2C%20Renewable%20Energy%20Targets.pdf

Fichera, A., Pluchino, A. & Volpe, R. (2021). Local production and storage in Positive Energy Districts: The Energy Sharing Perspective. *Frontiers in Sustainable Cities*, 3. https://doi.org/10.3389/frsc.2021.690927

Good, N., Ceseña, E. M., Mancarella, P., Monti, A., Pesch, D. & Ellis, K. (2017). Barriers, challenges, and recommendations related to development of energy positive neighborhoods and smart energy districts. In Elsevier eBooks, 251–274. https://doi.org/10.1016/b978-0-12-809951-3.00008-9

Grafakos, S., Enseñado, E., Flamos, A. & Rotmans, J. (2015). Mapping and measuring European local governments' priorities for a sustainable and Low-Carbon energy future. *Energies,* 8 (10), 11641–11666. https://doi.org/10.3390/en81011641

Grignani, A., Gozzellino, M., Sciullo, A. & Padovan, D. (2021). Community Cooperative: a new legal form for enhancing social capital for the development of renewable energy communities in Italy. *Energies,* 14 (21), 7029. https://doi.org/10.3390/en14217029

Huang, P., Ma, H. & Liu, Y. (2018). Socio-technical experiments from the bottom-up: The initial stage of solar water heater adoption in a 'weak' civil society. Journal of Cleaner Production, 201, 888–895. https://doi.org/10.1016/j.jclepro.2018.08.087

ISPI. (2022). From the Green Deal to REPowerEU: The green Transition in Europe and beyond. https://www.ispionline.it/en/publication/green-deal-repowereu-green-transition-europe-and-beyond-35902

Knox, S., Hannon, M., Stewart, F. & Ford, R. (2021b). The (in)justices of smart local energy systems: A systematic review, integrated framework, and future research agenda. Energy Research & Social Science, 83, 102333. https://doi.org/10.1016/j.erss.2021.102333

Koutra, S., Terés-Zubiaga, J., Bouillard, P. & Becue, V. (2022). Retracted: Decarbonizing Europe. A critical review on positive energy districts approaches. *Sustainable Cities and Society, 89*, 104356. https://doi.org/10.1016/j.scs.2022.104356

Mahzouni, A. (2017). Urban brownfield redevelopment and energy transition pathways: A review of planning policies and practices in Freiburg*. Journal of Cleaner Production, 195*, 1476–1486. https://doi.org/10.1016/j.jclepro.2017.11.116

Margaritopoulos, E. & Xenidis, Y. (2023). Condition-based maintenance using BIM: A case study of energy modeling for a residential building. *Journal of Engineering Project and Production Management*. https://doi.org/10.32738/jeppm-2023-0024

Mauree, D., Naboni, E., Coccolo, S., Perera, A., Nik, V. M. & Scartezzini, J. (2019). A review of assessment methods for the urban environment and its energy sustainability to guarantee climate adaptation of future cities. Renewable and Sustainable *Energy Reviews, 112*, 733–746. https://doi.org/10.1016/j.rser.2019.06.005

Moore, J. (2015). Ecological Footprints and Lifestyle Archetypes: Exploring dimensions of consumption and the transformation needed to achieve urban sustainability. Sustainability, 7(4), 4747–4763. https://doi.org/10.3390/su7044747

Musolino, M., Maggio, G., D'Aleo, E. & Nicita, A. (2023). Three case studies to explore relevant features of emerging renewable energy communities in Italy*. Renewable Energy, 210*, 540–555. https://doi.org/10.1016/j.renene.2023.04.094

Natanian, J., Guarino, F., Manapragada, N., Magyari, A., Naboni, E., De Luca, F., Cellura, S., Brunetti, A. & Reith, A. (2024). Ten questions on tools and methods for positive energy districts. *Building and Environment, 255*, 111429. https://doi.org/10.1016/j.buildenv.2024.111429

Newton, P. & Newman, P. (2013). The Geography of Solar Photovoltaics (PV) and a new Low Carbon Urban Transition Theory*. Sustainability, 5* (6), 2537–2556. https://doi.org/10.3390/su5062537

Proedrou, F. (2023). EU Decarbonization under Geopolitical Pressure: Changing Paradigms and Implications for Energy and Climate Policy. *Sustainability, 15* (6), 5083. https://doi.org/10.3390/su15065083

Qin, Z., Yang, H., Shi, L., Ying, O. & Liu, W. (2024). Do smart city policies improve energy efficiency? Evidence from China. *Chinese Journal of Population Resources and Environment, 22* (2), 185–193. https://doi.org/10.1016/j.cjpre.2024.06.010

Sæle, H., Sperstad, I. B., Hoiem, K. W. & Mathiesen, V. (2023). Understanding barriers to utilising flexibility in operation and planning of the electricity distribution system – Classification frameworks with applications to Norway. *Energy Policy, 180*, 113618. https://doi.org/10.1016/j.enpol.2023.113618

Sassenou, L., Olivieri, L. & Olivieri, F. (2023). Challenges for positive energy districts deployment: A systematic review. *Renewable and Sustainable Energy Reviews, 191*, 114152. https://doi.org/10.1016/j.rser.2023.114152

Segales, M., Hewitt, R. J. & Slee, B. (2023). Social innovation and global citizenship: Guiding principles for sustainable, just and democratic energy transition in cities. *Energy Research & Social Science, 106*, 103295. https://doi.org/10.1016/j.erss.2023.103295

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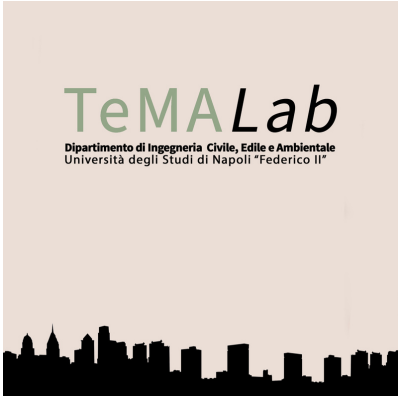

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REVIEW NOTES
Urban strategies, programmes and tools

Digitalization in urban planning: a framework to realize smart cities

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Abstract
Starting from the relationship between urban planning and mobility management, TeMA has gradually expanded the view of the covered topics, always remaining in the groove of rigorous scientific in-depth analysis. This section of the Journal, Review Notes, is the expression of continuously updating emerging topics concerning relationships between urban planning, mobility and environment, through a collection of short scientific papers written by young researchers. The Review Notes are made of four parts. Each section examines a specific aspect of the broader information storage within the main interests of TeMA Journal. In particular, the Urban strategies, programmers and tools section presents presents the different strategies and tools that guide the digitalization of urban planning.
The contribution explores how innovation is increasingly important in the current definition of urban planning processes. The policies and programs needed to support the transition towards smart cities, more efficient, sustainable and citizen-oriented, are outlined.
The analysis illustrates the key strategies and main programs implemented by the European Union and other International Organizations to promote the digital transformation of cities to make them "smart" and sustainable. Concrete examples are presented of cities that have successfully implemented these strategies, addressing challenges such as climate change and resource management, demonstrating how digitalization can create more liveable and resilient urban spaces.

Keywords
Smart cities; Sustainable; Urban strategies; Tecnologies; Digitalization.

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1. Policy framework to support smart cities

Digital transformation has been a priority for the European Union (EU) in recent decades, starting with the adoption in 2010 of a ten-year *Digital Agenda for Europe*, which identified for the first time the key enabling role of ICTs (Information and Communications Technology) in achieving Europe's economic and social goals. In 2020, a second five-year digital strategy, *Shaping Europe's digital future*, was adopted, which recognises how profoundly digital technologies are changing our lives and sets three main objectives up to 2025:

- technology at the service of people;
- a fair and competitive economy;
- an open, democratic and sustainable society.

In complementarity with the support for the digital transformation of cities and communities, EU financial support, including through the *Digital Europe Programme*, has supported the development of smart city initiatives (EC, 2023).

In particular, over the last decade, there has been an acceleration of digitalization and technology-based applications, Europe has witnessed a significant surge in smart city initiatives, reflecting a growing emphasis on harnessing data and innovative technologies to improve decision-making and citizen well-being. "These smart services can help to better manage resources like energy or water, to monitor and reduce local traffic and pollution or in the work towards greener ways to light and heat buildings. They can also mean a more interactive and responsive city administration, engagement and participation of citizens in decision and policy-making, safer public spaces and meeting the needs of an ageing population and people with disabilities" (EC, 2024a).

A smart city is an entity that uses ICTs effectively, to integrate the requirements of its urban community, in terms of energy and other utilities (production, distribution and use), environmental protection, mobility and transport, services for citizens (healthcare, education, emergency services, etc.) and with proper regard for security, both of individuals and their personal data, and use it as a driver for economic and social improvements. This would also increase the deployment of smart technologies and solutions in rural communities, contributing to the development of businesses and creating conditions for making smart communities attractive to the population (Rolling Plan for ICT standardisation, 2024).

The urban environment directly affects the quality of life of citizens. For this reason, it is essential to combat negative factors, such as traffic and polluting emissions, in order to transform cities into more liveable and attractive places, and new technologies can help in this transformation process.

The implementation of data spaces and digital twins at the local level emerges as an innovative approach with great potential for the development of smart cities. However, while the benefits of smart city projects are significant, public administrations face several challenges in implementing and managing these processes of change.

The European Commission defines smart cities as "a place where traditional networks and services are made more efficient with the use of digital solutions for the benefit of its inhabitants and business" (EC, 2025), where even the city administration is more interactive and responsive, public spaces are safer and the needs of its inhabitants are better met.

The European Commission is supporting the digital transformation of cities and communities through the development of various tools and services as well as the setup of community-based governance. An example of exchange of good practices started in 2019 with the *Living.in.eu movement*, founded by a group of city networks and other city representative groups (such as Open and Agile Smart Cities (OASC), Eurocities and European Network of Living Labs (ENoLL) (EC, 2023). It is a city-led collaborative platform for cities and communities to accelerate their citizen-centred digital transformation. It enables cities and regions to work together on societal challenges using digital, open and interoperable solutions.

Another European support tool is the *European Digital Infrastructure Consortium* (EDIC) a legal and policy tool designed to help Member States accelerate and simplify the setup and implementation of large-scale, multinational IT projects. The tool, for example, enables simulation and visualization of projects of urban planners that address real world challenges such as air pollution, congestion, energy grid optimization, water and waste management.

Among the services promoted by the European Commission, there is also *The Smart Communities Network*, a EU-wide community of organisations representing cities and municipalities from all 27 EU Member States that can support local communities in their early stages of digital transformation.

It aims to improve their connectivity and operational efficiency in urban governance in an increasingly digital world. The purpose of the Smart Communities Network is to facilitate collaboration among organisations, associations, and initiatives throughout the EU, with a shared goal of enhancing digital capabilities within local public authorities.

From the merger of two platforms, the "Marketplace of the European Innovation Partnership on Smart Cities and Communities (EIP-SCC Marketplace)" and the "Smart Cities Information System (SCIS)", "The Smart Cities Marketplace" was born, which aims to bring together cities, industries, investors, banks, researchers and many other smart city actors, developing common goals aimed at improving the quality of life of citizens, increasing the competitiveness of European cities and industry and achieving European energy and climate objectives (EC, 2025). The initiative, supported by the European Commission, supports cities of all sizes in the development of sustainable projects by providing free information, technical assistance, advice and matchmaking funding.

The Technical Support Instrument (TSI) is the EU programme that provides tailor-made technical expertise to EU Member States to design and to implement reforms at the national level, with an emphasis on the green and digital transitions. The TSI also supports the preparation and implementation of Recovery and Resilience Plans or National Smart Cities Strategies. Initiated in 2021, the TSI is the successor of the Structural Reform Support Programme (SRSP). Since 2017, both programmes have helped design, develop and implement over 1800 reform projects in 27 Member States.

In the context of EU multilevel governance, the European Commission in 2021 published the *Proposal for a European Interoperability Framework for Smart Cities and Communities* (EIF4SCC, 2021) establishing that interoperability is a prerequisite for electronic communication and information exchange between different actors and therefore is a necessary condition to achieve and further develop Smart Cities and Communities in Europe.

In response to urban challenges and the consequences of climate change that require an immediate transformation of urban and territorial planning strategies, EU encourages new approaches to research and innovation. EU Missions are a novelty of the Horizon Europe research and innovation programme for the years 2021-2027. Among the 5 missions scheduled there is "100 Climate-Neutral and Smart Cities by 2030".

The Cities Mission will engage local authorities, citizens, businesses, investors, regional and national authorities to achieve 100 smart and climate-neutral cities by 2030. At the same time, the Cities Mission ensures that these cities serve as hubs of experimentation and innovation to enable all European cities to follow suit by 2050. In total, 100 EU cities and 12 cities from Horizon Europe associated countries have been selected to participate in the mission in April 2022 and are currently testing innovative cross-sectoral approaches (EC, 2024b).

In the global panorama, there are numerous international initiatives and programs launched that actively contribute to the promotion and diffusion of smart cities.

The Organisation for Economic Co-operation and Development (OECD) is an international organisation plays an important role in promoting smart cities through research, analysis and policy formulation. In 2019, the OECD launched the *Smart Cities and Inclusive Growth Programme* to assess and measure the performance of

smart cities and how they contribute to inclusive growth and well-being. The programme analyses the potential of artificial intelligence (AI) and machine learning (ML) technologies to increase the ability of smart cities to anticipate people's needs and improve urban planning and management.

The *United for Smart Sustainable Cities* (U4SSC) initiative is a global UN collaboration, coordinated by the International Telecommunication Union (ITU), the United Nations Economic Commission for Europe (UNECE) and the United Nations Human Settlement Programme (UN-Habitat) and supported by 16 other UN agencies and programmes, to help cities and communities become smarter and more sustainable.

U4SSC is currently working on several thematic groups including (but not limited to) city platforms, lessons learned from building urban economic resilience at city level during and after COVID-19, artificial intelligence in cities, enabling people-centred cities through digital transformation, digital wellbeing, etc., accelerate digital transformation in cities and achieve the Sustainable Development Goals (SDGs) (Rolling Plan for ICT standardisation, 2024).

An international event that supports innovation and digitalization for a "better urban world" is the *Smart City Expo World Congress.*

Held in Barcelona since 2011, the Smart City Expo World Congress is the world's largest and most influential event for cities and urban innovation.

Each year, it brings together leaders from global businesses, governments and organizations to lead cities towards a better future with the aim of collectivizing urban innovation and enabling cities to address the critical challenges they face today.

2. Examples of smart and digital cities

Cities represent the core of human development, crucial engines of innovation, culture, and economic growth. Still, the quickening pace of city growth presents substantial difficulties in ensuring equitable provision of public services and safeguarding the quality of life within our urban landscapes.

In recent years, there has been growing global attention and effort for urban development, especially for the smart and sustainable transformation of cities, using digital technologies and innovative approaches to address growing challenges such as climate change, resource scarcity and urbanization pressures. Every city plays a crucial role in facilitating knowledge exchange and driving innovation, developing solutions and transformation paths towards smart and sustainable urban spaces.

Digitalization in urban planning is transforming the way cities are conceived and managed. Using data and digital technologies, we move from static to dynamic and interactive planning. Tools such as Geographic Information Systems (GIS), 3D models and simulations allow us to analyze future scenarios, optimize land use and predict the impact of new infrastructure. AI analyzes large amounts of data to identify patterns and trends, supporting evidence-based decisions.

The Internet of Things (IoT) connects sensors and devices, monitoring traffic, pollution and energy consumption. Digital apps and platforms improve communication between citizens and administration, facilitating civic participation.

Digitalization is opening up new perspectives for urban transformation, enabling the creation of smarter, more sustainable and citizen-oriented cities. Many are the measures and tools adopted by cities around the world to promote digitalization in urban organization and planning processes, in line with the national and international political guidelines of each country.

Below are some examples of strategies and tools adopted by some cities, European and non-European, to address urban challenges and at the same time exploit new technologies to create smarter and more sustainable cities.

Dìenmark – *Digital Growth Strategy 2025*

In 2019, the Government of Denmark introduced a "*National Artificial Intelligence Strategy Plan*", which aims to promote the development and integration of AI in Danish cities. This initiative not only identifies current challenges and priority areas for action but also defines the necessary policy instruments. The main goals of this strategy are:

- developing a common ethical and human-centred basis for AI;
- prioritising and support research in AI;
- encouraging the growth of Danish businesses by developing and using AI;
- ensuring that the public sector uses AI to offer world-class services for the benefits of inhabitants and society.

Denmark has also adopted the "*Digital Growth Strategy 2025*", which is a joint vision of the Danish government, in collaboration with various industries and sectors, trade associations and social partners, thus contributing to the digital transformation processes at the national level (U4SSC, 2024a).
Denmark's capital and most populous metropolis, Copenhagen, with approximately 1.5 million inhabitants, is committed to improving the quality of life of its citizens. To this end, the city has adopted a smart city model focused on carbon neutrality, aiming to create a more liveable and environmentally friendly urban environment. The AI adoption in the city of Copenhagen is largely governed by the National Strategy for AI. One of the projects initiated by the city of Copenhagen, for example, helps reduce energy consumption in buildings and ensure carbon savings. The project uses the ability of artificial intelligence to predict heating and ventilation requirements to enable monitoring of energy consumption and management of the indoor climate of buildings.

Vienna (AUSTRIA) – *Smart City Vienna Framework Strategy 2019 – 2050*

In June 2014, the Vienna City Council adopted the "*Smart City Vienna Framework Strategy*", which sets a cornerstone for the future development of the city. The Framework Strategy was further updated in 2019, building on existing strategic orientations and goals, and presents a long-term vision of the future, outlining perspectives up to 2050.
The target areas of the strategy include the radical conservation of resources, the contribution to the quality of life and social inclusion and the focus on innovation and digitalisation as central levers for sustainable development. Furthermore, new topics such as adaptation and management of the consequences of climate change, circular economy and consumption-based use of materials have been integrated (Smart City Wien, 2019).
The framework strategy outlines possibilities for achieving the objectives, but deliberately avoids concrete packages of measures, thus allowing for flexible ways of achieving them.
The mission of Smart City Vienna is to ensure a high quality of life for all Viennese while conserving resources through far-reaching social and technical innovations. A total of seven key objectives have been defined:

- quality of life;
- social inclusion;
- reduction of per capita greenhouse gas emissions;
- reduction of local final energy consumption per capita;
- careful and efficient use of resources;
- innovative capacity;
- digitalization.

PORTUGAL – *Action Plan for Digital Transition*

In April 2020, Portugal approved its "Action Plan for Digital Transition", acting under three pillars:

- Capacity Building and digital inclusion of people;
- Digital transformation of businesses;
- Digitalisation of public administration.

The European Commission supported the Portuguese authorities aiming to define the National Smart Cities Strategy, to foster the development of smart cities that provide people-centred, inclusive, sustainable and interoperable services to citizens and businesses -throughout the national territory.
Thanks to the European Funding Programme TSI (Technical Support Instrument), the project will establish a framework and a governance model for the common good, enabling the acceleration of innovation, optimising associated public expenditure and improving decision-making (National Smart Cities Strategy Factsheet Portugal, 2022).

Wyndham (MELBOURNE) – *Smart City Strategy 2019-2024*

Located in the outer western suburbs of metropolitan Melbourne, Wyndham is a city that is maximising the benefits associated with the use of technology, data and innovation to undertake a purposeful and planned transformation into a "smart city".
Wyndham City has already demonstrated commitment to its Smart City vision through several strategic documents, embodied by the "*Wyndham 2040 Community Plan*". This Smart City Strategy outlines approaches and priorities to citizen issues and local challenges, including issues around transportation and congestion, the environment and more generally how the city functions and operates. The "Smart City Strategy 2019-2024" and "Smart City Implementation Plan" expand on this and highlights the prioritisation placed on the future of transport, environmental challenges and driving modern local services.
In consultation with the community, key stakeholders, elected officials and staff, six strategic themes, supported by priority actions, have been identified to guide the City's efforts to meet smart city needs (Transport, Environment and Sustainability, Data Driven, Partnership and Collaboration, Citizen-Centric).
In its journey to becoming a smart city, the city has embraced technology and innovation by implementing them in many innovative projects including the creation of "Smart Parking", the implementation of "Smart Sensors", or the creation of "Smart Co-working Hubs". The city is looking to the future and preparing to use innovation to solidify its transformation into a smart city, such as by placing "Smart Traffic Lights" to reduce congestion and regulate traffic flow in real time and in response to actual demand. The city also plans to pilot "Urban ('Living') Labs" to understand impacts, test policies, drive economic growth and achieve better outcomes for the city (Smart City Strategy 2019-2024).
The City of Wyndham's planning and delivery of projects also integrates the principle of "20-minute neighbourhoods" promoted by Plan Melbourne 2017-2050, aiming to connect people locally within 20 minutes of walking, cycling or public transport to key services.

Hong Kong (CHINA) – "*Smart City Blueprint" plan*

Hong Kong, a major global financial hub and a special administrative region of China, established a strategic plan in 2017, the "Smart City Blueprint for Hong Kong", to build Smart Mobility, Smart Living, Smart Environment, Smart People, Smart Government and Smart Economy.
Hong Kong has integrated AI as a key tool in its smart city strategy, using it to address critical issues such as climate change, population aging and urban management.
The initiatives launched aim to bring benefits and convenience to the public, so that residents can better experience the benefits of smart cities and innovation and technology (I&T) in their daily lives. For example, AI implementations installed in the city include sensor networks for energy monitoring and disaster preparedness. These facilities have also been used to improve the safety of seniors and provide continuous community connections. Additionally, the city is experimenting with robotic assistance and is using AI for more participatory governance and better traffic management (U4SSC, 2024b).
Furthermore, to facilitate the healthy development and use of AI in Hong Kong, several government departments and independent organizations have formulated and launched guiding principles for AI. For example, The Office of the Privacy Commissioner for Personal Data (PCPD) has issued "The Guidance on Ethical Development and Use of AI" in August 2021. Another adoption of the city was "The Ethical AI Framework" providing guidance to IT planners, system analysts, system architects and data scientists to understand the ethical principles and practices of AI.

3. Conclusion

In recent decades, cities have been trying to respond and combat growing urban governance challenges, including but not limited to economic inclusiveness, increasing resource consumption, environmental deterioration, seamless and convenient mobility, increasing housing needs, new physical infrastructure, and city resilience.
In this context, digitalization and the use of AI represent frontier technologies that can be leveraged in decision-making processes to help address the various urban challenges that cities around the world experience. These technologies, leveraging advanced algorithms and citizen data analysis, enable the automation of decision-making processes at a speed and scale previously unimaginable.

Anyway, to build smart cities, it is not possible to simply implement new technologies, as has often happened in the past, but it is necessary to build a regulatory framework that takes into account the pre-existing technological context in the territory and in society.

City management, planning and the creation of liveable communities are at the threshold of a new age led by the adoption of new technologies and the use of advanced data analytics to improve operations, decision making and services. However, like all new technologies, they bring risks and pitfalls, which is why the successful implementation of AI must ensure parallel efforts and compliance with certain principles, for example, in terms of compliance with laws and regulations, or full compliance with the regulatory framework on data privacy in force at national or supranational level, or the guarantee of better security, explainability and transparency of the mechanisms. Only in this way can planning be done effectively, ensuring reliability and trust.

Comprehensive digitalization permeates all areas of life. This raises many new questions, such as the transparent and careful handling of large amounts of data, the ethical and moral limits of using digital achievements such as artificial intelligence, and the distribution of opportunities and benefits of new technologies. Nevertheless, it is essential to highlight how digital technologies offer new tools to find innovative solutions to many future urban problems, create new opportunities for participation, or simply make life more pleasant.

City administrators have a wide range of tools at their disposal to encourage and incentivize the implementation of digitalization in urban planning processes. Knowledge exchange at local, regional and international levels will help to further develop these new technologies to create more competitive, resilient and smart cities.

References

EC (2023). D06.02 In-depth report of organisational and cultural interoperability issues and practices in place within public administrations related to the four use cases. Retrieved from: https://interoperable-europe.ec.europa.eu/sites/default/files/inline-files/In-depth%20report%20on%20organisational%20and%20cultural%20interoperability%20issues%20and%20practices%20in%20place%20within%20public%20administrations_vFINAL.pdf

EC (2024a). *Smart Cities and Communities.* Retrieved from: https://digital-strategy.ec.europa.eu/en/ policies/smart-cities-and-communities

EC (2024b). *EU missions – 100 climate-neutral and smart cities.* European Commission: Directorate-General for Research and Innovation. Publications Office of the European Union. https://data.europa.eu/doi/10.2777/85010

EC (2025). *Smart cities.* Retrieved from: https://commission.europa.eu/eu-regional-and-urban-development/topics/cities-and-urban-development/city-initiatives/smart-cities_en

EIF4SCC (2021). Proposal for a European Interoperability Framework for Smart Cities and Communities. Publications Office of the European Union. https://data.europa.eu/doi/10.2799/816559

National Smart Cities Strategy Factsheet Portugal (2022). *National Smart Cities Strategy*. Retrieved from: https://reform-support.ec.europa.eu/publications-0/national-smart-cities-strategy-factsheet-portugal_en

Rolling Plan for ICT standardisation (2024). *Smart and sustainable cities and communities (RP2024).* Retrieved from: https://interoperable-europe.ec.europa.eu/collection/rolling-plan-ict-standardisation/smart-and-sustainable-cities-and-communities-rp2024

Smart City Wien (2019). *Smart City Wien Rahmenstrategie 2019–2050. Die Wiener Strategie für eine nachhaltige Entwicklung.* ISBN 978-3-903003-52-1 Retrieved from: https://smartcity.wien.gv.at/wp-content/uploads/sites/ 3/2019/10/Smart-City-Wien-Rahmenstrategie-2019-2050.pdf

U4SSC (2024a). *Copenhagen, Denmark. Case study of the U4SSC Guiding principles for artificial intelligence in cities.* ISBN 978-92-61-38131-8 Retrieved from: https://u4ssc.itu.int/publications/

U4SSC (2024b). *Hong Kong, China. Case study of the U4SSC Guiding principles for artificial intelligence in cities.* ISBN 978-92-61-38111-0 Retrieved from: https://u4ssc.itu.int/publications/

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REVIEW NOTES
Urban Practices

Competitive climate adaptation. Italian startups leading the way to climate change adaptation in cities

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Abstract
Starting from the relationship between urban planning and mobility management, TeMA has gradually expanded the view of the covered topics, always remaining in the groove of rigorous scientific in-depth analysis. This section of the Journal, Review Notes, is the expression of continuously updating emerging topics concerning relationships between urban planning, mobility and environment, through a collection of short scientific papers written by young researchers. The Review Notes are made of five parts. Each section examines a specific aspect of the broader information storage within the main interests of TeMA Journal. In particular, the Urban Practices section aims at presenting recent advancements on relevant topics that underline the challenges that the cities have to face.
This note provides an overview of the role that innovative climate startups can play in fostering climate adaptation in cities while promoting urban competitiveness, and the strategic support that these entities can provide in managing urban and territorial transformations. The nature of these entities and the role they can play in the governance of urban transformation is outlined, and a brief review of Italian cases is carried out. Finally, the results are discussed, highlighting the potential that these economic constructions have in urban climate adaptation and urban competitiveness, but also the challenges they face. Three significant case studies of startups promoting climate adaptation in urban areas are presented, showing the relevance of the topic and its potential role in the urban adaptation discussion.

Keywords
Climate change; Adaptation; Urban practices; Competitiveness; Climate startups.

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1. Introduction

The Intergovernmental Panel on Climate Change's sixth Assessment Report states it clearly: without proper adaptation strategies, some regions and natural systems could reach unrecoverable states of alteration and degradation, the so-called tipping points (IPCC, 2021). The reaching of these critical thresholds within the Earth's climate system can trigger large-scale, irreversible changes in key Earth system elements (ocean currents, glaciers, forests, ecosystems, etc.) critically impacting natural and human systems, posing a risk to communities around the world (Lenton et al., 2019).

Despite the widespread awareness of these global risks, adaptation goals are still far from being met. To cite some data, the UNEP Adaptation Gap Report 2023 reports that financial needs for adaptation in developing countries are 10 to 18 times greater than current international public financial flows (UNEP, 2023), highlighting the significant imbalance between funding needs for climate change adaptation and the funds actually available. Moreover, according to the report "Global Landscape of Climate Finance 2024" published by the Climate Policy Initiative (CPI), most global financial flows for climate are aimed at mitigation (89%) while only 5% targeted adaptation (CPI, 2024), illustrating its lower priority.

The disparity in the availability of funding for mitigation and adaptation stems from the fact that, over the years, mitigation strategies have given rise to actual markets. Technologies such as electric or hybrid vehicles, renewable energy systems, and even CO_2 emissions—through mechanisms like carbon emissions trading—have become tradable assets with tangible economic value. In contrast, adaptation measures are often perceived as riskier investments, as they typically lack clear revenue streams and offer limited short-term financial returns, making them less attractive to private investors.

In this context, there is a growing need to diversify and expand funding sources for climate adaptation. This could be achieved either through the establishment of new international financial instruments or by fostering the development of a market for adaptation-related solutions, which could help mobilize private sector investments. Encouraging private finance for adaptation is particularly urgent given the persistent gap in public funding. As the UNEP notes, "there is an urgent need to scale up adaptation finance from both public and private sources to meet growing climate risks" (UNEP, 2023). Similarly, the OECD emphasizes the importance of creating enabling environments for private investment in adaptation, including through blended finance and risk-sharing mechanisms (OECD, 2023).

A crucial dimension of the concept of adaptation, by its definition, is that it can drive transformative shifts in social and economic systems, besides merely reducing potential physical damages. It can enable climate-resilient development by addressing structural vulnerabilities and creating new opportunities (IPCC, 2021), and it can spur innovation and economic diversification (OECD, 2023).

The transformative potential of climate change adaptation inherently links it to processes of research, innovation, and economic growth, positioning it as a key paradigm for fostering the resilient development of urban systems. Notably, the concept of adaptation closely aligns with that of urban competitiveness, a multidimensional concept which has been defined as "the ability of a city to meet future challenges" (Sgambati & Gargiulo, 2022), with climate change representing one of the most pressing among them.

Contemporary challenges and uncertainties expose cities and local communities to multiple and non-linear risk factors that require a spatial planning approach to integrate the dimensions of complexity and unpredictability. To address the complexity and multidimensionality of today's challenges, it is essential to adopt a systemic approach, conceiving cities as complex systems formed by a set of elements and the relationships between them that define their organization.

Addressing climate change requires indeed rethinking urban systems in their physical, social, and economic dimensions. This involves not only reducing vulnerabilities, but also turning threats into opportunities, redirecting climate investments as catalysts for resilient urban growth and enhanced quality of life for citizens.

2. Competitiveness and climate adaptation: the role of startups

In the context of urban climate adaptation, startups emerge as agile and innovative actors capable of accelerating the transformation of urban systems toward greater resilience and competitiveness.

Broadly defined, startups are newly established, innovation-driven companies that aim to scale rapidly by offering disruptive solutions, often leveraging technology and novel business models (Blank & Dorf, 2020). Their flexibility, risk-taking capacity, and ability to prototype and iterate solutions at high speed make them particularly well-suited to respond to complex and evolving challenges such as those posed by climate change. In urban adaptation, startups can play a crucial role by developing nature-based solutions, climate risk analytics, early warning systems, or resilient infrastructure technologies.

They can help translate scientific knowledge into scalable solutions, foster public-private collaboration, and unlock new investment channels for adaptation, including through green fintech, insurtech, or adaptive urban planning tools.

Moreover, by embedding adaptation into market logic, startups can create new economic opportunities, enhance urban competitiveness, and support a shift from reactive to proactive strategies. In this sense, they act as catalysts of both climate resilience and economic regeneration, particularly in cities seeking to position themselves as innovation hubs.

According to the OECD (Koirala, 2019), fostering startup ecosystems aligned with climate goals is key to "stimulating inclusive and sustainable growth while addressing climate vulnerabilities". Also in the European context, startups are increasingly being recognized and included in EU policy frameworks – such as the New European Innovation Agenda – as strategic actors in advancing the twin green and digital transitions, including the adaptation dimension. The transition of cities is a top priority in academy and policy.

Startups are thus being recognized worldwide as a powerful alternative to innovate the economic landscape while confronting the world's biggest challenges, and this evolution is supported by data. According to the MIT Technology Review, investment in this area exceeded $70 billion in 2023, a 50% increase over the previous year. Analysis by the company PwC shows that in the first three quarters of 2024 about 28% of climate tech deals supported startups working on adaptation and resilience (A&R) offerings (Baber, 2024).

Italy is also keeping pace with the growth of investment in climate tech startups. Research conducted by Net Zero Insights reports that €241 million were invested in climate tech startups in Italy in 2023, and equity investment in the sector increased from €79 million in 2022 to €215 million in 2023 (Buratti, 2024).

For both climate techs dedicated to mitigation and adaptation technologies, the impact of the solutions is strongly projected on the territory and in urban systems. From the implementation of renewable energy, energy efficiency in buildings, transportation and sustainable mobility to the use of AI for disaster risk reduction, water resource management, or climate monitoring and data analysis, all topics of interest have a direct impact on land use, the implementation of urban structures and infrastructures, and the organization and monitoring of urban data. The strong alignment between the innovation agenda of climate startups and the core priorities of the digital and ecological transition in urban systems positions territorial-impact startups as key players in current debates on urban adaptation and competitiveness.

3. Italian climate tech startups, a review

Along with many of the world's industrialized countries, Italy is also keeping up with investment in climate techs. Research by Medium reported the existence of about 350 climate tech startups active in Italy in 2023, 2.5% of the total (14,000), a lower-than-average number but still significant for the size of the country.

All Italian regions see the presence of climate tech startups, but with a clear prevalence in Lombardy, followed by Lazio and Piedmont, confirming Milan, Rome and Turin as the core hubs of the Italian climate tech ecosystem, representing 37.1% of the total climate tech startups. The geographic distribution of climate tech startups does not directly reflect the geographic distribution of funds, with Lombardy always in first place,

Piedmont second, Emilia-Romagna third, Trentino-Alto Adige fourth, and only Lazio fifth (Massa & Cuppoloni, 2023).

Most relevant to the parallelism with climate change adaptation and the governance of urban and land transformation are the sectors identified by Massa and Cuppoloni as among the most addressed by Italian climate tech startups:

- Agriculture, Forestry & Food;
- Energy;
- Manufacturing & Industry;
- Transportation & Mobility;
- Water, Waste & Remediation;
- Construction & Real Estate;
- Carbon Neutrality;
- Climate Monitoring.

The identification of these categories of action is of great interest to the discourse on climate change adaptation in Italy, given the climate risks to which the Mediterranean peninsula is most susceptible to. Beyond the more traditional key sectors for mitigation, such as energy and mobility, we find startups focused on the theme of Water Management, a crucial issue in Italy due to both the threat posed by flood risk and drought risk, also recalled by the Agriculture, Forestry & Food category. The Construction & Real Estate sector also incorporates a reflection on the built environment, the need to update it in design, integrated technologies, and resilience shown in response to extreme weather phenomena. Emerging as a major theme in both the literature and technology solutions developed for the construction market are Nature-Based Solutions, technologies and actions that harness natural green or blue elements and ecosystem services to increase the capacity of urban areas to respond to the effects of climate change.

In addition, although last in terms of spread, the Climate Monitoring category stands out. To support planners in enhancing sustainable urban land use planning, there is a need to understand how human impacts may affect urban land cover (Dinç & Gül, 2021).

Therefore, innovative sensor technologies, monitoring, drones, satellite modeling, and the use of AI, among others, are cutting-edge technologies critical to refining the ability to analyze climate risk on the ground, and to prepare appropriate responses in the necessary timeframe.

The interest of venture capitals, funds, and investors in supporting these innovative economic entities working on issues of absolute priority for climate change adaptation is an aspect of strong potential to increase funds and efforts to adapt urban systems to the challenges of climate change and should be given more attention by institutions that are materially involved in promoting adaptation on the ground nationwide.

To provide an example of the spatial impact that some of these climate tech startups have on urban systems, 3 italian startups that promote urban climate change adaptation practices were selected as case studies. These address in a systemic way several of the "hottest" issues in terms of adaptation to climate change in urban areas, including two of the most prominent at the European and global level: temperature extremes and urban flooding.

The first case study is an exemplary case of using the latest AI, machine learning and satellite imagery technologies to spatially map climate hazards and provide public administrations with a detailed reference for urban planning. This startup's work takes climate monitoring a step further by integrating analyses related to various climate indices, from air pollution to the heat island phenomenon, with the ultimate goal of effectively implementing Nature-Based Solutions and green areas in an integrated way to reduce emissions, improve air quality, and make urban environments healthier and more resilient.

The second startup presented aims to address, with the most advanced technology available, one of the central climate risks for the Italian peninsula: urban, coastal, and riverine flooding. The startup integrates

geospatial, satellite, climate data and AI-based models into a cloud computing environment providing highly accurate and precise simulations of flooding phenomena in urban, river and coastal areas. These models are then used to provide technical support to administrations, as was done in the collaboration with the Metropolitan City of Venice to map the risk of urban flooding.

The last case study combines reforestation and reduction of atmospheric CO_2, with climate change adaptation in terms of crops and soil resilience to drought and hydrogeological disruption of soils. While implementing this territorial resilience transformation, the startup pursues a parallel social goal, involving social communities in the reforestation projects and reintegrating in the working environment individuals who are in vulnerable situations.

1.1 Latitudo 40. Identify risks, support decisions

Latitudo40 is an Italian innovative startup based in Naples that develops urban environmental monitoring solutions by integrating satellite data, artificial intelligence, and predictive modeling.

The company's core mission is to support cities, public authorities, and private organizations in understanding and managing the impacts of climate change at the urban scale, providing tools for sustainable and resilient planning. Through a proprietary platform, Latitudo 40 processes high-resolution satellite imagery and geospatial data, combining them with machine learning models to generate dynamic environmental indicators, including impervious surface extent, vegetation indexes, urban heat islands, and localized climate risk. Their technology enables temporal analysis of urban areas, continuously mapping how territorial and climatic changes affect buildings, infrastructure, and populations. Latitudo 40's data-driven approach is designed to inform strategic decision-making by local governments and to foster effective interventions for climate adaptation, urban regeneration, and ecological transition, in line with the objectives of the 2030 Agenda and the European Green Deal. Among its key projects are collaborations with Italian and European cities such as Turin, Helsinki, and Barcelona, within smart city and urban sustainability initiatives.

One of its most relevant contributions to climate resilience and urban innovation is the project Urban EVOLUTION (Earth obserVatiOn and nature-based soLUTions agaInst urban pollution), a multidisciplinary research initiative addressing critical urban environmental challenges such as air pollution and the urban heat island effect. The project leverages cutting-edge remote sensing technologies, artificial intelligence, and Nature-Based Solutions (NBS) to assess pollution levels and evaluate the effectiveness of ecological interventions in mitigating CO_2 emissions, particulate matter (PM), and temperature rise. Piloted in Naples, Catania, and Perugia—three Italian cities characterized by diverse urban morphologies and climatic conditions—Urban EVOLUTION aims to develop scalable, adaptable models tailored to Mediterranean urban environments and applicable globally. Through a multi-stakeholder, 12-month collaborative framework involving universities, research institutions, and public authorities, the project supports data-informed policymaking for sustainable land use and urban planning. Urban EVOLUTION is aligned with the Paris Agreement's targets, aiming to reduce emissions by 50% by 2030 and reach climate neutrality by 2050, emphasizing the strategic potential of urban green spaces to offset up to 40% of emissions and improve air quality. Latitudo 40's advanced geospatial analytics are central to translating environmental data into actionable insights, thereby enhancing cities' capacities to design healthier, more resilient urban ecosystems.

Startup page: https://www.latitudo40.com/

Project's page "Urban EVOLUTION": https://www.latitudo40.com/uses-cases/urban-evolution

1.2 SaferPlaces: Global Platform. AI-based Digital Twin Solution for Flood Risk Intelligence

SaferPlaces is an Italian climate-tech startup specializing in flood risk assessment and climate adaptation planning through the integration of Earth observation, hydrological modeling, and artificial intelligence. The company was established with the goal of making high-resolution flood risk intelligence accessible and actionable for public administrations, urban planners, and infrastructure managers. Their flagship solution is a cloud-based platform that provides rapid, cost-effective simulations of pluvial, fluvial, and coastal flooding under current and future climate scenarios. Designed to align with the principles of the EU Floods Directive and the Paris Agreement, SaferPlaces empowers local authorities to design resilient, data-driven adaptation strategies and infrastructure interventions.

By leveraging satellite imagery, digital elevation models, and local land use data, the platform can map hazard exposure at the parcel level, helping cities identify vulnerable assets and prioritize green and grey infrastructure responses.

One of SaferPlaces' most notable case studies is its collaboration with the city of Venice, a globally recognized urban center facing increasing risk from both sea level rise and extreme rainfall events. In this context, SaferPlaces supported local authorities by modeling multiple flooding scenarios to evaluate the effectiveness of planned and existing protection measures. The platform's simulations incorporated tidal dynamics, rainfall patterns, and storm surge projections to provide a comprehensive picture of the city's vulnerability. The results informed updates to emergency planning protocols and long-term urban development strategies, especially in critical areas such as the historic city center and the surrounding lagoon. This case exemplifies SaferPlaces' capacity to provide tailored, location-specific insights that are essential for heritage cities exposed to complex climate threats.

Startup page: https://saferplaces.co/

Project's page "SaferPlaces Helps the Metropolitan City of Venice to Fight Pluvial Flooding": https://saferplaces.co/saferplaces-helping-the-metropolitan-city-of-venice-to-fight-pluvial-flooding/

1.3 ZeroCO2. Fighting the climate crisis with high social impact reforestation

ZeroCO2 began as an Italian social and environmental impact startup, founded with the aim of fighting climate change through reforestation with high social impact.

Founded in 2019, the company started by operating mainly in Latin America (Guatemala in particular), and then expanded its activities to Peru, Argentina, Tanzania and Italy.

Their business idea combines:

- Environmental sustainability: they plant trees to offset CO_2 emissions.
- Social impact: they collaborate with local communities, farmers and social cooperatives.
- Innovation: they use tree tracking technologies and make the process of growth, location and impact transparent.

From a socially focused innovative startup (SIAVS), it is now a certified B Corp Benefit Society developing natural solutions to address climate change, protect ecosystems and support rural communities.
In Italy, the company is carrying out the project "Italy resisting climate change." Active in all regions of Italy, the initiative works with more than 45 social agricultural cooperatives, educational farms, and agribusinesses to promote reforestation projects based on sustainable agricultural practices that incentivize social support. Key objectives include educating people about sustainable agriculture, improving the resilience of soils and crops, and supporting local communities by promoting job placement for socially disadvantaged individuals. In fact, social agriculture projects deal with sociotherapy, rehabilitation, housing, and work integration to promote social agriculture at the local level, generating welfare for territorial communities and the Italian social fabric.
Moreover, to pursue the main goal to fight climate change, zeroCO2 promotes the sustainable management of Italian lands and forests to preserve existing ecosystems. Their tree planting projects improve soil quality, absorb CO_2, and provide habitats for local wildlife. Collaborating with agricultural cooperatives across Italy, the organization implements solutions to combat desertification, drought, and hydrogeological instability. Rather than reforestation, zeroCO2 focuses on making land more climate-resilient and empowering local communities through low-impact, sustainable farming practices that help conserve biodiversity and mitigate climate change.

Startup page: https://zeroco2.eco/it/

Project's page "Italy Resisting Climate Change": https://zeroco2.eco/it/progetti/supporto-alle-cooperative-agricole-sociali-in-italia/

4. Considerations from case studies

With each fraction of a degree of temperature increase, the effects and consequences of climate change become more intense and dramatic (IPCC, 2021). The answer to impending climate risks is adaptation to climate change, and increasing the resilience of physical, economic, and social systems (IPCC, 2022). Building resilience to contain the risks for inhabitants, businesses and infrastructures deriving from the impact of climate change represents a challenge for local planners and public decision-makers.
To make this transformation viable, optimizing investments that directly impact cities, engaging diverse social and economic actors, and promoting technologically innovative solutions is of utmost importance.
In this multi-stakeholder scenario, examples of organizations that carry out business activities with the objective of developing, producing, and commercializing innovative products or services, such as innovative startups, assume a strategic role. These economic organizations, given their strong vocation toward innovation, often start from groups of young students, researchers or innovators, catalyzing the potential of young minds and creating value on the territory, revealing themselves as powerful tools for cultivating social capital locally. Furthermore, the territorial impact that some startups have makes them a potential tool to support public administrations in making the challenges posed by urban planning more effective and smarter and suggests possible citywide implementation of these cooperations.
The three case studies—ZeroCO_2, Latitudo 40, and SaferPlaces—illustrate the diverse and complementary roles that climate-oriented startups can play in enhancing urban resilience to climate change.
ZeroCO_2 exemplifies how nature-based solutions and socially inclusive afforestation projects can contribute to local ecosystem restoration while engaging communities in adaptive land management. Latitudo 40 demonstrates the power of geospatial intelligence and AI in monitoring environmental dynamics and guiding urban greening interventions, as showcased by their Urban EVOLUTION initiative. Meanwhile, SaferPlaces provides a data-driven approach to flood risk assessment, offering crucial support to municipalities like Venice

in managing climate-related hazards.Together, these startups highlight how technological innovation, environmental insight, and participatory planning can intersect to support climate adaptation at the city scale. Their contributions underscore the importance of integrating flexible, scalable solutions into urban planning processes, particularly in Mediterranean and climate-vulnerable regions. As local governments strive to meet adaptation goals, partnerships with such innovation-driven actors can help bridge data gaps, accelerate implementation, and promote more adaptive and inclusive planning frameworks.

References

Agricoltura sostenibile in Italia: scopri il progetto | ZeroCO2. (2024). zeroCO2. Retrieved from: https://zeroco2.eco/it/progetti/ supporto-alle-cooperative-agricole-sociali-in-italia/

Baber, L. (2024). *State of Climate Tech 2024*. PwC. https://www.pwc.com/gx/en/issues/esg/climate-tech-investment-adaptation-ai.html

Blank, S. & Dorf, B. (2020). *The startup Owner's manual: The Step-By-Step Guide for Building a Great Company*. John Wiley & Sons.

Buratti, C. (2024). Quanto si investe in startup di climate tech in Italia? *StartupItalia*. https://startupitalia.eu/economy/quanto-si-investe-in-startup-di-climate-tech-in-italia/

Climate Policy Initiative (CPI). (2024). *Global Landscape of Climate Finance 2024: Insights for COP 29*. Retrieved from: climatepolicyinitiative.org/publication/global-landscape-of-climate-finance-2024

IPCC (2021). *Climate change 2021: The physical science basis*. In V. Masson-Delmotte et al. (Eds.), *Sixth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press. https://doi.org/10.1017/9781009157896

IPCC. (2022). *Climate change 2022: Impacts, adaptation and vulnerability*. In H.-O. Pörtner et al. (Eds.), *Sixth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press. Retrieved from: https://www.ipcc.ch/report/ar6/wg2/

Koirala, S. (2019), "SMEs: Key drivers of green and inclusive growth", *OECD Green Growth Papers*, No. 2019/03, OECD Publishing, Paris, https://doi.org/10.1787/8a51fc0c-en.

Latitudo 40. (n.d.). *Empower Sustainable Growth with AI-Driven Satellite Insights*. Latitudo 40. Retrieved from: https://www.latitudo40.com/

Latitudo40. (n.d.). *Urban evolution - Use cases*. Retrieved from: https://www.latitudo40.com/uses-cases/urban-evolution

Lenton, T. M., Rockström, J., Gaffney, O., Rahmstorf, S., Richardson, K., Steffen, W. & Schellnhuber, H. J. (2019). Climate tipping points — too risky to bet against. *Nature*, *575*(7784), 592–595. https://doi.org/10.1038/d41586-019-03595-0

Massa, L. & Cuppoloni, F. (2023). State of Italian Climate Tech Startups. *Medium*. Retrieved from: https://medium.com/%40italianclimatetech/state-of-italian-climate-tech-d3ca23fccdfb

OECD (2023), *Scaling Up the Mobilisation of Private Finance for Climate Action in Developing Countries: Challenges and Opportunities for International Providers*. OECD Publishing. https://doi.org/10.1787/17a88681-en.

SaferPlaces. (2024). *SaferPlaces helps the metropolitan city of Venice to fight pluvial flooding*. SaferPlaces. https://saferplaces.co/saferplaces-helping-the-metropolitan-city-of-venice-to-fight-pluvial-flooding/

SaferPlaces (2025). *SaferPlaces Global Platform — AI-based digital twin solution for flood risk intelligence*. Retrieved from: https://saferplaces.co/

Sgambati, S., & Gargiulo, C. (2022). The evolution of urban competitiveness studies over the past 30 years. A bibliometric analysis. *Cities*, *128*, 103811. https://doi.org/10.1016/j.cities.2022.103811

United Nations Environment Programme (UNEP) (2023). *Adaptation Gap Report 2023: Underfinanced. Underprepared. Inadequate investment and planning on climate adaptation leaves world exposed.* UNEP. https://doi.org/10.59117/20.500.11822/43796

zeroCO2 (2024). *zeroCO2 - Progetti sostenibili e ambientali per aziende & privati*. Retrieved from: https://zeroco2.eco/it/

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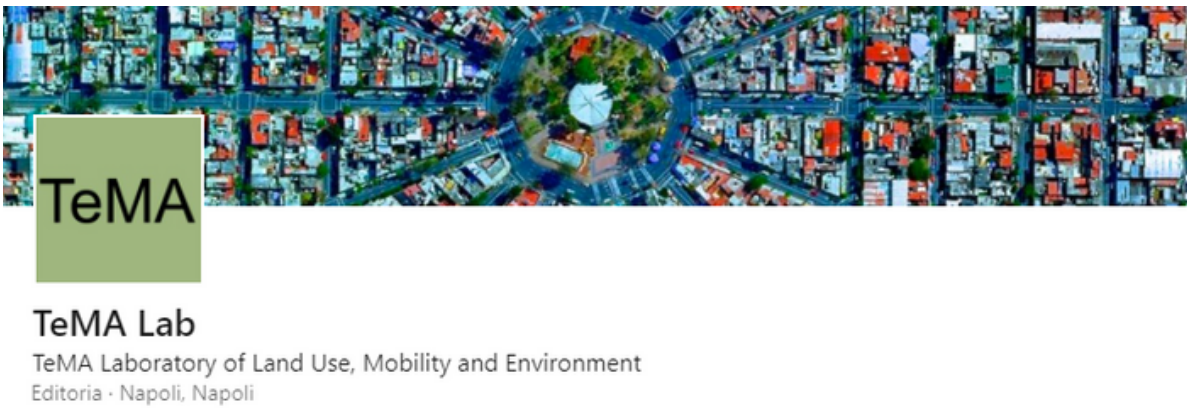

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REVIEW NOTES
Urban planning literature review

Exploring open and green space characteristics for climate change adaptation: a focus on the urban heat island

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Abstract
Starting from the relationship between urban planning and mobility management, TeMA has gradually expanded the view of the covered topics, always remaining in the groove of rigorous scientific in-depth analysis. This section of the Journal, Review Notes, is the expression of continuously updating emerging topics concerning relationships between urban planning, mobility, and environment, through a collection of short scientific papers written by young researchers. The Review Notes are made of five parts. Each section examines a specific aspect of the broader information storage within the main interests of TeMA Journal. In particular, the Urban planning literature review section presents recent books and journals on selected topics and issues within the global scientific panorama.
For the first issue of TeMA Journal volume no. 18, this section provides a comprehensive overview of the challenges and solutions related to the role of open and green spaces in climate change adaptation, with particular attention to the urban heat island effect. Using a variety of scientific sources and practical resources, this contribution aims to identify the key characteristics of these spaces that can influence adaptation strategies, examining the solutions proposed in the scientific literature, specifically in books, journals, and reports.

Keywords
Green Spaces; Open Spaces; Literature review; UHI.

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1. Introduction

The urban heat island (UHI) effect represents one of the most critical environmental challenges for contemporary cities (Bouketta, 2023), it results from heat accumulation in built areas due to dense urban morphology, high levels of impervious surfaces and human activities that alter the local climate (Bai et al, 2024). Rising global temperatures due to climate change increase this phenomenon, leading to raise energy consumption, health risks and a reduction in the quality of life for urban populations (Wang et al, 2022), so adapting to the UHI effect requires targeted strategies, in particular through the integration of open and green spaces in urban areas. Vegetation plays a crucial role in reducing temperatures through processes such as evapotranspiration and shading, which lower surface and air temperatures (Bowler et al., 2010); while green spaces, such as parks and tree corridors, are widely recognized for their cooling benefits, open spaces, including squares, parking areas and other built environments, play a crucial role in promoting urban climate resilience (Carpentieri et al., 2023). The use of reflective surfaces, permeable pavements, and shaded structures can enhance their cooling potential and complement the benefits of green infrastructure (Schmid et al., 2021). This persistent heat accumulation contributes to thermal discomfort and poses significant health risks, particularly for vulnerable populations such as the elderly, children, and individuals with pre-existing health conditions (Harlan et al., 2006). Additionally, the presence of water bodies within urban environments amplifies cooling effects by enhancing latent heat flux and evapotranspiration processes (Zhang et al., 2022). Given the complexity of urban heat dynamics, effective UHI mitigation strategies must integrate a mix of green and open spaces tailored to the specific climatic and morphological characteristics of each city (Gargiulo & Zucaro, 2023). The role of urban governance in implementing these strategies is essential, as it determines the spatial configuration and accessibility of cooling areas, ensuring equitable benefits for all residents (Gunawardena et al., 2017). Therefore this study want to explore how different characteristics of open and green spaces contribute to climate adaptation, drawing on scientific studies that assess their effectiveness in mitigating the UHI.

2. Agreements and strategies developed at international level

Various international policies and agreements recognize the importance of green and open spaces in climate adaptation strategies, for example the European Green Deal and the EU Green Infrastructure Strategy promote nature-based solutions to create climate-resilient cities. At the global level, the Paris Agreement and the United Nations Sustainable Development Goals (particularly SDG 11: Sustainable Cities and Communities) emphasize the need to integrate urban green spaces into climate policies (Gargiulo & Zucaro, 2020).

At regional and municipal levels, many cities have implemented specific regulations to promote urban greening, mandate green roofs, and protect open spaces. The European Commission has launched initiatives encouraging Member States to develop green infrastructure projects that mitigate the urban heat island (UHI) effect and enhance overall urban resilience and, additionally, innovative urban planning strategies are incorporating new technologies to optimize green space management, ensuring long-term environmental and social benefits. Green spaces contribute not only to climate adaptation but also to biodiversity conservation, improved air quality, and enhanced public health, reinforcing their essential role in sustainable urban development.

3. Morphological characteristics of open spaces and their role in UHI adaptation

In contemporary urban governance management, there is a growing shift towards a holistic perspective of urban systems, which emphasizes adaptation to the impacts of climate change. This approach emphasizes the need to understand the complex interactions between urban components and their responses to environmental

challenges, both expected and unexpected (Carpentieri et al., 2024). A key aspect of this discourse is the role of open spaces, their morphology and their impact on urban heat island (UHI) adaptation, infact the research shows that green infrastructure, such as tree cover, vegetation and water bodies, play a critical role in adapting to UHI effects by reducing surface and air temperatures through shading and evapotranspiration (Bouketta, 2023). The presence of greenery within urban open spaces contributes to the creation of urban cooling effects, which provide optimal thermal comfort to pedestrians (Bouketta, 2023; Wang & Gou, 2024) and the cooling potential of these spaces depends not only on vegetation structure and impervious surface reduction, but also on the spatial configuration of buildings and urban form. Wang and Gou (2024) showed that open spaces enclosed by low-density buildings provide the highest levels of thermal comfort, while those surrounded by a combination of green spaces and high-density built environments exhibit reduced cooling effectiveness. Open space characteristics, including vegetation, pavement type, and water elements, interact with urban form to shape microclimatic conditions.

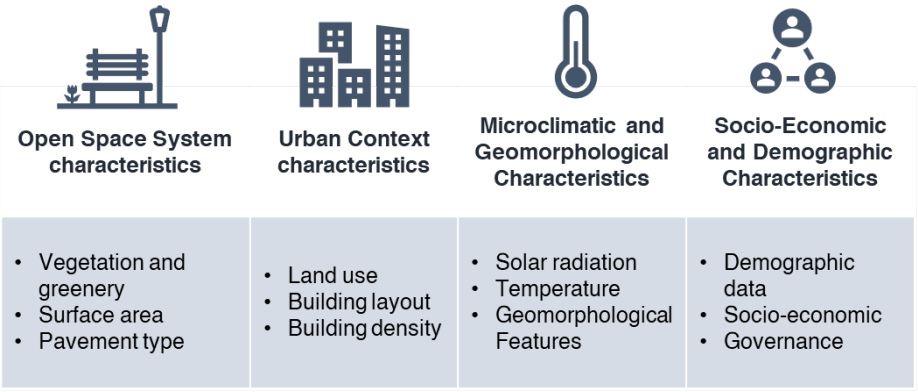
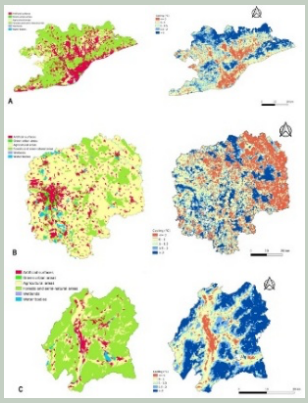


Fig.1 Definition of urban characteristics (Carpentieri et al., 2024)

The literature categorizes these elements into four main groups: open space system, urban context, microclimatic and geomorphological characteristics, and socio-economic and demographic characteristics (Carpentieri et al., 2024). Among them, the open space system, including vegetation, surface, and pavement type, is particularly relevant for UHI adaptation. The proportion of green cover, grass, and permeable surfaces contributes to surface cooling, while the spatial distribution of parks and courtyards improves airflow and reduces localized heat accumulation (Nirnac et al., 2022). In addition, the materials used in paved surfaces influence urban albedo and exposure to solar radiation, further impacting microclimatic conditions (Shen et al., 2022). The urban context also plays a key role in regulating microclimate, infact the land use, the building density, and the building layout affect the effectiveness of open spaces in reducing urban heat. High building density and compact urban fabrics tend to retain heat, amplifying UHI effects, while a strategic combination of open spaces and low-density buildings promotes better air circulation and heat dissipation. Furthermore, urban infrastructure elements, such as shading systems and tree corridors, influence solar radiation exposure and temperature variation (Das et al., 2022). Microclimatic and geomorphological characteristics, including solar radiation, wind patterns, humidity, and temperature variations, further determine the cooling capacity of urban open spaces. Factors such as global solar radiation, mean radiant temperature (MRT), and land surface temperature (LST) are critical to assess UHI intensity (Zhang et al., 2022). Urban wind flow, dictated by street orientation and building configuration, facilitates natural ventilation and enhances cooling effects (Rajagopalan et al., 2014). Similarly, the presence of water bodies in urban areas contributes significantly to thermal regulation by absorbing and dissipating heat (Patle & Ghuge, 2024). Finally, socio-economic and demographic characteristics influence the accessibility and use of open spaces. Population density, age distribution, lifestyle and governance structures determine how urban spaces are maintained and integrated into climate adaptation strategies (Cruz et al., 2021). Effective policy interventions, supported by government and local institutions,

are essential to increase the resilience of cities to UHI effects through strategic urban design and planning (Pigliautile et al., 2021).

Urban Heat Island Mitigation by Green Infrastructure in European Functional Urban Areas



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Publication year: 2021

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This study evaluates the ecosystem service of microclimate regulation provided by green areas in 601 European cities. The findings highlight that urban green infrastructure (UGI) significantly reduces urban temperatures, with an average cooling effect of 1.07°C and peaks of up to 2.9°C in some areas. The research underscores the need for strategic integration of UGI into urban planning to enhance adaptation and mitigate climate risks. Notably, a tree covers of at least 16% is required to achieve a 1°C reduction in urban temperatures.

European Commission - More vegetation in targeted urban areas can mitigate extreme heat

A JRC-led study published in *Nature Communications* demonstrates that targeted greening efforts in heat-prone areas are more effective than uniform city-wide vegetation distribution. By analyzing 200 cities worldwide, the study emphasizes the importance of precise spatial planning in mitigating heat stress. The research supports policy recommendations that prioritize localized green interventions to reduce heat exposure and improve urban livability.

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https://joint-research-centre.ec.europa.eu/jrc-news-and-updates/more-vegetation-targeted-urban-areas-can-mitigate-extreme-heat-2023-05-31_en

Demonstrating heat stress in European cities

Urban areas experience higher temperatures than rural surroundings due to artificial infrastructure and human activities, causing health risks. The UrbClim® model, using C3S ERA5 climate data, maps urban heat islands for 100 European cities at 100m resolution. This data helps urban planners implement green infrastructure and adaptation strategies, such as cool spots and green roofs, to mitigate heat stress and improve urban resilience. The tool is free and accessible.

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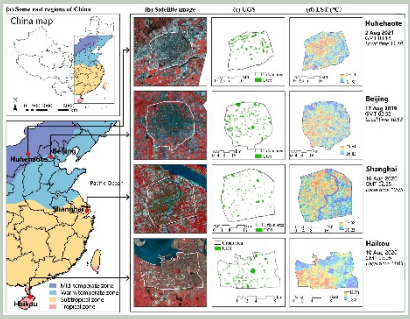
How can urban green spaces be planned to mitigate urban heat island effect under different climatic backgrounds? A threshold-based perspective



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A comparative analysis of four Chinese cities with varying climatic conditions reveals that the cooling intensity of urban green spaces depends on local climate backgrounds. The study identifies key factors, such as the presence of water bodies and vegetation density, that influence the effectiveness of urban greening strategies. These findings offer practical guidelines for designing urban landscapes that maximize cooling benefits.

How can urban green spaces be planned to mitigate urban heat island effect under different climatic backgrounds? A threshold-based perspective

The EU Green Infrastructure Strategy promotes the development of urban green spaces as a tool for climate mitigation and biodiversity conservation. This policy-driven approach underscores the multifunctionality of green infrastructure, which not only reduces heat stress but also enhances water management, air quality, and public well-being. Integrating green infrastructure into urban planning ensures long-term sustainability and resilience against climate change.

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https://environment.ec.europa.eu/topics/nature-and-biodiversity/green-infrastructure_en#:~:text=Well%2Ddesigned%20urban%20green%20spaces,well%2Dbeing%20of%20urban%20residents.

4 Conclusion

Climate adaptation strategies, in particular to reduce UHI effects, cannot only count on traditional green spaces such as parks and tree canopies. Built open spaces, including public squares, brownfields and brownfield sites, offer valuable opportunities for climate adaptation interventions. Urban policies must therefore recognise the interconnected role of natural and built environments in mitigating temperature extremes. Strategies that incorporate green and open spaces into urban planning will increase the adaptability of cities to climate change, reduce heat-related health risks and improve overall urban quality of life. Future research should focus on implementing hybrid solutions that combine nature-based interventions with innovative urban design techniques. By harnessing the combined potential of green infrastructure and open space adaptation, cities can build more climate-resilient environments for present and future generations.

References

Bai, X., Yu, Z., Wang, B., Zhang, Y., Zhou, S., Sha, X., Li, S., Yao, X. & Geng, X. (2024). Quantifying threshold and scale response of urban air and surface temperature to surrounding landscapes under extreme heat, *Building and Environment, 247*, p. 111029. https://doi.org/10.1016/j.buildenv.2023.111029

Bouketta, S. (2023). Urban Cool Island as a sustainable passive cooling strategy of urban spaces under summer conditions in Mediterranean climate. *Sustainable Cities and Society*, 99, 104956. https://doi.org/10.1016/j.scs.2023.104956

Bowler, D. E., Buyung-Ali, L., Knight, T. M. & Pullin, A. S. (2010). Urban greening to cool towns and cities: A systematic review of the empirical evidence. *Landscape and Urban Planning, 97* (3), 147–155. https://doi.org/10.1016/j.landurbplan.2010.05.006

Carpentieri, G., Zucaro, F. and Guida, C. (2023) 'Urban energy consumption in the city of Naples (Italy): A geographically weighted regression approach', Resilient Horizons: Building Sustainable Environments for Climate Adaptation and Health, 93–104. https://doi.org/10.1007/978-3-031-46109-5_8

Carpentieri, G., Gargiulo, C., Stiuso, T. & Zucaro, F. (2024). Greening and cooling urban areas: the Open Space System contribution for energy saving and climate change adaptation. In Lecture notes in computer science, 412–429. https://doi.org/10.1007/978-3-031-65273-8_27

Cruz, J. A., Blanco, A. C., Garcia, J. J., Santos, J. A. & Moscoso, A. D. (2021). Evaluation of the cooling effect of green and blue spaces on urban microclimate through numerical simulation: A case study of Iloilo River Esplanade, 74. Philip-pines: *Sustainable Cities and Society*, Article 103184. https://doi.org/10.1016/j.scs.2021.103184

Das, M., Das, A. & Momin, S. (2022). Quantifying the cooling effect of urban green space: A case from urban parks in a tropical mega metropolitan area (In-dia). *Sustainable Cities and Society*, 87, 104062. https://doi.org/10.1016/j.scs.2022.104062

Gargiulo C. & Zucaro F. (2023). A Method Proposal to Adapt Urban Open-Built and Green Spaces to Climate Change. *Sustainability, 15* (10):8111. https://doi.org/10.3390/su15108111

Gargiulo, C. & Zucaro, F., (2020). Greening networks for smart and resilient cities: From methodology to application in densely built urban Contexts. *Archivio di Studi Urbani e Regionali*, 130-148. https://doi.org/10.3280/asur2020-127-s1008.

Gunawardena, K., Wells, M. & Kershaw, T. (2017). Utilising green and bluespace to mitigate urban heat island intensity. *The Science of the Total Environment*, 584–585, 1040–1055. https://doi.org/10.1016/j.scitotenv.2017.01.158

Harlan, S. L., Brazel, A. J., Prashad, L., Stefanov, W. L. & Larsen, L. (2006). Neighborhood microclimates and vulnerability to heat stress. Social Science & Medicine, 63(11), 2847–2863. https://doi.org/10.1016/j.socscimed.2006.07.030

Massaro, E., Schifanella, R., Piccardo, M. et al. Spatially-optimized urban greening for reduction of population exposure to land surface temperature extremes. Nat Commun 14, 2903 (2023). https://doi.org/10.1038/s41467-023-38596-1

Nimac, I., Bulić, I. H. & Žuvela-Aloise, M. (2022). The contribution of urbanisa-tion and climate conditions to increased urban heat load in Zagreb (Croatia) since the 1960s. *Urban Climate*, 46, 101343. https://doi.org/10.1016/j.uclim.2022.101343

Patle, S. & Ghuge, V. V. (2024). Urban fragmentation approach for assessing thermal environment dynamics: A case study of semi-arid city from a comfort perspective. *Urban Climate, 53*, 101784. https://doi.org/10.1016/j.uclim.2023.101784

Pigliautile, I., D'Eramo, S. & Pisello, A. L. (2021). Intra-urban microclimate map-ping for citizens' wellbeing: Novel wearable sensing techniques and automatized data-processing. *Journal of Cleaner Production*, 279, 123748. https://doi.org/10.1016/j.jclepro.2020.123748

Rajagopalan, P., Lim, K. C. & Jamei, E. (2014). Urban heat island and wind flow characteristics of a tropical city. *Solar Energy, 107*, 159–170. https://doi.org/10.1016/j.solener.2014.05.042

Shen, Y., Lin, Y., Cheah, W., Lin, J., Li, X. & Li, Y. (2022). Influences and path-ways of urban form and lifestyle on carbon emission reduction. *Urban Climate, 46*, 101325. https://doi.org/10.1016/j.uclim.2022.101325

Wang, M. & Gou, Z. (2024). Gaussian Mixture Model based classification for analyzing longitudinal outdoor thermal environment data to evaluate comfort conditions in urban open spaces. *Urban Climate, 53*, 101792. https://doi.org/10.1016/j.uclim.2023.101792

Wang, M., Wang, W. & Wu, L. (2022). Application of a new grey multivariate forecasting model in the forecasting of energy consumption in 7 regions of China. *Energy, 243*, 123024. https://doi.org/10.1016/j.energy.2021.123024

Weilnhammer, V., Schmid, J., Mittermeier, I., Schreiber, F., Jiang, L., Pastuhovic, V., Herr, C. & Heinze, S. (2021). Extreme weather events in europe and their health consequences - A systematic review. International Journal of Hygiene and Environmental Health, 233, 113688. https://doi.org/10.1016/j.ijheh.2021.113688

Zhang, Q., Zhou, D., Xu, D. & Rogora, A. (2022). Correlation between cooling effect of green space and surrounding urban spatial form: Evidence from 36 urban green spaces. *Building and Environment, 222*, 109375. https://doi.org/10.1016/j.buildenv.2022.109375

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REVIEW NOTES
Urban planning literature review

Global warming reports: a critical overview of IGOs publications

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Abstract
Starting from the relationship between urban planning and mobility management, TeMA has gradually expanded the view of the covered topics, always remaining in the groove of rigorous scientific in-depth analysis. This section of the Journal, Review Notes, is the expression of continuously updating emerging topics concerning relationships between urban planning, mobility, and environment, through a collection of short scientific papers written by young researchers. The Review Notes are made of five parts. Each section examines a specific aspect of the broader information storage within the main interests of TeMA Journal. In particular, the Urban planning literature review section presents recent books and journals on selected topics and issues within the global scientific panorama.
For the first issue of TeMA Journal volume no. 18, this section provides a critical overview of recent reports and documents on climate change, published by different types of stakeholders. This review examines the landscape of climate change reporting through a comparative lens, focusing on key findings, strengths, weaknesses, and implications of selected publications. This contribution aims to examine reports produced by International Governmental Organizations (IGOs), analyzing their approach, findings, and potential limitations.

Keywords
Global warming; Climate change; Reports; Adaptation; Intergovernmental organizations.

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1. Introduction

Climate change is potentially the most challenging and complex issue of this era. The impacts of global warming are already visible such as sea rising, hurricanes, floods, and heatwaves that are becoming stronger and more recurrent posing risks to population, natural assets, and invaluable cultural heritage. Cities play a important role in this emergency. They are, in the first place, the biggest greenhouse gas emitters; secondly, they are among the most exposed to climate change. Their role in fighting this is irrefutable.

As the global temperature is already at 1°C above pre-industrial levels, according to IPCC Sixth Assessment Report, maybe mitigation will not be enough. Urban policy and planning must place a high value on adaptation so that cities are more resilient and capable of withstanding the impacts of a warmer world (Guida, 2021).

Adaptation to climate change is becoming part of the plan of many varied organizations worldwide. Intergovernmental Organizations (IGOs) play a crucial role in this process, as they supply decision-making for governments and international stakeholders (Abegón, 2023). IGOs such as the Intergovernmental Panel on Climate Change (IPCC), the World Health Organization (WHO), the United Nations Environment Programme (UNEP), the United Nations Framework Convention on Climate Change (UNFCCC), the United Nations Office for Disaster Risk Reduction (UNDRR) and many others promote mainstreaming of adaptation policies at different sectors and scales (Dellmuth & Gustafsson, 2021). As part of these efforts, increasing attention has been given to urban resilience as a key strategy for ensuring cities remain liveable, efficient, and safe in the face of climate change. Regenerating urban resilience through data-driven approaches is essential to address the multifaceted challenges posed by a changing climate. A series of reports produced by IGOs are analyzed in this article, providing detailed analyses of the effects of climate change, mitigation efforts, and future projections

The aim of this analysis is to give a critical evaluation of these reports, highlighting their strengths and weaknesses, internal consistency between sources, and potential biases resulting from their approach.

The article is organized into four sections. After this introduction, the following section provides a comprehensive overview of three IGO reports. The third section presents a comparative analysis of the reports, highlighting their strengths and weaknesses, along with the similarities and differences between them. The fourth section provides a conclusion, summarizing the main findings.

2. Reports summary

This section provides a detailed analysis of three reports published by different intergovernmental organizations, offering insight into the diverse perspectives and approaches adopted at the international level. Each report focuses on a different aspect of climate adaptation and through a comparative reading of these reports, it is possible to understand how different international institutions frame and implement climate action across sectors. The selected reports are presented in the following Tab.1

Title	**Organization**	**Publication date**
Adaptation Gap Report 2024 - *Come hell and high water*	UNEP	2024
COP 29 Special Report on Climate Change and Heath - *Health is the argument for climate action*	WHO	2024
Implementation guide for land use and urban planning - Words into Action.	UNDRR	2019

Tab.1 Overview of the reports analyzed, including their title, publishing organization and year of publications

Adaptation Gap Report 2024 - *Come hell and high water*

The Adaptation Gap Report is an annual publication by the United Nation Environment Programme (UNEP), which serves as leading global authority on environmental issues. UNEP collaborates with government, civil society and the private sectors to address environmental challenges. Its work focuses on climate change, nature and biodiversity loss and pollution (UNEP, 2024). The 2024 Adaptation Gap Report, titled "Come Hell and High Water", presents a revised analysis of the status of climate change adaptation, highlighting the gap between existing policies and required action. The report focuses on the technological and financial resources to be mobilized for adaptation and those available.

The report, in its first part, identifies the acceleration impacts of climate change, with a disconcerting increase in extreme weather phenomena. Against this context, it underscores the urgency of adaptation action to safeguard human lives. Nevertheless, despite growing consciousness and the availability of planning tools, the uptake of concrete adaptation actions is slow and fragmented. Many countries, particularly those most exposed or those affected by conflict, do not have the resources and capacities to develop and finance effective adaptation plans according to financial capability and constrained institutional ability. The planning tools also significantly differ in terms of quality, with others failing to respond fully to the needs of local populations or incorporating social inclusion dimensions to their maximum extent. The following section discusses the gap in finance, examining the disparity between public and private finance. As much as the contribution of the private sector is towards addressing adaptation, the sector's participation is still low. Addressing these challenges, Adaptation Gap Report 2024 presents key propositions for accelerating and scaling-up global adaptation action with citations of adaptation projects undertaken. Some of its key propositions include mobilizing additional finance resources, setting more effective tools for planning, enhancing capacity development and technology transfers, promoting the adoption of justice- and equity-focused approaches, and developing surveillance mechanisms to measure progress. The other critical sector the report outlines is the relations between National Adaptation Plans (NAPs) and Nationally Determined Contributions (NDCs). NAPs are a strategic national adaptation plan over the long term, while NDCs set out nations' contributions towards addressing climate change, including adaptation measures. The report finds that while adaptation aspects are mostly included in NDCs by countries, consistency between NAPs and NDCs is not established to a significant degree. To ensure coherence between these frameworks is crucial to effective integration of adaptation efforts, preventing duplication of effort and inefficient use of resources.

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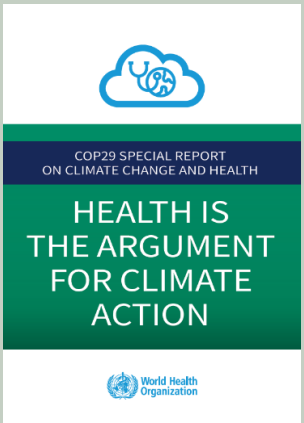
COP 29 Special Report on Climate Change and Heath - *Health is the argument for climate action*



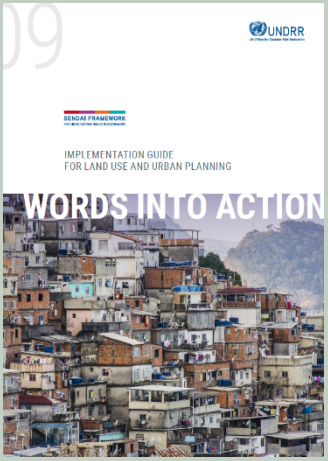
World Health Organization (WHO) is a specialized UN agency and the international global health authority. It is the coordinating center for world health and plays an important role in the reaction to public health problems worldwide. WHO periodically releases reports on principal health-related issues. It has released a special report on the occasion of COP29, titled "Health is the Argument for Climate Action."

The report introduces a new perspective with health not only being one of the most vulnerable sectors to climate change impacts but also as an essential driver of accelerating and transforming climate action. WHO states that climate emergency is indeed a health emergency of a multichallenger nature one that has direct and circular effects on our physical and mental health, and indirect effects on the transmission of infectious diseases, food and water safety and the resilience of health care systems

In addition, the report presents compelling evidence that climate mitigation actions can yield significant co-benefits to health within a virtuous cycle of social, environmental, and economic well-being. To more clearly illustrate this complex interconnection, the report examines specific health concerns linked to the impacts of climate change. It addresses issues such as an increase in extreme temperatures and their influence on death, heatwaves, and destructive storms, which pose significant threats to both housing and mental well-being. The report places emphasis on the high level of association between air pollution and elevated mortality rates after severe weather events, stressing the need to integrate these risks into formal future analyses and policy considerations at every level of specific interest is the report's examination of the social and environmental determinants of health, including access to safe drinking water, food, clean energy, healthy living conditions and high-quality health services. WHO stresses that while the health sector itself is a source of emissions, it can also contribute significantly to health promotion through low-emission policies, climate resilience, and transition to sustainable health systems. The report recognizes the potential of renewable energy, sustainable transport, and healthy diets not only to reduce emissions but also to improve air quality, food security, living standards, social justice, and mental health.
Also, the report issues a call to action in three critical areas: people, by bringing together health workers to mobilize people and to counsel patients; place, through enabling collective action by municipal institutions through sustainable city policies and planet, through the management of the economic, financial and governance origins that underlie the climate emergency.

Retrieved from: https://www.who.int/teams/environment-climate-change-and-health/climate-change-and-health/advocacy-partnerships/talks/health-at-cop29/

Implementation guide for land use and urban planning - Words into Action.



The UNDRR is the lead coordinating international efforts geared towards reducing disaster risk. UNDRR serves as a coordinating agency to provide guidance on advocacy, monitoring and reporting on with the implementation of the Sendai Framework for Disaster Risk Reduction 2015-2030. This non-binding, voluntary agreement was adopted by UN Member States at the Third World Conference on Disaster Risk Reduction in Sendai in Japan in 2015 and aims to avoid new disasters risk and reduce existing ones to the extent possible.
This report is part of UNDRR's "Words into Action" series, which seeks to provide clear guidelines to translate disaster risk reduction (DRR) into practice through urban and territorial planning. The report is intended for lead stakeholders, including policymakers, urban planners, and researchers. It describes the importance of including disaster risk assessments in land use planning and urban policies. The report singles out climate change as a major driver of rising urban risks and urges national and local governments to consider climate action plans as mechanisms to implement disaster risk reduction actions that take future climatic conditions into account, and steer urban development in line with changing patterns of the environment. As a first step towards resilience cities, mainstreaming DRR in urban planning is provided as an important action. The report examines how risk reduction may be integrated into urban law and building codes while also advocating for greater flexibility to create context-specific solutions.
Through case studies, the report explains how cities around the world have successfully adopted DRR interventions, such as the creation of urban green spaces and enhanced building regulations, to reduce disaster risk. In conclusion, the report emphasizes governance and social engagement. Shaping DRR interventions with citizens as active stakeholders from the beginning not only makes these interventions effective, but also socially sustainable. The way forward to build safety and resilient cities of the future is through a holistic approach that considers climate change, population growth and economic development as a common strategy

Retrieved from: https://www.undrr.org/words-into-action/implementation-guide-land-use-and-urban-planning

3. Critical overview and comparative analysis

The three reports under analysis share a common objective, which is the need to reduce climate impacts and foster more resilient cities thought adaptation strategies. Whether their origin is different, climate finance for adaptation gap report, public health for WHO special report or disaster risk reduction for UNDRR, all these documents lead to the core finding that these challenges demand a globally coordinated response to accelerating climate impacts. Overall, the reports highlight the need for a rigorous, cross-sectoral approach to integrate risk mitigation and building towards sustainable development, equity and social justice.

The UNEP adaptation gap report provides an in-depth assessment of the financial and policy aspects of climate adaptation. Its strength is the data, quantitative approach that highlights global funding deficits and policy gaps. It is a high-level set of policy recommendations that would benefit decision makers and financial institutions for the most part. However, its emphasis on macroeconomic indicators means that it often lacks the nuance required for region-specific recommendations and detailed implementation pathways. This limitation may hinder its practical applicability in localized contexts.

Moreover, the WHO special report focuses on the health impacts of climate change and frames the issue as a public health crisis with broad co-benefits.

The strength of this report is its innovative, qualitative approach that integrates case studies, epidemiological data and expert insights to highlight how action on climate can also yield major public health benefits. Its emphasis on co-benefits and equity grounds the case for climate action in the experiences of health professionals and community leaders, making it relevant to a wider audience. However, the report is rather general, offering less emphasis on the economic mechanisms necessary to support its proposals, reducing its direct applicability to financial policymakers.

The UNDRR Implementation guide for land use and urban planning report focuses on action and implementation for disaster reduction. Its strength lies in its application-oriented approach, it gives examples of concrete, measurable actions with which resilience can be incorporated into the management of urban planning and land-use. Because of its technical recommendations and examples of best practices from around the world, this report has a particularly strong utility for local governments, urban planners, and disaster risk managers. Also, over the years, disaster risk reduction has moved up the decision-making hierarchy, gradually being recognized as a key policy area at both the local and national levels (Weichselgartner & Pigeon,2015). This increasing focus has led to calls for more integrated approaches that also address climate adaptation's broader financial and health aspects. A summary of all the considerations discussed is provided in Table 2.

Report	**Focus**	**Approach**	**Target Audience**
Adaptation Gap Report 2024 – "*Come hell and high water*"	Climate adaptation financing and policy gaps	Data-driven, quantitative analysis and policy-oriented	Decision makers, financial institutions and climate adaptation planners
COP 29 Special Report on Climate Change and Heath – "*Health is the argument for climate action*"	Health impacts of climate change and co-benefits	Qualitative, case study-based and public health-focused	Health professionals, decision makers and community leaders
Implementation guide for land use and urban planning - Words into Action.	Disaster risk reduction and urban resilience	Practical, implementation-oriented and technical guidelines	Local governments, urban planners and disaster risk managers

Tab.2 Summary of key findings, similarities, and differences among the reports

4. Conclusions

Climate change continues to be one of the greatest challenges of this time, requiring collective action across all levels of government (Di Gregorio et al., 2019). Considering that cities are inherently complex systems,

characterized by dynamic interactions between physical infrastructure, socio-economic factors, and governance structures, the challenges of climate change further compound this complexity. Addressing these challenges requires a multi-faceted approach that focuses on concrete
interventions such as building robust infrastructure, fostering community preparedness, investing in early warning systems, and promoting equitable access to resources and information.

Intergovernmental organizations (IGOs) have emerged as key players in this arena with a range of perspectives that are complementary to one another for deploying better action to increase resilience and adapt to the changing climate risk. This multifaceted approach is illustrated by the three reports examined in this study. The UNEP Adaptation Gap Report, for example, allows an understanding of the financial and policy measures gaps that must be addressed to facilitate effective adaptation responses, forming the basis for data-informed investing shortfalls and strategies.

This WHO Special Report reframes climate change as a public health emergency, highlighting the interdependence between environmental sustainability and human health and well-being, and thus promoting policies that have health and environmental co-benefits. On the other hand, the UNDRR "Words into Action" report provides realistic and action-oriented implementation principles to enhance urban resilience, incorporating disaster risk reduction measures. While each of these reports has a different focus and approach, the insights they present together to provide a fuller picture of climate resilience. However, to translate these into transformative climate adaptation, it is critical for them to be integrated into a unified policy framework, although this becomes indispensable, especially at the local scale.

Future efforts should prioritize interdisciplinary collaboration, the development of clear implementation pathways, and the establishment of standardized metrics that can effectively translate recommendations into tangible, sustainable outcomes.

References

Abegón Novella, M. (2023). On the Role of International Governmental Organizations in the Global Response to Adapt to Climate Change-induced Sea-level Rise: Conditioning Factors and Opportunities. *Spanish Yearbook of International Law*, 2023, num. 26 (2022), 45-66. https://doi.org/10.36151/SYBIL.2023.003

Dellmuth, L. M. & Gustafsson, M. T. (2021). Global adaptation governance: how intergovernmental organizations mainstream climate change adaptation. *Climate Policy*, 21(7), 868-883. https://doi.org/10.1080/14693062.2021.1927661

Di Gregorio, M., Fatorelli, L., Paavola, J., Locatelli, B., Pramova, E., Nurrochmat, D. R., ... & Kusumadewi, S. D. (2019). Multi-level Governance and Power in Climate Change Policy Networks. *Global Environmental Change*, 54, 64-77. https://doi.org/10.1016/j.gloenvcha.2018.10.003

Guida, C. (2021). *I rischi naturali del cambiamento climatico nelle città del Mediterraneo*. FedOAPress. https://doi.org/10.6093/978-88-6887-107-9

Intergovernmental Panel on Climate Change (IPCC) (2022). Climate Change 2022: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. H.-O. Pörtner, D.C. Roberts, M. Tignor, E.S. Poloczanska, K. Mintenbeck, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem, B. Rama (Eds.). Cambridge University Press. https://doi.org/10.1017/9781009325844

Richardson, K., Steffen, W. & Liverman, D. (Eds.). (2011). *Climate change: Global risks, challenges and decisions*. Cambridge University Press.

UN Office for Disaster Risk Reduction (2020). Implementation guide for land use and urban planning - Words into Action. UNDRR. Retrieved from: https://www.undrr.org/words-into-action/implementation-guide-land-use-and-urban-planning

United Nations Environment Programme (2024). Adaptation Gap Report 2024: Come hell and high water. As fires and floods hit the poor hardest, it is time for the world to step up adaptation actions. Nairobi. Retrieved from: https://wedocs.unep.org/20.500.11822/46497

Weichselgartner, J. & Pigeon, P. (2015). The role of knowledge in disaster risk reduction. *International Journal of Disaster Risk Science*, 6, 107-116.

World Health Organization (2024). COP29 special report on climate change and health: Health is the argument for climate action. World Health Organization. Retrieved from: https://www.who.int/teams/environment-climate-change-and-health/climate-change-and-health/advocacy-partnerships/talks/health-at-cop29/

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