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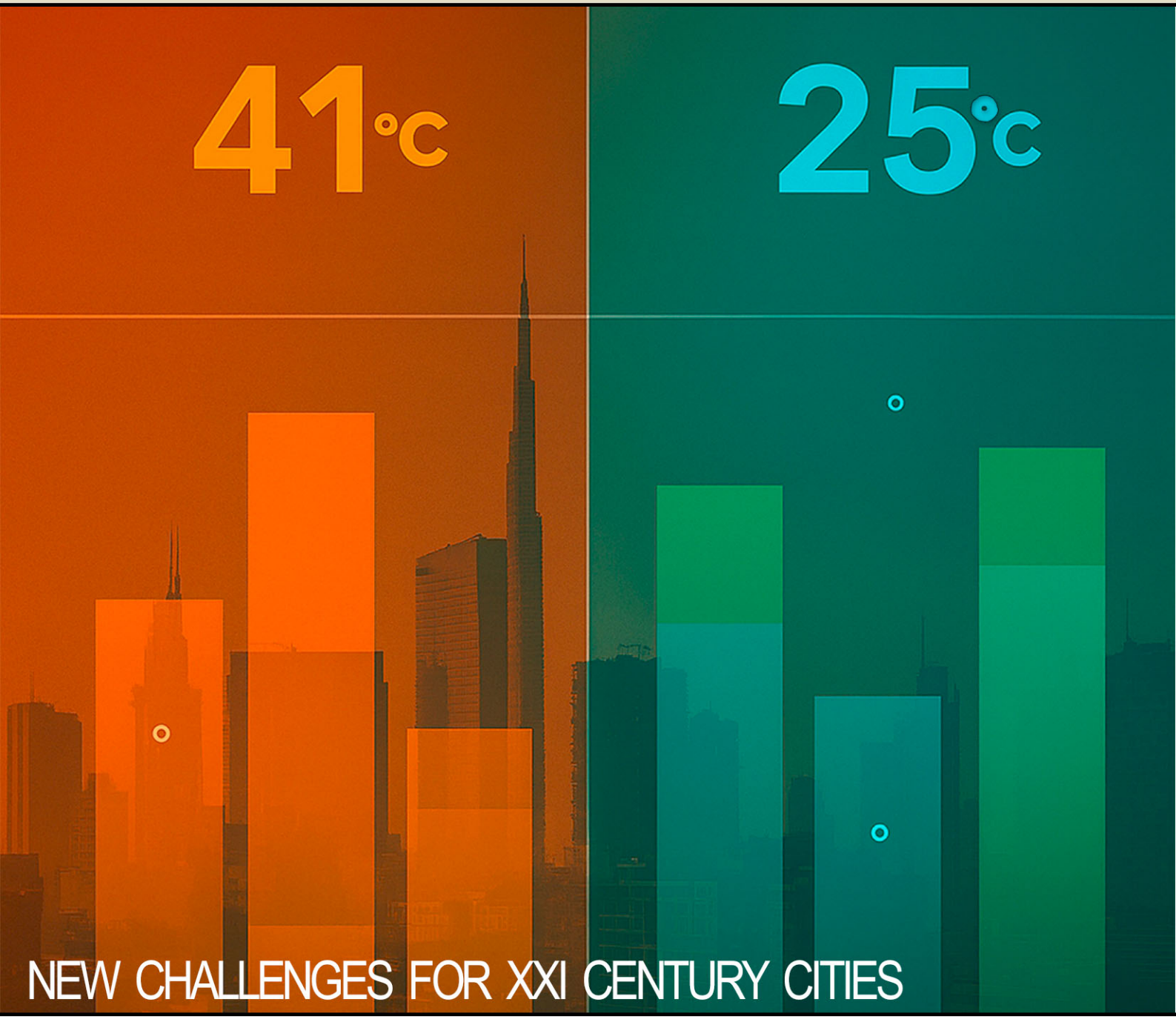

NEW CHALLENGES FOR XXI CENTURY CITIES

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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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, optimisation of land use, analysis and evaluation of civil protection plans in areas especially vulnerable to natural disasters and a multilevel governance approach to adaptation.

In this issue, the section "Focus" contains two studies. The first paper, titled "Landscape planning based on tourism uses in urban historical areas: the case of Bursa", by Zeynep Pirselimoğlu Batman (Bursa Uludag University in Turkey), aims to optimise the use of these areas for both locals and tourists by revealing their character through landscape planning in urban historic regions. To ensure the sustainability of tourism and recreational uses in Bursa's historical city centres, landscape designs must be planned to preserve the historical fabric.

The second contribution is "Assessing the impacts of climate change on peri-urban land use in Nigeria. A study of Ibeju-Lekki LGA, Lagos State", by Chinenye L. Okafor, Olusola E. Orebiyi, Raimot T. Akanmu and Sandra O. Omonubi (Lagos State University and Lagos State University in Nigeria), investigating the impact of climate change on land use dynamics in the peri-urban region of Nigeria, focusing on Ibeju-Lekki Local Government Area in Lagos State.

The section "LUME" includes ten studies. The first contribution of the section is "Assessing heat stress risk to inform urban heat adaptation. A method applied in the Friuli Venezia Giulia region, Italy", by Davide Longato, Nicola Romanato and Denis Maragno (IUAV University of Venice in Italy). The paper aims to propose and test a spatially explicit risk index to assess the likelihood that urban populations will be negatively affected by heat-stress-related impacts.

The second contribution of the section is "Capacity assessment of the creation and development of regional brands in Guilan province", by Atefeh Faghih Abdollahi, Ali Soltani and Nader Zali (University of Guilan in Iran and Flinders University in Australia). The paper investigates the capacity for regional branding for Guilan province concerning the existing brands' identification, new brands' creation opportunities, and development obstacles.

The third contribution of the section is "The Axis Contract for the regeneration of fragile territories. An experiment along the Civitavecchia Capranica Orte railway line", by Chiara Amato and Mario Cerasoli (INU Lazio and Sapienza University of Rome in Italy). The paper explores the revitalisation of Italy's "inner areas" - fragile territories facing challenges such as depopulation, abandonment, and a lack of essential services, primarily due to limited mobility.

The fourth contribution of the section is "GIS-based bikeability approach as a tool in determining urban bicycle infrastructure capacity for Eskisehir, Turkey", by İlker Atmaca and Saye Nihan Çabuk (Yozgat Bozok University and Eskisehir Technical University in Italy). The paper assesses the bicycle accessibility of Eskisehir, Turkey, by analysing both existing and planned bicycle infrastructure using GIS-based methods.

The fifth contribution of the section is "Risk as a wicked problem in planning: the role of future non-knowledge", by Maria Rosaria Stufano Melone and Domenico Camarda (Polytechnic University of Bari in Italy). The paper explores how to address "non-knowledge" in spatial planning, particularly by integrating local risk perceptions and decision-making dynamics into agent-based simulation models developed with NetLogo software.

The sixth contribution is "Urban physical characteristics for sense of security", by Mohammad Sedaghatfard and Ali Soltani (Shiraz University in Iran and University of New England in Australia). The study examines how four key urban physical characteristics, green space, land use, street lighting, and road networks, influence residents' sense of security in Shiraz, Iran.

The seventh article, "Developing the charging infrastructure for electric cars. Northwestern Italy facing European targets", by Luca Staricco and Angelo Sammartino (Politecnico and Università di Torino in Italy), analyses the development of charging infrastructure for electric light-duty vehicles in northwestern Italy in relation to the targets set by EU Regulation 2023/1804.

The eighth article, "Landscape enhancement and river preservation. The case of the Aniene River in Rome, Italy", by Donatella Cialdea and Fabio Massera (University of Molise in Italy). The paper integrates concepts of landscape restoration with improvements to river areas. The case study focuses on the Aniene River, situated in a region of Rome adjacent to the Rome Ring Road.

The ninth article, "The levels and correlates of paratransit use in Egypt and Lebanon before and during the outspread of COVID-19", by Dina M. Dief-Allah, Sofia A. Dawoud, Basma M. Khalifa and Houshmand E. Masoumi (Future University, Innovation University and Ain Shams University in Egypt and Technische Universität Berlin in Germany). The paper addresses informal public transportation or paratransit, investigating the behaviour and preferences regarding this mode in the Middle East and North Africa.

The last article, "Urban planning research from 2014-2024: a systematic literature review using text mining techniques" by Gerardo Carpenteri and Laura Ascione (University of Naples Federico II in Italy). The paper examines the evolution of urban planning research through a systematic review of the literature published between 2014 and 2024, with text-mining techniques.

The Review Notes section proposes five insights on the themes of the TeMA Journal.

The International Regulation and Legislation for the Energy Transition section of Review Notes is entitled "From RED II to RED III: Renewable Acceleration Areas as a new challenge for urban and territorial planning", authored by Valerio Martinelli. The RN explores the Renewable Energy Directive III, which introduces more ambitious targets for renewables and Renewable Acceleration Areas, where plants can be authorised more quickly. This makes urban and territorial planning crucial in the location of energy infrastructure. The Italian case highlights the central role of multilevel governance and digital tools in accelerating, making fairer, and making more sustainable an energy transition.

The Urban Strategies, Programmes and Tools section of Review Notes is entitled "Digitalization in urban planning: how Europe is building its digital future", authored by Annunziata D'Amico, aims to provide an overview of the policy tools deployed by the European Union for digital transformation, highlighting how this process is a crucial factor for the EU's competitiveness, resilience, and technological sovereignty and how it applies specifically to the governance of urban and territorial transformations.

The Urban Practices section of Review Notes is entitled "Competitive climate adaptation. Startups and urban innovation ecosystems driving climate change adaptation in cities", authored by Stella Pennino. The RN explores innovative urban planning tools that enable cities to integrate climate startups into strategic climate planning. It then presents three climate startup case studies, illustrating the proactive role these actors can play in driving effective climate change adaptation in urban contexts.
The Urban planning literature review section of Review Notes is entitled "Exploring open and green space characteristics for climate change adaptation: a focus on energy consumption", authored by Tonia Stiuso, provides an in-depth analysis of emerging issues in urban planning, mobility and the environment. The aim is to shed light on effective approaches and innovative strategies to deal with climate change effects and how different characteristics of urban open and green spaces contribute to reducing energy consumption.
The Urban planning literature review section of Review Notes is entitled "Global warming reports: a critical analysis of R&D centres publications", authored by Laura Ascione. This contribution explores the perspectives of research and development (R&D) centres on climate change, highlighting their role in advancing scientific knowledge and supporting its translation into actionable insights for society, while critically evaluating the strengths and potential shortcomings of their reporting approaches.

Finally, with the release of the third issue of 2025, this journal marks its 18th anniversary. The first issue was published in December 2007. Over the years, the journal has published 58 regular issues, initially quarterly, then every four months, comprising 690 scientific articles. Additionally, 18 Special Issues containing 288 articles have been released. During this period, over 800 authors worldwide have shared their research through TeMA Journal. For this milestone, sincere gratitude is extended to the Editorial Board, Associate Editors, Editorial Team, and Publisher (FeDOA - Federico II University Press), whose enthusiasm and voluntary efforts have significantly contributed to this achievement. The journal's esteem is reflected in its inclusion in major international indexed databases such as Scopus and Web of Science. Best wishes for TeMA's 18th birthday, with hopes that its reaching adulthood will bring even greater achievements.

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Landscape planning based on tourism uses in urban historical areas: the case of Bursa

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Abstract
Landscape planning in urban historic areas aims to support preserving historical and cultural places, promote sustainable development processes, and help protect communities' cultural identities. However, comprehensive studies on holistic planning approaches for tourism and recreational uses in urban historic areas are limited. This study was conducted in Bursa's historical and cultural center, a city with a strong landscape character, possessing significant historical and cultural values. This study aims to optimize the use of these areas for both locals and tourists by revealing their character through landscape planning in urban historic regions. In this study, the landscape character of the historical city center of Bursa has been evaluated based on SWOT analysis and the weighted criteria method. To ensure the sustainability of tourism and recreational uses in the historical city centers of Bursa, landscape designs reflecting the city's identity must be planned in a way that does not damage the historical fabric. The proposed arrangements should integrate appropriately with both living and non-living materials while developing landscape designs that preserve the unique value of urban fabric.

Keywords
Landscape Planning; Tourism; Historical areas

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1. Introduction

Landscape planning approaches in historical and cultural urban areas play a critical role in shaping urban identity, preserving cultural heritage, and enhancing residents' and visitors' quality of life. Cities are shaped as dynamic entities integrating natural and cultural components transmitted from the past to the present through historical processes (Kaya, 2003). Landscape elements shaped by these natural and cultural components are the foundation of urban identity.

The UNESCO World Heritage Committee defines cultural landscapes as "the combined works of nature and man". It acknowledges them as the result of the evolution of human society and settlements under the influence of cultural, social, economic, and internal-external forces (Perihan & Aşur, 2020).

Landscape planning aims to protect historical environments and ensure the continuity of urban identity. Historical structures and cultural landscape components are significant in creating, reinforcing, and promoting a sense of place in cities (Kaya, 2003). Urban transformation should be viewed as a temporal corridor connecting the past, present, and future. When this transformation accelerates, the continuity of historical environments may be jeopardized, leading to complex problems (Hassler et al., 2002).

Conversely, when transformation slows excessively, issues such as abandonment, decay, or demolition of historical areas may arise. Therefore, preserving cultural landscapes is crucial both for the continuity of urban identity and for enhancing tourism and recreational value.

Urban tourism and recreational activities should aim to preserve the past and improve society's future quality of life. Accordingly, conserving the cultural and natural environment and using cultural resources are essential (Kuntay, 2004). However, in alignment with the Sustainable Development Goals (SDGs), the role of tourism requires a multidimensional transformation beyond economic returns. Tourism is responsible for environmental sustainability, social justice, and cultural continuity (Buhalis et al., 2023; Dwyer, 2022).

While tourism has the potential to contribute positively to development, its associated negative externalities must also be acknowledged. Overtourism, environmental degradation, the commodification of cultural heritage, gentrification, and the displacement of local communities from public spaces are among the possible consequences (Musavengane, et all., 2020). These issues, particularly in historic city centers, necessitate the alignment of tourism with urban planning processes and the inclusive participation of local communities (D'Auria & Sánchez-Rivas García, 2025).

Cultural landscapes vary worldwide and gain value over time by interacting with nature and culture. These landscapes can be spatially bounded by natural, cultural, visual, and symbolic qualities. They reflect human social development, creativity, and spiritual richness, and form essential parts of our shared identity. By maintaining the continuity of the relationship between people and their environment, they aim to preserve vanishing cultural traces. Thus, protecting cultural heritage in assessing and transmitting cultural landscapes to future generations is critical (Soykan, 2003).

Today, the urban centers of cities, particularly those with high population and economic density, must adapt to contemporary socio-cultural and spatial developments. This adaptation necessitates the integration of historical accumulation with modern development without conflict (Van Oers, 2010; Dinçer, 2013). A balance between urban order and tourism activities must be established, and planning approaches that enable both areas to function harmoniously should be developed. From a critical perspective, it is evident that planning processes must address aesthetic and economic dimensions, social equity, accessibility, and the continuity of cultural identity. At this point, the impact of tourism on local identities becomes a matter of debate; in some cases, regional identities are strengthened, while in others, local identities may be suppressed or transformed in line with global tourism demands (Monaco, 2024).

Therefore, in order to prevent a conflict between identity preservation and economic growth objectives, strategies based on the principle of cultural sustainability must be prioritized (Buhalis et al., 2023). From a critical perspective, it is evident that planning processes must address aesthetic and economic dimensions,

social equity, accessibility, and the continuity of cultural identity. In this context, landscape planning seeks to conserve historical and cultural urban areas, support sustainable development processes, and maintain the cultural identities of societies. In historic metropolitan areas, landscape planning is a process that aims to reveal the character of these places and optimize their use by both residents and tourists. The studies of Yenice (2014), Çermikli (2016), Rey-Pérez & Pereira Roders (2020), and Turgut & Özden (2005) provide significant examples related to the landscape character and planning of historic urban areas. However, considering the pressures caused by tourism and recreational uses, comprehensive research grounded in integrated planning approaches within such areas remains limited. In addition to tourism and recreational uses, several studies focusing on urban transportation corridors, pedestrian zones, pedestrianized areas, and their functional roles—such as those by Arslan et al. (2018), Gargiulo& Sgambati (2022), Fior et al. (2022), Türken & Conticelli (2024), Rossetti et al. (2024), Mazzola & Bove (2024), and Pirselimoğlu Batman et al. (2024) offer significant insights that can be evaluated in conjunction with landscape planning strategies. Tourism, while offering important opportunities in multifunctional urban spaces that contain historical, cultural, and commercial values, may also lead to adverse effects such as user overload, spatial pressure, and social segregation (Musavengane et al., 2020). In this regard, evaluating landscape planning approaches in multifunctional urban areas points to a significant research gap concerning the relationship between natural and cultural landscape values, urban identity, and functional use. Particularly in historic city centers with high pedestrian and vehicular density, it is essential to thoroughly examine the potential for tourism- and recreation-oriented space use that serves both residents and visitors. Within this scope, the historical corridor located in the center of Bursa stands out with its rich historical and cultural heritage, as well as its diverse spatial functions serving the local community. However, a comprehensive planning approach has not yet been developed for this multifunctional area. Planning strategies for such areas must be shaped according to sustainability principles, balancing conservation and utilization. Adopting a planning approach that aligns with the landscape character would enable these areas to serve as multifunctional spaces supporting tourism and recreation while meeting the needs of everyday urban life. Bursa, in addition to its historical and cultural functions, is a significant tourism center with valuable natural resources. Key heritage and cultural areas such as the Yeşil Tomb, Setbaşı, Heykel, Hanlar District, Tophane, Ahmet Vefik Pasha Theater, and the Irgandı Bridge are evaluated in terms of their tourism and recreation potential. These areas encompass various elements including religious sites, shopping streets, venues offering traditional Bursa cuisine (such as İskender kebab and cantık), the historical inns district, covered bazaars, business centers, statues, the clock tower, public squares, monumental trees, and broader cultural landscape components.In a city like Bursa, which holds rich tourism assets, identifying and emphasizing core values is of critical importance. In this regard, when historical monuments, cultural and natural attractions are supported by user-friendly infrastructure, the urban core of Bursa will offer a stronger tourism and recreational potential. Accordingly, this study aims to develop an integrated approach to the landscape planning of Bursa. Through the use of SWOT analysis and a weighted criteria method, appropriate planning strategies have been generated based on the area's natural and cultural landscape values. The goal is to develop a planning vision that not only considers aesthetics and tourism potential but also aligns with principles of cultural continuity, social inclusivity, and environmental responsibility. In conclusion, by preserving Bursa's historical areas and landscape character while balancing urban and touristic uses, this region can become a sustainable attraction center for both residents and visitors.

2. Materials and Methods

2.1 Study Context

Bursa is located in the northwestern part of Turkey, within the southeastern region of the Sea of Marmara. Bilecik and Adapazarı border it to the east, İzmit, Yalova, Istanbul, and the Sea of Marmara to the north,

Eskişehir and Kütahya to the south, and Balıkesir to the west. The city has a coastline of approximately 135 kilometers along the Sea of Marmara. About 35% of the province's surface area is mountainous, and the town lies at an altitude of 155 meters above sea level. Although Bursa generally has a temperate climate, significant microclimatic variations exist. The maritime climate of the Marmara Sea influences the northern part, while the southern part experiences the colder and harsher climate of Mount Uludağ.

The present study focuses on the historical city center of Bursa, specifically examining Namazgah Street and Atatürk Street, two major urban corridors that play key roles in the city's commercial, cultural, and touristic functions (Fig.1).

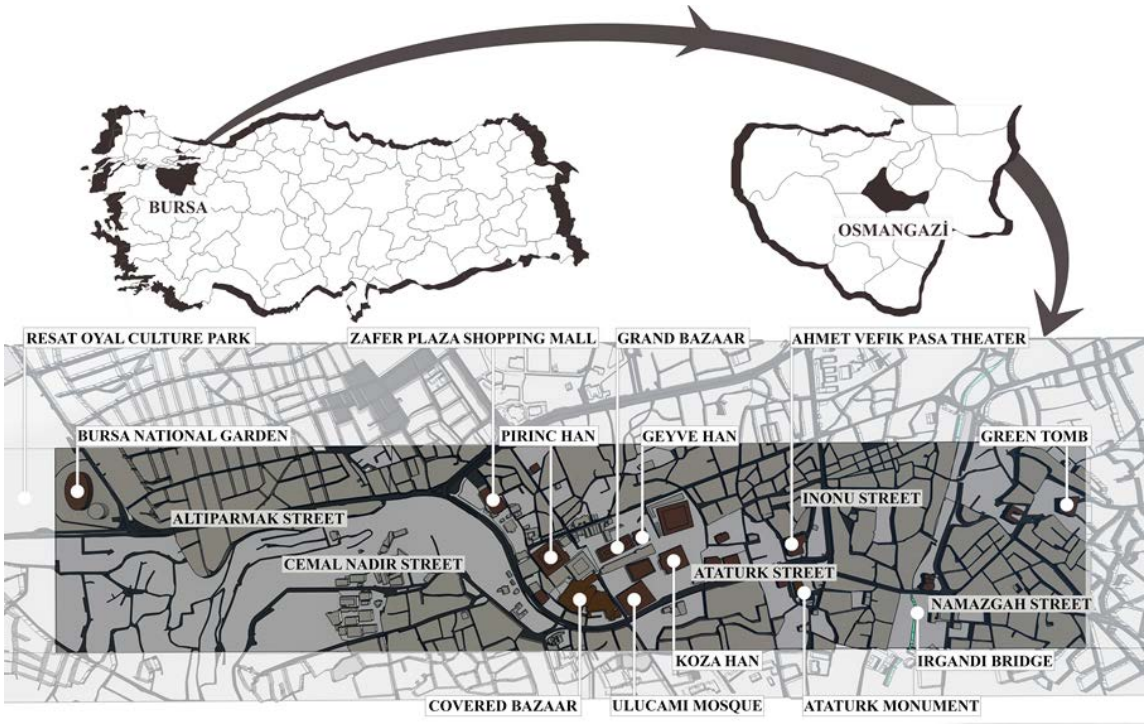

Fig.1 Location of study area

Bursa is one of Turkey's most prominent cultural tourism destinations and was inscribed on the UNESCO World Heritage List 2014. According to data, the city hosted approximately 1.4 million domestic and over 500,000 international tourists in 2023 (2025j). The main types of tourism in Bursa include cultural and heritage, gastronomic, faith-based, and winter, particularly in the Uludağ mountain region. Tourism in the city exhibits a distinctly seasonal character. Domestic tourist arrivals peak during the summer and national holidays. At the same time, international visitors are more evenly distributed throughout the year, with notable increases during spring and autumn due to festivals and religious events. The contribution of tourism to the local GDP is estimated at approximately 8.2%, reflecting the importance of both short-term visitors and heritage-focused longer stays in Bursa's urban economy (2025k). Bursa's tourism infrastructure includes over 250 accommodation facilities, ranging from boutique hotels in the Hanlar District to large-scale resort complexes in Uludağ. The city is also home to five major museums, numerous caravanserais, covered bazaars, cultural centers, and more than 40 officially registered heritage sites. However, several ongoing challenges affect the tourism experience, including insufficient directional signage, overcrowding in historic zones, and limited accessibility infrastructure for disabled individuals (2025k; 2025l).

2.2 Method

The study's methodology involves site inspection, data collection, and a survey. In this context, shopping streets, historical and cultural sites, the covered bazaar, and gastronomic food and beverage venues, along

with their historical processes, usage purposes, and existing deficiencies, have been examined in light of the literature review and site analysis.

As a result of these investigations, the current situation and deficiencies in the corridor extending from Yeşil Türbe, Heykel, Ulucami, Kapalı Çarşı, Hanlar District, and along Altıparmak Street were identified and incorporated into the plans. Along this route, natural, historical, and cultural data and elements such as facilities, vegetation, buildings, recreational areas, tourism values, circulation data, and pedestrian and vehicular traffic routes were presented and evaluated from a landscape architecture perspective.

Furthermore, while assessing the current situation of the area, the key landscape values and urban relationships to be considered in the use of this area were examined based on the criteria presented in Tab.1. These criteria were derived from and supported by the literature, in which scholars have emphasized the importance of ecological, socio-cultural, and functional aspects in landscape planning (Gültekin & Altunkasa, 2008; Ender, 2011; Yin, 2013; Zayed, 2016).

Subsequent studies further contributed to the refinement and contextualization of these criteria in relation to urban forests, cultural landscapes, and recreational planning (Altay & Pirselimoğlu Batman, 2019; Gündoğdu & Dinçer, 2020; Batman & Altay, 2020; Altay & Pirselimoğlu Batman, 2021; Carra et al., 2022). More recent research has provided updated perspectives and empirical validations, reinforcing the applicability of the criteria outlined in Tab.1 (Altay & Şenay, 2023; Pişkin & Seyidoğlu Akdeniz, 2023; El kébir & Ghédira, 2024; Altay & Zencirkıran, 2024; Batman et al., 2024; Altay & Batman, 2025).

A multi-step process was followed to determine the evaluation criteria to ensure methodological transparency and replicability. First, a comprehensive literature review focused on previous studies on sustainable tourism and cultural landscape analysis. Subsequently, expert consultations were held with landscape architects and local decision-makers.

Main criteria	Sub-criteria
Accessibility	Road width and surface treatments, Existing roads, Roads connecting the area, Current road widths, Stairs/steps, Presence of pedestrian paths, Pedestrian path widths, Presence of bicycle paths, Road width of connecting roads, Compliance with accessibility standards on existing roads, Accessibility standards for connecting roads, Pedestrian-friendly surface treatments on existing roads, Pedestrian-friendly surface treatments on connecting roads
Urban Texture	Traditional architectural texture The traditional architectural texture in the areas parallel to and surrounding the site The urban texture features a combination of different architectural characters. Promotional signs mounted on building facades
Land Uses	Transportation, Parking, Rest areas, Dining areas, Shopping areas, Squares, Green areas
Plant Materials	Roadside trees, Trees, Shrubs, Conifers, Broadleaf trees, Monumental trees
Structural Landscape-Furnishing Elements	Seating units, Trash bins, Lighting, Directional signs, Billboards, Boundary elements, Water features, Fountains
Historical and Cultural Structures	Mosques, Inns, Tombs, Bazaars, Museums, Bridges, Statues, Others
Tourism Activities	Religious tourism, Historical and cultural heritage, Natural heritage, Museum tours, Architectural tours, Historical tours, Festivals, Traditions, Cultural walks, Cultural routes, Traditional food and beverages

Tab.1 Evaluation criteria

These consultations were used to assess the selected criteria's contextual relevance and evaluate the availability and accessibility of related data. Initially, broader indicators such as economic development metrics

and land value analyses were also considered. However, these indicators were excluded due to the lack of site-specific data and overlap with other existing criteria.

The final set of main and sub-criteria was determined based on their alignment with sustainability goals, practical applicability, and relevance to the historical and urban context.

The relationship between the central and sub-criteria identified in the first phase and the field-specific SWOT criteria was evaluated in the study's second phase. This assessment was conducted by numerically correlating the prioritization and current status, resulting in weighted scores for the main criteria.

SWOT analysis is a management process and one of the most widely used strategic evaluation methods. Planning is mainly employed to consider and assess existing data within the study areas.

In this context, SWOT analysis allows for examining internal and external environmental factors regarding strengths, weaknesses, opportunities, and threats (Pickton & Wright, 1998; Uçar & Doğru, 2005; Goranczewski & Puciato, 2010). When conducting the evaluation in SWOT analysis:

- For Strengths: What are the superior features of the area? What are the characteristics and positive attributes of the area? Questions like these are addressed.
- For Weaknesses: What are the negative attributes of the area? What areas within the organization require improvement? What are the weaknesses when compared to similar areas? These questions are explored.
- For Opportunities: What opportunities does the area offer? What are the resources that create opportunities for the area? What are the national, international, regional, or local opportunities for the area, considering its socio-cultural structure? These questions are investigated.
- For Threats: What obstacles might the area encounter? What factors surrounding the area could pose potential threats? These questions are examined.

In this study, a SWOT analysis (Hay & Castilla, 2006; Batman & Demirel, 2012; Batman et al., 2017; Zhiqiang et al., 2024; Nygaard, 2024) of the area was conducted, where each region was evaluated separately in terms of strengths, weaknesses, opportunities, and threats. This evaluation was based on the criteria and sub-criteria used to analyze the current situation of the area (Gültekin & Altunkasa, 2008; Ender, 2011; Yin, 2013; Zayed, 2016; Özdemir et all., 2016; Altay & Pirselimoğlu Batman, 2019; Gündoğdu & Dinçer, 2020; Batman & Altay, 2020; Altay & Batman, 2021; Carra et al., 2022; Altay & Şenay, 2023; El kébir & Ghédira, 2024; Batman et al., 2024). The evaluations obtained through the SWOT analysis were analyzed based on the weighted criteria method to determine the area's tourism and recreation uses and urban landscape performance.

In line with this method, when calculating the weighting score, the appropriate criteria and subheadings determined for the area were evaluated according to their strengths (+), weaknesses (-), opportunities (+), and threats (-). The evaluation was scored based on the positive and negative aspects of the SWOT framework, with the scores assigned in order of importance.

Strengths (4), opportunities (3), weaknesses (2), and threats (1) were used as the scoring system. Scores based on the SWOT analysis results for each criterion were assigned. The average weight score was calculated by taking the average score values for each criterion. The weighted score was obtained by multiplying the total score for each criterion by its average weight score.

This multi-layered approach—combining literature synthesis, expert consultation, contextual filtering, and integration with a weighted SWOT score analysis—aims to enhance the study's scientific robustness and replicability.

3. Results

3.1 Current status of the study area

The study area is heavily used for pedestrian and vehicular traffic, particularly in areas designated for historical and tourism purposes.

Landmarks such as the Sculpture, City Museum, Ulucami Mosque, Pirinç Han, Kapan Han, Emir Han, İpek Han, Fidan Han, Koza Han, Geyve Han, Covered Bazaar, Bedesten, Yeşil Türbe (Green Tomb), Yeşil Cami (Green Mosque), Setbaşı, Irgandı Bridge, Kılıç Kalkan House, various historical mosques and baths, tombs, Clock Tower, Tophane, and Cumhuriyet Street mainly attract high user density due to their tourism, business, and historical significance. Additionally, the area also accommodates modern usage spaces such as shopping centers.

Cumhuriyet Street has been fully pedestrianized and hosts a wide range of commercial spaces (shops), public institutions, historical mosques, old-style trains, cafes, and traditional dining establishments emblematic of Bursa. Parallel to this street, there are some of the city's largest market networks, including the Covered Bazaar, the Jewelers' Street, Uzun Çarşı, and Tuzpazarı Street.

This area houses businesses in diverse sectors, including clothing, technology, food, jewelry, household goods, goldsmithing, and herbal shops. In addition, private healthcare facilities, law offices, and service offices are also commonly found in this region (Fig.2).

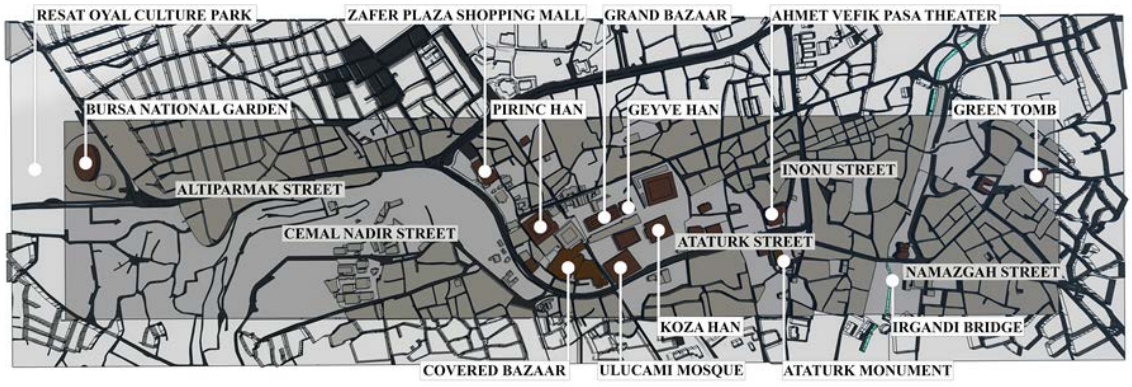

Fig.2 Current status of the study area

Accessibility: The study area, which focuses on the urban core of Bursa, is centered around Namazgâh Street, Cumhuriyet Street, Atatürk Street, and Cemal Nadir Street. This region has constituted an essential route in Bursa's transportation plans from the early city layouts to the present. As a result, the street, which experiences heavy vehicular traffic, is also favored by visitors due to Bursa's socio-cultural and historical characteristics. This leads to an increased load of both vehicular and pedestrian traffic in the area. The current road configurations on these streets are insufficient to address the needs of both pedestrian and vehicular traffic. For these reasons, Cumhuriyet Street is closed to vehicular traffic. The area is accessible by private cars, taxis, minibusses, municipal buses, an old-style train, silkworm transport, commercial taxis, or on foot from all parts of the city. The area has numerous historical mosques, tombs, inns, a museum, historical buildings, and various businesses that meet different shopping needs. While this area attracts local users, it also draws considerable attention from tourists.

The Setbaşı area in the region connects to Atatürk Street, which experiences heavy pedestrian traffic. Parallel to Atatürk Street, Cumhuriyet Street extends from Zafer Plaza Shopping Mall to İncirli, with a nostalgic train route running along this line, forming Cumhuriyet Street. In addition to dining areas, the street is also used as a shopping avenue.

Within the boundaries of the study area, the shop entrances along the transportation axes are not aligned with the sidewalk level, which has led to the creation of step solutions for elevation differences, and the dimensions of these steps are not standardized. As a result, sidewalks become narrow and wide in places, and physical barriers such as steps without ramps occasionally appear on the ground. These factors disrupt the continuity of pedestrian movement and pose issues not only for people with disabilities and parents with strollers but also for healthy adults, creating both problems and hazards. It is also evident that the pretty old pavement materials have become problematic over time. Due to poor sub-base preparation in material

applications, depressions have formed over time, creating uneven surfaces on the sidewalks, and maintenance-related issues have arisen.

In the area surrounding the Yeşil Türbe (Green Tomb) and Yeşil Cami (Green Mosque), the narrow spacing between buildings has resulted in a roadway that is as narrow as possible, and the sidewalks are pretty poorly maintained, leading to difficulties for all users. In some parts of the area, standard brick flooring is applied on pedestrian sidewalks. The road width is insufficient, and traffic flows in both directions, with sidewalk widths occasionally narrowing to as little as 60 cm.

As one approaches the city center, the type of materials used changes, and different materials are observed on the ground. The width of the sidewalks increases as one gets closer to the center. The quality of the materials is generally good around historical structures such as buildings, mosques, and tombs.

Within the study area's boundaries are 3-4 lane roads, such as Cemal Nadir and Atatürk Streets. Due to this area's high pedestrian and vehicle circulation, Cumhuriyet Street has been closed to vehicular traffic, and traffic on Atatürk and Cemal Nadir Streets flows in one direction only. The width of the sidewalks extends to a minimum of 2 meters but is still insufficient. The curb heights have been raised to prevent vehicles from parking at the roadside. Within the study area, the pavement materials include marble, granite cubes, tumbled granite stones, andesite slabs, base bricks, gravel-filled empty concrete slabs, yellow marble, granite cubes, colored paving stones for disabled access, and natural slate stones.

Urban Texture: The construction in this area of Bursa began in the 14th century with the development of the inns (Hanlar) district (2025a). The quality and cleanliness of the materials used during that period and the design approach have created a unique model that has lost architectural unity over time. In other words, it is impossible to speak of a general architectural characteristic in the streets that feature buildings constructed after the 1950s. This situation is further complicated by the irregularity of promotional signage on building facades, resulting in a chaotic appearance. Each of these elements, which physically delimit and enclose the street, represents individual choices made at the level of shops/stores/passages, and it is evident that little attention has been paid to their coherence with each other.

Land Uses: In this context, various land use types, such as transportation, parking, recreation areas, dining areas, shopping areas, squares, and green spaces, have been evaluated within the study area. The study area is located on a backbone formed by transportation systems. Along with the transportation networks, the area also features numerous roadside parking spaces. Surrounding these transportation networks are squares such as Orhangazi Square and Gazi Orhan Park. These squares and their surroundings are further enriched with resting areas and small pockets of leisure spaces near the transportation routes. One of the primary land uses in the area is dining and shopping spaces, which are among the essential functions of the region. Additionally, green spaces are another significant land use within the area. In regions with heavy pedestrian and vehicular traffic, most enclosed and open parking lots are located on the area's periphery and along the main road route in opposite directions, creating a significant transportation issue for users. When evaluating open and green space arrangements about transportation axes, the width of streets and sidewalks is critical in shaping the usage areas. Green spaces along the roads provide resting and shaded areas for users. In terms of commercial potential, the area is dominated by the retail and marketing sectors across all regions. Furthermore, there are also food and beverage establishments within the area.

Plant Material: The street trees in pedestrian areas play an essential role in organizing the streetscape, contributing to the physical definition of space in open areas. Although not consistently present throughout the area, street trees can be found in various locations. Particularly on wider streets, such as Atatürk Street and Cemal Nadir Street, the diversity of plant species along the roads increases. Several historical trees, such as plane trees and cedar trees, can be found in places like Okçu Baba Park, the park area next to the Ulucami Mosque, and the garden of the Bursa City Museum. Notable street tree species in the area include Fraxinus ornus (Flowering Ash), Platanus orientalis (Oriental Plane), Tilia tomentosa (Silver Linden), and Aesculus

hippocastanum (Horse Chestnut). Platanus orientalis (Plane) trees particularly enclose the area surrounding the Yeşil Türbe and Yeşil Cami. In addition to permanent green spaces and trees, plant compositions are created in broad sidewalk areas using wooden fences and planters. The species used in these areas are generally slow-growing, shapeable, and prunable shrub and small tree species. However, a cohesive overall unity has not been achieved due to the irregularity of the street trees and the intermixing of species such as linden and plane trees.

Structural Landscape - Furnishing Elements: It has been observed that the street furniture, which constitutes most of the pedestrian space's landscape elements, is not used to create cohesion across the working area. In the shopping street, where pedestrian activity is intense, an average sidewalk width of 3.5 meters is not expected to accommodate all the street furniture elements. However, essential urban furniture elements such as lighting fixtures, benches, trash bins, signs, wayfinding boards, kiosks, and advertisement panels should be organized and positioned in harmony with each other and the surrounding environment. Therefore, selecting the type and style of street furniture is essential. There appears to be complete chaos within our study area, as there is no unity in materials and design. The limiting elements on the street have been created with different designs and materials as needed, resulting in a lack of material and design coherence in the area. Different materials and designs have been used in all the furniture elements, including benches, trash bins, lighting, and boundary elements.

- Historical and Cultural Structures: The area contains numerous significant buildings such as mosques, baths, cultural centers, museums, caravanserais, and historic houses, each holding substantial historical and artistic importance. Some of these structures include:
- Yeşil Tomb: Located just above the Yeşil Mosque, Yeşil Tomb was commissioned in 1421 by Çelebi Mehmet, the son of Yıldırım Bayezid. The tomb is one of the significant examples of early Ottoman architecture, noted for its rich decorations and architectural features.
- Yeşil Mosque: Situated in the Yeşil neighborhood, the Yeşil Mosque was commissioned in 1419 by Çelebi Sultan Mehmed. The mosque, with its reverse "T" plan, is one of the early examples of Ottoman mosque architecture. External walls surround the mosque courtyard, and upon entering through the garden gate, visitors encounter historical Platanus orientalis (plane) trees. Tourists and day-trippers frequently use this large courtyard.
- Irgandı Bridge: Located to the south of Boyacı Kulluğu Bridge, Irgandı Bridge was constructed during the reign of Sultan Murad II. In Evliya Çelebi's Seyahatname (1640), it is noted that 200 shops existed on the bridge. Today, there are a total of 32 shops on both sides of the bridge (2025b).
- Kılıç Kalkan House: Kılıç Kalkan House is an important cultural center where the historic Kılıç Kalkan (Sword and Shield) Dance, one of Bursa's most significant folkloric symbols, is performed (2025c).
- Bursa City Museum: As one of the oldest settlements in Anatolia and a pioneer in urbanization history, the Bursa City Museum showcases the city's transformations throughout its 7,000-year history (2025d).
- Ulu Mosque: Ulu Mosque, which occupies a large area near Orhan Gazi Park, was built during the reign of Yıldırım Beyazıt in the 14th century. It is one of the earliest examples of multi-domed mosques in the Ottoman period. The western minaret was built during Yıldırım Beyazıt's reign, and the eastern minaret was constructed by Çelebi Sultan Mehmed (2025e).
- Atatürk Monument: The structure is located in an area that shapes Bursa's urban identity and holds significant importance in the collective memory of society. Following the construction of the Atatürk Monument in 1931, the area began to be referred to by the public as "Heykel" (Statue). At the same time, the monument, which serves as the focal point of the Republic Square, is positioned on an elevated base, allowing it to be perceived and visually recognized from the surrounding area. Around the monument are hard surfaces, green spaces, an amphitheater behind it, and seating elements (Okumuş, 2021).

- Ahmet Vefik Paşa Theater: The theater used by the Bursa State Theater is named after Ahmet Vefik Paşa, who founded the first Turkish theater in Bursa. Ahmet Vefik Paşa served as the governor of Bursa from 1879 to 1882 and established a theater in the city during his tenure. Completed in 1940, the theater has been operating under the General Directorate of State Theaters since 1957 and is the first regional theater under this institution (2025h).
- Koza Khan: Koza Han, built in the late 15th century during the reign of Sultan Bayezid II, was designed by the architect Abdül Ula bin Pulat Şah. The caravanserai continues to serve commercial functions today (2025ı).
- Tophane Clock Tower and Osmangazi-Orhangazi Tombs: Tophane Park, which contains the Osmangazi and Orhangazi Tombs, was constructed during the reign of Orhan Gazi (1281-1362). The tomb has changed its function following the conquest of Bursa. A clock currently stands in the location, and the Bursa Metropolitan Municipality uses it as a fire lookout tower (2025f).
- Bursa Caravanserai/Khans area District: Bursa, located on the trade routes of Anatolia, is famous for its caravanserais and inns where merchants would stay overnight. As a historically significant commercial city, Bursa's economy has been closely linked to these caravanserais and covered bazaars. The area began as a commercial district in the 14th century and was developed with inns, covered bazaars, and bazaars by the 16th century. This region includes essential structures such as Koza Han, Fidan Han, Pirinç Han, İpek Han, Emir Han, Geyve Han, Galle Han, Çukur (Kütahya) Han, Kapan Han, and Tuz Han (2025g).

Current Tourism Utilization in the Area: The city center of Bursa holds significant potential for tourism due to its natural landscape and historical richness. This region, in particular, attracts a high volume of visitors, primarily for historical tourism and religious tourism. However, it has been observed that tourists arriving from outside the city center face challenges in locating historical buildings and key tourist sites. One of the main reasons for this issue is the insufficient information and directional signs, and their lack of proper placement at strategic locations. In addition to numerous tombs, mosques, caravanserais, baths, historical structures, and artifacts found in the area, visitors are also drawn to the region through activities such as shopping and gastronomic tourism. This area, which encompasses Bursa’s natural and cultural heritage, generates significant interest in tourism and recreation. Key tourist attractions in Bursa, including Ulucami, the Grand Bazaar (Kapalıçarşı), the Hanlar District, Koza Han, Yeşil Türbe, Yeşil Camii, Irgandı Bridge, Tophane, and the Orhangazi and Osmangazi Tombs, are among the most significant historical and tourist landmarks of the region. These structures enhance the city's tourism potential and play a vital role in promoting Bursa’s rich cultural heritage.

3.2 SWOT analysis of the area based on tourism and recreational uses

The sustainable potential of the study area within the urban landscape character has been evaluated in terms of its strengths, weaknesses, opportunities, and threats. In addition, a detailed and methodologically grounded analysis has been conducted to examine the area's current state under eight main categories. Each category has been subdivided into sub-parameters. These parameters have been assessed based on their strengths, weaknesses, opportunities, and threats in specific zones within the study area. The impacts of these parameters on the region have been analyzed through SWOT analysis (Table 2).

The SWOT analysis conducted regarding the tourism and recreational use of the study area has evaluated various factors in the region. In terms of transportation, the presence of both vehicle and pedestrian pathways and the diversity of alternative transportation options has been identified as a strength. However, parking facilities and stop points, developed in connection with transportation systems, were found to be insufficient and considered a weakness. Additionally, the lack of rest areas, when considering the boundaries of the entire study area, was noted as a weakness. On the other hand, food and beverage establishments and shopping

areas stand out as strengths. The squares within and around the area, which possess historical and urban features, have been evaluated as both a strength and an opportunity for the area.

The study area is located in an urban setting, and due to the surrounding urban development and construction, the lack of green space has emerged as a threat. However, the presence of historical sites and the green spaces within these sites is an essential value for the area. Additionally, green spaces in other regional uses have been assessed as a strength.

Located at a significant point in Bursa, the study area can be defined as a densely populated zone for vehicle and pedestrian use. The transportation opportunities within and around the area have been evaluated according to various accessibility criteria, and this situation is regarded as a strength and opportunity for the area. However, factors such as road width, the presence of stairs, the condition and width of pedestrian paths, the existence of bicycle lanes, compliance with standards for accessibility, and maintenance issues have been identified as weaknesses. The material properties used on the roads were considered a strength, as they are suitable for walking. However, surface coverings and the width of connecting paths were considered potentially hazardous elements for the area.

The dominance of urban fabric is another key characteristic observed in this study area. While Ottoman-period buildings and structures exist within the region, modern-era buildings are also present.

This juxtaposition highlights the traditional fabric as a strength, but structures that contradict this conventional fabric and may disrupt it were assessed as weaknesses. This contradiction also applies to the surrounding areas, and it is generally regarded as a weakness and a threat.

Regarding vegetative material, street trees within the area were considered a weakness. Still, the natural structures and the associated pathways in the surrounding area offer a significant opportunity for the system. Although there are trees, shrubs, and trimmed bushes outside the road systems in the area, their presence is insufficient. However, such vegetative materials in the surrounding natural and cultural regions present a significant opportunity for the area.

Although coniferous trees are insufficient, their existence in the surrounding area is an opportunity. The presence of broadleaf trees was considered a strength. Monumental trees are significant parameters for preserving plant material and essential values. The enormous trees in the study area are regarded as a strength, while the immense trees in the surrounding area present an opportunity for continuity within the region.

Regarding structural landscape and amenities, the seating-resting areas and seating units within the area were found to be insufficient, and this issue extends to the surrounding area, posing a threat to recreational use.

On the other hand, amenities such as waste bins found within pedestrian axes, shopping areas, and commercial zones are adequately provided, and this situation is also sufficient in the surrounding area. Similarly, lighting elements are adequate, which is considered a strong feature of the area. Signage and directional signs within the area were found to be acceptable and were evaluated as a strength.

However, advertisement boards were insufficient and were assessed as a weakness. Boundary elements, water features, and fountains were considered sufficient and strong features for the area. The study area and its surroundings house important historical and cultural values for Bursa, which adds significant value to the area. Additionally, historical and cultural values around the area create a substantial opportunity for the region. With these values, the area also possesses rich characteristics for tourism activities. The area has a strong feature in terms of faith-based tourism and offers various opportunities related to this feature.

The study area holds significant value in its historical, cultural, and natural heritage, contributing to different cultural activities such as museum tours, architectural tours, historical tours, festivals, traditions, cultural walks, cultural axes, and traditional food and beverage features. These strengths also present opportunities for the area.

Factors	**Internal characteristic**		**External characteristic**	
Accessibility	***Strengths***	***Weakness***	***Opportunity***	***Threat***
Existing roads	X	0	0	0
Roads connecting to the area	0	0	X	0
Existing road widths	0	X	0	0
Stairs/Steps	0	X	0	0
Presence of pedestrian paths	0	X	0	0
Pedestrian path widths	0	X	0	0
Presence of bicycle paths	0	X	0	0
The width of the roads connecting to the area	0	0	0	X
Compliance of existing roads with accessibility standards	0	X	X	0
Accessibility standards on roads connecting to the area	0	X	X	0
Pedestrian-friendly pavement materials on existing roads	X	0	0	0
Pedestrian-friendly pavement materials on roads connecting to the area	0	0	0	X
Maintenance	0	X	0	X
Urban Texture	***Strengths***	***Weakness***	***Opportunity***	***Threat***
Traditional architectural Texture	X	X	0	0
The traditional architectural texture in the areas parallel to and surrounding the site	X	X	X	0
The urban texture features a combination of different architectural characters	0	X	0	X
Promotional signs mounted on building facades	0	X	0	X
Land Uses	***Strengths***	***Weakness***	***Opportunity***	***Threat***
Transportation	X	0	0	0
Parking	0	X	0	0
Rest areas	0	X	0	0
Dining areas	X	0	0	0
Shopping areas	X	0	0	0
Squares	X	0	X	0
Green areas	X	0	0	X
Plant Material	***Strengths***	***Weakness***	***Opportunity***	***Threat***
Roadside trees	0	X	X	0
Trees, Shrubs	X	X	X	0
Conifers	0	X	X	0
Broadleaf trees	X	0	X	0
Monumental trees	X	0	X	0
Structural Landscape - Furnishing Elements	***Strengths***	***Weakness***	***Opportunity***	***Threat***
Seating/Rest Areas - Seating Units	0	X	0	X
Recreational Uses - Pedestrian Areas - Shopping Areas - Commercial Areas - Trash Bins	X	0	X	0
Recreational Uses - Pedestrian Areas - Shopping Areas - Commercial Areas - Lighting	X	0	X	0
Directional signs, Signage along road routes	X	0	0	0
Billboard, Billboards along road routes	0	X	0	0
RecreatiOnal Uses - Pedestrian Axes - Shopping Areas - Commercial Areas - Boundary Elements	X	0	0	0
Recreational Uses - Pedestrian Areas - Shopping Areas - Commercial Areas - Squares - Water Features	X	0	0	0
Recreational Uses - Pedestrian Areas - Shopping Areas - Commercial Areas - Fountains	X	0	0	0

Historical And Cultural Structures	***Strengths***	***Weakness***	***Opportunity***	***Threat***
Mosques	X	0	X	0
Inns	X	0	X	0
Tombs	X	0	X	0
Bazaar	X	0	X	0
Museum	X	0	0	0
Bridge	X	0	0	0
Statue	X	0	0	0
Other (Clock Tower, Historical Restaurant, Theatre, Cultural Center, Library, Etc.)	X	0	X	0
Tourism Activities	***Strengths***	***Weakness***	***Opportunity***	***Threat***
Religious tourism	X	0	X	0
Historical and cultural heritage	X	0	X	0
Natural heritage	X	0	0	0
Museum tours, Architectural tours, Historical tours	X	0	X	0
Festivals, Traditions	X	0	X	0
Cultural walks, Cultural routes	X	0	0	0
Traditional food and beverages	X	0	0	0

Tab.2 Evaluation of Key Criteria Based on SWOT Analysis

3.3 Weighted score of SWOT analysis results

The values identified through the SWOT analysis were calculated separately for each criterion. Each criterion's priority and average scores were multiplied to obtain the weighted scores. Using these weighted scores, the total value of the area and the distribution of the total score across the main criteria were calculated. According to the evaluation results, historical and cultural structures held the highest percentage in this distribution. In contrast, the accessibility value received the lowest score in the area (Tab.3, Fig.3).

Factors	**Internal characteristic**		**External characteristic**			
Accessibility	**S**	**W**	**O**	**T**	**Average**	**Weighted score**
Existing roads	4	0	0	0	1.00	4.00
Roads connecting to the area	0	0	3	0	0.75	2.25
Existing road widths	0	2	0	0	0.50	1.00
Stairs/Steps	0	2	0	0	0.50	1.00
Presence of pedestrian paths	0	2	0	0	0.50	1.00
Pedestrian path widths	0	2	0	0	0.50	1.00
Presence of bicycle paths	0	2	0	0	0.50	1.00
The width of the roads connecting to the area	0	0	0	1	0.25	0.25
Compliance of existing roads with accessibility standards	0	2	3	0	1.25	6.25
Accessibility standards on roads connecting to the area	0	2	3	0	1.25	6.25
Pedestrian-friendly pavement materials on existing roads	4	0	0	0	1.00	4.00
Pedestrian-friendly pavement materials on roads connecting to the area	0	0	0	1	0.25	0.25
Maintenance	0	2	0	1	0.75	2.25
					TOTAL	30.50

Urban Texture	S	W	O	T	Average	Weighted score
Traditional architectural texture	4	2	0	0	1.50	9.00
The traditional architectural texture in the areas parallel to and surrounding the site	4	2	3	0	2.25	20.25
The urban texture features a combination of different architectural characters	0	2	0	1	0.75	2.25
Promotional signs mounted on building facades	0	2	0	1	0.75	2.25
					TOTAL	33.75

Land Uses	S	W	O	T	Average	Weighted score
Transportation	4	0	0	0	1.00	4.00
Parking	0	2	0	0	0.50	1.00
Rest areas	0	2	0	0	0.50	1.00
Dining areas	4	0	0	0	1.00	4.00
Shopping areas	4	0	0	0	1.00	4.00
Squares	4	0	3	0	1.75	12.25
Green areas	4	0	0	0	1.75	6.25
					TOTAL	32.50

Plant Material	S	W	O	T	Average	Weighted score
Roadside trees	0	2	3	0	1.25	6.25
Trees. Shrubs	4	0	3	1	2.25	20.25
Conifers	0	2	3	0	1.25	6.25
Broadleaf trees	4	0	3	0	1.75	12.25
Monumental trees	4	2	3	0	1.75	12.25
					TOTAL	57.25

Structural Landscape- Furnishing Elements	S	W	O	T	Average	Weighted score
Seating/Rest Areas - Seating units	0	2	0	1	0.75	2.25
Recreational Uses - Pedestrian Axes - Shopping Areas - Commercial Areas - Trash bins	4	0	3	0	1.75	12.25
Recreational Uses - Pedestrian Areas - Shopping Areas - Commercial Areas - Lighting	4	0	3	0	1.75	12.25
Directional signs. Signage along road routes	4	0	0	0	0.50	1.00
Billboards. along road routes	0	2	0	0	0.50	1.00
Recreational Uses - Pedestrian Areas - Shopping Areas - Commercial Areas - Boundary elements	4	0	0	0	0.50	1.00
Recreational Uses - Pedestrian Areas - Shopping Areas - Commercial Areas - Squares - Water Features	4	0	0	0	1.00	4.00
Recreational Uses - Pedestrian Areas - Shopping Areas - Commercial Areas - Fountains	4	0	0	0	1.00	4.00
					TOTAL	37.75

Historical and Cultural Structures	S	W	O	T	Average	Weighted score
Mosques	4	0	3	0	1.75	12.25
Inns	4	0	3	0	1.75	12.25
Tombs	4	0	3	0	1.75	12.25
Bazaar	4	0	3	0	1.75	12.25
Museum	4	0	3	0	1.75	12.25
Bridge	4	0	0	0	1.00	1.00

Statue	4	0	3	0	1.75	12.25
Other (Clock Tower, Historical Restaurant, Theatre, Cultural Center, Library, Etc.)	4	0	3	0	1.75	12.25
					TOTAL	89.75
Tourism Activities	**S**	**W**	**O**	**T**	**Average**	**Weighted score**
Religious tourism	4	0	3	0	1.75	12.25
Historical and cultural heritage	4	0	3	0	1.75	12.25
Natural heritage	4	0	3	0	1.75	12.25
Museum tours, Architectural tours, Historical tours	4	0	3	0	1.75	12.25
Festivals, Tradition	4	0	3	0	1.75	12.25
Cultural walks, Cultural routes	4	0	3	0	1.75	12.25
	4	0	3	0	1.75	12.25
					TOTAL	85.75
					OVERALL TOTAL	367.25

Tab.3 Weighted Score of SWOT Analysis

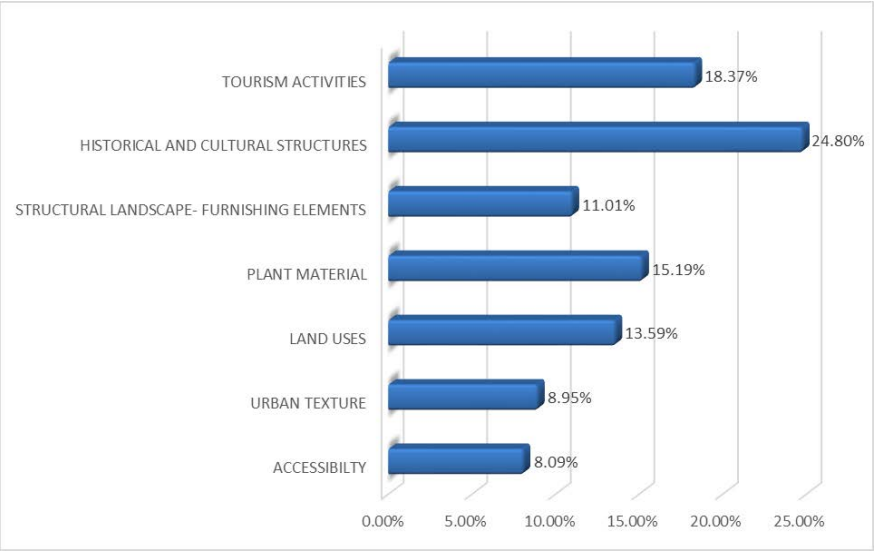

Fig.3 Comparison of evaluation criteria

4. Discussion

Historical city centers are among the most significant urban areas, representing the spatial reflections of past societies' cultural, social, philosophical, religious, architectural, aesthetic, technical, economic, and political traces. The relationships between history, space, and society are formed in these areas.

Their preservation depends on maintaining continuity between past, present, and future balancing original values with contemporary functions, and transferring physical and social heritage to future generations. Enhancing spatial quality and ensuring sustainability are critical (Çermikli, 2016).

In recent years, growing interest in tourism has led to diversification and development in both natural and cultural domains. Especially in areas rich in historical and cultural values, increasing tourist demand must be evaluated within the framework of conservation-use balance and sustainability. In this context, SWOT analysis is an effective tool for guiding planning strategies and informing decision-making processes. SWOT not only reveals the potential of an area but also contributes to planning through both qualitative and quantitative assessments. This study employed SWOT analysis to define planning decisions along a significant cultural route within Bursa's historic center. Urban landscape character components —land use, accessibility, cultural

identity, landscape infrastructure, and tourism activities— were evaluated. The analysis revealed that historical and cultural structures received the highest score (24.80%), emerging as the strongest feature, while accessibility scored the lowest (8.09%), marking it as one of the primary weaknesses. Accordingly, based on the SWOT analysis conducted for the area, the key strengths, weaknesses, opportunities, and threats have been effectively identified and are presented in Tab.4.

Streghts	**Weakness**
Offering visitors an authentic, holistic, and vibrant urban atmosphere through the preservation of historical and cultural heritage elements (such as mosques, caravanserais, tombs, museums, and bazaars), the traditional architectural fabric, green spaces, and an integrated shopping and gastronomy experience within the historical environment.	Insufficient accessibility, inadequate wayfinding infrastructure, narrow pedestrian zones, and irregular signage contribute to visual pollution and negatively affect the visitor experience, thereby diminishing the functionality and holistic perception of the area.
Opportunities	**Threats**
Enriched with themes such as faith tourism, cultural heritage routes, festivals, and traditional gastronomy, the area highlights its environmental values through monumental trees and landscape elements. It holds significant potential for developing sustainable and experience-oriented tourism routes through pedestrian-focused and wayfinding-supported corridor planning.	Insufficient transportation connections, physical deterioration due to intensive use, identity erosion caused by architectural incompatibilities, and the threat posed to green spaces and cultural heritage elements by urban pressures present significant risks to the area's sustainability.

Tab.4 SWOT Analysis

The strong score of historical and cultural structures highlights the dominance of tangible heritage in shaping both the identity and attractiveness of the city center. This confirms the theoretical assumption that physical monuments and historical landmarks play a key role in anchoring collective memory, establishing place identity, and acting as catalysts for tourism. However, these static elements alone cannot sustain long-term engagement unless supported by accessible and inclusive public space networks. Conversely, the low accessibility score reveals a fundamental shortcoming in the spatial configuration and mobility systems of the area. Poor pedestrian circulation, lack of ramps or inclusive infrastructure, and disorganized wayfinding limit the usability of the heritage space for different user groups. This is especially problematic for vulnerable populations such as the elderly, people with disabilities, and families with children. The implication is that physical preservation must be accompanied by social inclusion to meet the requirements of sustainable urban tourism. Field observations demonstrated that the area possesses both positive and negative attributes regarding structural and functional aspects. Urban focal points, recreational areas, historic structures, and shopping streets are heavily used. However, this density leads to visual clutter, reduced usable space, and restricted pedestrian movement. For example, restaurant sidewalk encroachments and improperly placed vendor stalls limit mobility, particularly on narrow walkways.

Comparative literature supports these findings. Batman et al. (2024) emphasize that dense construction and excessive hardscape along Atatürk Street do not contribute to ecological landscape quality and fail to reflect the city's historical identity. Yenice (2014) proposed revitalization strategies in Konya's city center by integrating cultural assets such as Mevlana and Mevlevi heritage into tourism. Similarly, Turgut & Özden (2005) suggested a SWOT-based development model for Istanbul's Eminönü district that supports historical identity. Using spatial indexing and landscape metrics, Cengiz and Günaydın (2021) enhanced urban readability in the Malatya city center. Keçeci et al. (2021) developed landscape-based coastal development strategies for Yalova’s urban core using SWOT analysis to identify strengths and weaknesses. Aydın Türk (2006) employed SWOT and TOWS matrices in Trabzon/Akçaabat to propose an integrated urban planning model. Recent studies further reinforce the importance of combining SWOT with AHP methods in strategic planning for

heritage-rich urban contexts. For instance, Dahmani & Makhloufi (2023), in their study of Bou Saada (Algeria), used SWOT–AHP to identify environmental degradation and lack of heritage-focused tourism products as key threats, while highlighting eco-tourism potential as a critical opportunity. Similarly, Gerami & Hosseini (2021) proposed an offensive tourism strategy for Iran's Pasargad World Heritage site based on local environmental and cultural assets. These studies highlight the transferability and analytical robustness of the weighted SWOT framework used in our research.

Other contemporary research underlines the role of mixed methods and route planning in preserving historic urban landscapes. Ramazanova et al. (2025) conducted on-site interviews, social surveys, and workshops in Porto to explore how visitor experiences can foster heritage conservation. Meanwhile, in a UNESCO-listed port city in Türkiye, Karataş et al. (2025) applied integrated GIS–AHP–SWOT tools to develop an eco-cultural tourism route for under-researched regions. These examples resonate with our corridor-based approach in Bursa and emphasize the importance of participatory and data-driven strategies in heritage and tourism planning.

These studies collectively highlight the necessity of sustainable, inclusive, and locally grounded planning approaches in historic urban centers. Our findings confirm that historical and cultural assets constitute the city center's core values in tourism planning. However, accessibility received the lowest score, which points to a critical issue regarding spatial justice and inclusivity. Inadequate access particularly affects vulnerable groups such as older people, families with children, and individuals with disabilities. Thus, sustainable tourism must go beyond physical conservation to include diverse user needs and universal accessibility.

Furthermore, the analysis indicates that high criteria reflect passive conservation elements, whereas lower scores correspond to active areas requiring design and policy interventions. This reveals a gap in local planning: while there is awareness regarding heritage conservation, there is insufficient strategic focus on contemporary urban needs such as pedestrian flow, wayfinding, and public comfort. Compared to the literature, our findings emphasize that city centers should be evaluated based on historical-cultural identity, experiential quality, accessibility, and overall public space performance. The Bursa example reveals the urgent need to build a sustainable bridge between spatial heritage and contemporary urban life. Hence, the implications of this study are not limited to Bursa. It offers transferable insights for the planning, managing, and designing of other historic city centers facing similar challenges. Especially in contexts with growing tourism pressure and fragile conservation-use balance, spatial quality and accessibility-focused strategies must be more systematically integrated. This research contributes to the theoretical discourse on sustainable tourism and heritage planning by operationalizing a landscape-based SWOT analysis model that integrates spatial accessibility with cultural-historical valuation. Moreover, the emphasis on multi-scalar planning and the layered structure of landscape values respond to emerging concepts in cultural landscape theory, where urban heritage is understood as a dynamic system rather than a static artifact.

5. Conclusion

This study underscores the necessity of integrating historical and cultural values into tourism sustainably and functionally within historic urban centers. In line with the objectives outlined in the introduction, the research emphasizes the importance of improving spatial quality, conserving cultural heritage, and approaching tourism planning through a holistic framework.

A weighted SWOT analysis allowed for a multi-dimensional evaluation of the historical urban fabric. The study identified actionable and context-sensitive planning strategies by combining qualitative and quantitative data. The findings reveal that historical and cultural structures are the strongest assets, while shortcomings in accessibility, wayfinding, and circulation infrastructure represent critical weaknesses.

These insights are relevant to Bursa and offer valuable implications for other cities with comparable historical fabrics. The study contributes methodologically and theoretically to academic literature by showcasing the

applicability of the weighted SWOT framework in strategic planning for urban heritage areas. It provides a model that can be adapted to other contexts within cultural heritage management, urban design, and sustainable tourism policy.

From a policy-making perspective, the study presents the following concrete recommendations:

- Improve accessibility infrastructure (e.g., inclusive pedestrian pathways, signage systems, transportation connectivity);
- Implement landscape interventions to reduce visual and physical clutter (e.g., sidewalk encroachments, irregular vending units);
- Develop capacity-based management plans for high-traffic heritage areas.
- Align tourism policies with the socio-cultural needs of the local population;
- Promote identity-sensitive and environmentally conscious urban landscape design.

These proposals aim to enhance the physical environment and support social cohesion, cultural continuity, and local economic resilience. Ultimately, the successful implementation of sustainable tourism strategies in historic urban centers depends on integrating urban landscape planning into multi-layered and interdisciplinary approaches. Such integration can contribute to the protection of cultural heritage and strengthen the urban social fabric and overall quality of life.

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Assessing the impacts of climate change on peri-urban land use in Nigeria. A study of Ibeju-Lekki LGA, Lagos State

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Abstract
The study investigated the impact of climate change on land use dynamics in the peri-urban region of Nigeria, focusing on Ibeju-Lekki Local Government Area (L.G.A.) in Lagos State. Integrating both primary and secondary data, the study deployed a structured questionnaire which was administered among 125 respondents across three peri-urban communities in Ibeju-Lekki: Imobido, Idaso, and Ilege. Geographic Information System (GIS) tools, alongside Landsat 7 and 8 imagery, were used for comprehensive land use and land cover (LULC) analysis. The Normalized Difference Vegetation Index (NDVI) was employed to quantify temporal changes in vegetation cover, revealing notable shifts in land use patterns. Findings underscore significant LULC changes within Ibeju-Lekki, reflecting the extensive influence of climate change on land management and urban planning in rapidly urbanizing peri-urban areas. The study highlights the necessity for integrated, adaptive land use policies that address climate-induced challenges and promote sustainable development. These insights offer policy recommendations aimed at enhancing resilience in land use systems, fostering a model for sustainable urban expansion in similar coastal communities.

Keywords
Climate change; Land use and land cover; Peri-urban; Geographic information system; Flooding

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1. Introduction

Climate change, as asserted by Ahove et al. (2021), stands out as a prominent global environmental concern that has garnered widespread attention due to its multifaceted impacts. It represents a singular issue that has spawned a multitude of related challenges, including but not limited to flooding, rising sea levels, warming oceans, heightened temperatures, fluctuations in rainfall patterns, increased evaporation rates, and the intensification of tropical storms. These consequences have manifested in various adverse effects, such as diminished agricultural productivity, drought occurrences, population displacement, public health issues, conflicts between farmers and herders, inundation events, soil erosion, food insecurity, and poverty. Moreover, additional ramifications are anticipated as the full extent of climate change unfolds. Since the early 1990s, climate change has gained prominence as a significant concern for development, primarily owing to its anticipated effects on biodiversity, rural communities, and both national and global economies. The adverse impacts of climate change are expected to disproportionately affect impoverished nations and individuals, who possess limited institutional support, financial resources, and technological capabilities necessary for adaptation (Ogunnaike et al., 2013). Extreme weather events of rare severity that are expected to occur within a 100-year frequency have been noted in almost all regions of the world challenging the traditional forecasting patterns (Pennino, 2024). Climate change is usually caused by the rising average temperature of the earth due mainly to global warming and majorly Human activities, particularly widespread land-use change, large-scale deforestation, and prolonged reliance on fossil fuels, can worsen climate change. Land use is a process of turning the natural ecosystem (land cover) into a socioeconomic ecosystem (Olokeogun et al., 2014). Over time, the rise in population and human activities, such as the conversion of natural land cover such as forests and wetlands to impervious surfaces like roads and buildings, has significantly disrupted natural ecosystem processes (Ogunlade et al., 2021). Peri-urban areas, located at the interface between urban and rural zones, experience dynamic land use changes driven by urban expansion, population growth, and economic development (Tacoli, 2003). These areas often serve as transitional zones where agricultural lands are converted to residential, commercial, and industrial uses, leading to significant alterations in land use patterns (Varkey, 2019). The vulnerability of peri-urban areas to climate change is heightened by their exposure to both urban and rural stressors, making them critical zones for studying the impacts of environmental changes on land use.

As cities expand and develop, they often drive significant changes in land use and land cover, triggering a cascade of ecological consequences. These changes pose substantial challenges to achieving environmental sustainability at both local and global scales. In recent decades, a growing concern has emerged: the ability of ecosystems to provide essential services, such as food production, freshwater resources, healthy forests, and climate and air quality regulation, is increasingly under threat. Addressing this challenge necessitates a delicate balancing act: meeting immediate human needs while safeguarding the biosphere's long-term capacity to provide these vital goods and services (Adewale et al., 2024). Sustainable development has become a cornerstone principle in land-use planning, emphasizing both the preservation of natural resources and the promotion of land-use patterns that are beneficial ecologically, socially, and economically (Leitão & Ahern, 2002).

As opined by Kebede et al. (2024), the factors influencing land use and cover change are complex, dynamic and vary between locations. The changes also are mostly as a result of both natural and human factors. Scholars have raised concerns regarding the ecological aspects of land-use planning, particularly within the framework of human-environment interactions. This framework emphasizes the interconnectedness of spatial and social dimensions within urban ecosystems (Pickett et al., 2001; Grimm et al., 2008).

Climate change, primarily driven by human activities and the emission of greenhouse gases, has become a significant issue with major political and economic consequences. The scientific agreement on this matter has

grown stronger, as highlighted in the Intergovernmental Panel on Climate Change's (IPCC) Fourth Assessment Report of 2007 (IPCC, 2007).

Nigeria on the other hand was also identified as one of the nation's most susceptible to the impacts of climate change (Okafor et al., 2025). This vulnerability is evidenced by the escalating instances of drought and desertification in the northern regions, as well as coastal flooding and erosion in the southern areas. A notable obstacle confronting Nigeria involves harmonizing its trajectory with the global trend toward low-carbon development, a daunting task given its heavy reliance on the oil and gas sector. This dilemma is particularly evident along the Lagos coastline, where the adverse effects of climate change, including rising sea levels and intensified weather extremes, disrupt both the physical landscape and socioeconomic frameworks (Okeke, 2022).

In Lagos and other subtropical regions, the most concerning impacts of climate change includes; increased flooding, environmental degradation, heightened pest and disease outbreaks on crops, depletion of household resources, rural-urban migration, biodiversity loss, wildlife depletion, shifts in vegetation types, declining forest resources, soil degradation (including moisture and nutrient depletion), increased health risks from infectious diseases, and disruptions to traditional livelihoods. Nigeria, being a developing country, is particularly vulnerable to the negative effects of climate change due to its heavy dependence on agriculture and natural resources for both sustenance and economic stability (Onyeneke et al., 2019). Ibeju-Lekki, a region within Lagos State, exemplifies a rapidly urbanizing area that is also highly susceptible to various climate change impacts, such as sea level rise, extreme weather events, and changes in rainfall patterns (Adelekan, 2010).

One major issue in Ibeju-Lekki is the spread of urban development into areas that were previously rural or semi-rural, resulting in the loss of agricultural land and natural habitats (Ajibade, 2017). This expansion not only changes the landscape but also threatens the livelihoods of local communities that rely on farming and natural resources. Additionally, the absence of effective land use policies and enforcement is exacerbating these problems, leading to unplanned and chaotic development. Moreover, the interaction between climate change and land use in Ibeju-Lekki is worsening environmental degradation. Problems like soil erosion, flooding, and water scarcity are becoming more common, undermining the area's ecological stability and resilience (Ndimele et al., 2024). These environmental changes are not only transforming the physical landscape but also posing serious risks to the socio-economic well-being of the local population.

Therefore, there is an urgent need for thorough research to understand the specific impacts of climate change on peri-urban land use in Ibeju-Lekki. This research investigates the impact of climate change on the interplay between land use and land cover (LULC) alterations in the peri-urban region of Ibeju-Lekki spanning from 1993 to 2023. The assessment of climate change impacts on land use in Ibeju-Lekki is crucial for understanding the interplay between environmental changes and human activities in peri-urban areas. By examining the effects of climate change on land use patterns, this study aims to provide insights into how climate-induced changes influence land allocation, resource management, and sustainable development in Ibeju-Lekki. Understanding these dynamics will aid in the formulation of adaptive strategies and policies to mitigate the adverse effects of climate change and promote resilient land use practices in peri-urban areas.

This research will provide crucial insights into how land use is changing in response to climate variability and help develop sustainable land use strategies that can reduce the negative effects of climate change while encouraging resilient and adaptive urban growth.

This was done by raising the following objectives: ascertain the various land uses in the study area; examine the extent to which climate change has affected land use in Ibeju-Lekki between 2003 and 2023; assess the vulnerability of different land use types to climate change impacts; identify adaptation and mitigation strategies to enhance the resilience of land use systems and finally, analyze the anticipated land use changes over the next decade.

2. Materials and methods

2.1 Research design

Both qualitative and quantitative methodologies was employed in this study, which included case study research design and geospatial analysis. Terrain changes related to land use, vegetation, and ecosystem services were evaluated. Utilizing remote sensing and geographic information systems, the study analyzed the impact of urban land use change effect on ecosystems and their services in Ibeju Lekki, assessing its repercussions on human well-being. The ultimate goal is to propose effective strategies to alleviate the impact of climate change on land use changes and its effects in this specific area.

2.2 Data collection

The primary data collection method involved the distribution of questionnaires to residents and the use of semi-structured interview guides with officials from the various State Government ministries, departments, and agencies in Ibeju Lekki. Additionally, historical satellite datasets were acquired from the United States Geological Survey (USGS). These datasets consisted of unprocessed but high-quality Landsat images captured in, 2003, 2013, and 2023, with specific details needed. These data will be employed to conduct spatio-temporal analyses of land cover changes, thereby examining shifts in land use and land cover within Ibeju Lekki over the specified study period. To supplement this analysis, Google Earth will be utilized to access historical information about Ibeju Lekki, aiding in ground-truthing efforts and the identification of key areas susceptible to significant changes in land cover. The secondary data sources for this research will include government reports and statistics between 1993 and 2023, which will be obtained from the Ministry of Lands in Lagos State. Population data will be obtained from the National Bureau of Statistics to project the population of Ibeju Lekki. Other data regarding historical temperature, human well-being, and ecosystem services will be obtained from academic journals, technical reports, conference proceedings and newspapers.

2.3 Study area

Ibeju-Lekki encompasses an approximate land area of 445 km², representing a significant portion of Lagos State's landmass, situated within the creek zone of tropical South-western Nigeria. Its geographical coordinates are Latitude 6029'36" N, Longitude 3043'14" E, and Latitude 6023'21" N, Longitude 4021'31" E. According to the 2006 Census data, the population of Ibeju Lekki was recorded as 117,793 individuals, with projections indicating an expected population increase to 388,226 by 2023, reflecting a growth rate of 3.2%. The region is characterized by relatively flat terrain, with an elevation of approximately 6.40m, and experiences a tropical climate featuring distinct rainy and dry seasons typical of a tropical monsoon climate. Rainy seasons occur from April to July, with a secondary rainy period, while a brief dry spell occurs in August and September, followed by a more extended dry season from December to March (Folorunso et al., 2024; Olomolatan et al., 2024; Adebisi et al., 2016). Notably, the Lekki Free Trade Zone (LFTZ), Dangote refinery and numerous housing estates are located within the Ibeju-Lekki local government area (LGA) of Lagos state, Nigeria. The area predominantly supports rural communities whose livelihoods depend on natural resource-based activities such as fishing, farming, and oil palm processing. It boasts an environmental landscape characterized by mangrove wetlands along the coasts of the Lekki Lagoon and lush tropical vegetation in central and lower areas, with the Atlantic Ocean and Lekki Lagoon serving as the primary water bodies in the region. These coastal features create a conducive environment for a variety of marine fish, which are crucial for the local economy. Additionally, the predominant soil type in the area is sandy and loosely loamy swamp marsh soil, ideal for palm trees and coconut farms, thereby supporting the promotion of ecotourism in Ibeju-Lekki. Consequently, the abundant marine and terrestrial resources fuel rapid development in the area (Uddin et al.,

2021; Adedire & Adegbile, 2018). Fishing serves as the primary source of income in Ibeju Lekki, supplemented by activities in hospitality, ecotourism, and housing development.

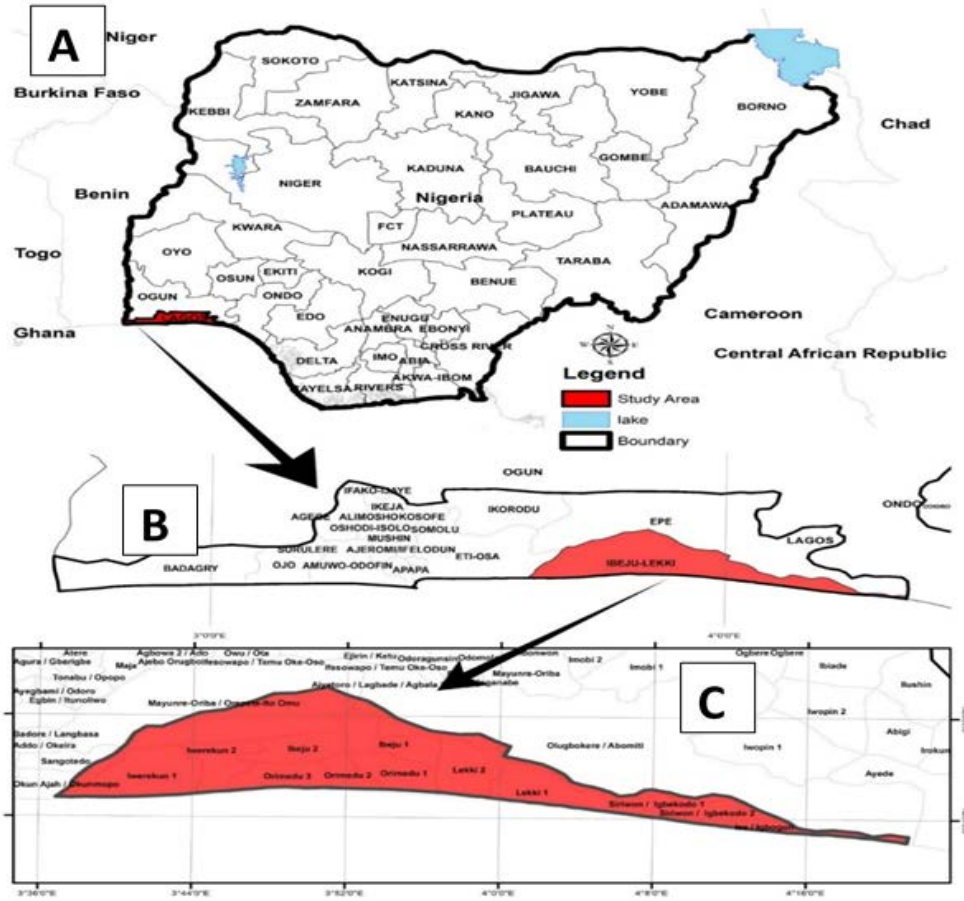


Fig.1 (A) Map of Nigeria showing Lagos State in the National Context, (B) Map of Lagos State showing Ibeju Lekki and (C) Map of Ibeju Lekki showing surrounding communities

2.4 Sample, sampling technique and data collection

The study population includes the companies, stakeholder groups, and communities along the Free Trade Zone and Dangote Refinery in Ibeju Lekki. From a preliminary investigation, 24 companies, 12 other stakeholder groups, and 15 communities are found in the free trade zone at Ibeju Lekki. Interview guide was adopted to elicit information from the companies and other stakeholder groups, while questionnaires were used for the communities. Three communities were randomly selected for questionnaire administration using the Random Number Generator of the SPSS package. The three communities are Ilege, Idasho, and Imobido. The systematic random sampling technique with replacement was adopted to select 20% of the buildings in each community for questionnaire administration. The Random Number Generator in the SPSS Application was used to select the first sample, and then every 5th building was selected for questionnaire administration. Where the selected building on the map is discovered to be commercial, religious or industrial purposes on the ground, it will be replaced with the nearest residential building. The selected sample is as seen in Tab.1.

Settlements	No. of buildings	Sample size (20%)
Ilege	171	34
Idasho	250	50
Imobido	204	41
Total	625	125

Tab.1 Selected settlements and sample size. Source: Authors' Field Work (2024)

Geographic Information Systems and Remote Sensing (GIS & RS) techniques were employed to perform a geospatial analysis regarding the land use land cover change analysis and Normalized Differential Vegetation Index (NDVI) in Ibeju Lekki. NDVI is a common tool used as an indicator to analyze the vegetation and the biomass of an area using multi spectral satellite images (Dahanayake et al., 2024). This involved using historical Landsat data in spatial analysis to ascertain changes over the years in the selected parameters. The Maximum Likelihood (ML) Classification Algorithm technique will be used for the classification. Map algebra script was used to generate spectral indices for the NDVI.

2.5 Data analysis

After obtaining Landsat imageries for 1993, 2003, 2013, and 2023. The images were pre-processed to establish a proper relationship between the acquired satellite data and various biophysical conditions (Abd El-Kawy et al., 2011). This is vital in rectifying and removing various atmospheric conditions from satellite images. A geometrically corrected satellite imagery is vital for successive land cover mapping and change detection analysis (Hassan et al., 2016). The study area was delineated using Google Earth Imagery and digitized into a polygon feature class using ArcGIS 10.8. This was overlaid on the acquired historical Landsat datasets. Appropriate band compositions were made using the Raster Processing algorithm in ArcGIS 10.8 for land use and land cover changes. The clip function was used to delineate the Landsat imageries using the digitized feature class as a mask. This enabled attribute of the study area to be obtained for the various years, displaying the different land uses and land cover.

From the Image Classification algorithm, a supervised classification function was adopted to create training samples, which was subjected to the Maximum Likelihood Classification technique. This produced classification including built-up areas, forest/vegetated areas, bare ground, and water bodies based on the study of (Anderson et al., 1976). These classifications were overlaid on a spatially disaggregated ecosystem dataset, which showed different ecosystem biomes in the study area. Hence, to aid the spatial analysis for detecting the ecosystem biomes that have depleted over the years through changes in spectral indices. The simple benefit transfer, as used by (Costanza et al., 2014) and (Popoola et al., 2018), was used to monetarily quantify the ecosystem services in Ibeju Lekki for the year 1993 as well as the changes in value by the year 2023. Maps will be produced to show areas of change and will be highlighted in percentages for the years considered. Classifications made for the Land Use Land cover map are seen in Tab.2.

Classifications	**Method of data collection**
Built-up areas	Residential, commercial, industrial, government facilities and settlements
Bare Land	Areas cleared for physical development are usually open spaces with little or no vegetation at all.
Dense Vegetation	Areas that are ever green with a high density of trees.
Sparse Vegetation	Open areas with very light vegetation.

Tab.2 Classification made for the Land Use Land cover map. Source: Popoola (2021)

The responses obtained from the companies and stakeholders was analyzed using the Content Analysis method. This method is used mainly in qualitative assessments, especially in interviews and focused group discussions. The responses were transcribed using Microsoft Excel for Content Analysis. The Statistical Package for the Social Sciences (SPSS) was used to enter, code and transpose the responses from the structured questionnaires.

3. Results and discussion

The socio-economic characteristics of the respondents reveal a diverse composition that reflects the dynamics of a peri-urban community undergoing change. The age distribution shows that the majority of the respondents are middle-aged, with 28.8% falling within the 40-50 years age bracket. This indicates that the area is predominantly populated by adults in their prime working years, which could influence local land use dynamics, as these age groups are typically more involved in economic and residential decision-making. However, considering the land use dynamics in the area such as the free trade zone, Dangote refinery and numerous new housing estates with the employment opportunities that come with them, having a working population in such a peri-urban area is not uncommon.

The gender distribution is skewed slightly towards females, who make up 53.6% of the sample. This female predominance is notable in peri-urban areas, where women often play significant roles in household management and informal trading activities, contributing to the local (Lenshie et al., 2021). In terms of educational attainment, most respondents (39.2%) have received secondary education, while a smaller percentage (21.6%) have attained tertiary education. This education profile suggests that the population is relatively well-educated, which could influence their awareness and adaptability to environmental changes, such as those brought about by climate change. Higher levels of education are often associated with greater involvement in decision-making processes and a better understanding of sustainable land use practices. The occupational data reveals that trading and self-employment are the most common occupations, each accounting for 25.6% of the respondents. This highlights the importance of informal economic activities in Ibeju-Lekki, which is consistent with findings in other peri-urban areas where formal employment opportunities are limited, and residents often engage in small-scale trading or entrepreneurship (Adeyinka et al., 2006). The prominence of self-employment and trading in this area underscores the potential vulnerability of these individuals to changes in land use, particularly if commercial spaces are affected by urban expansion or climate impacts such as flooding.

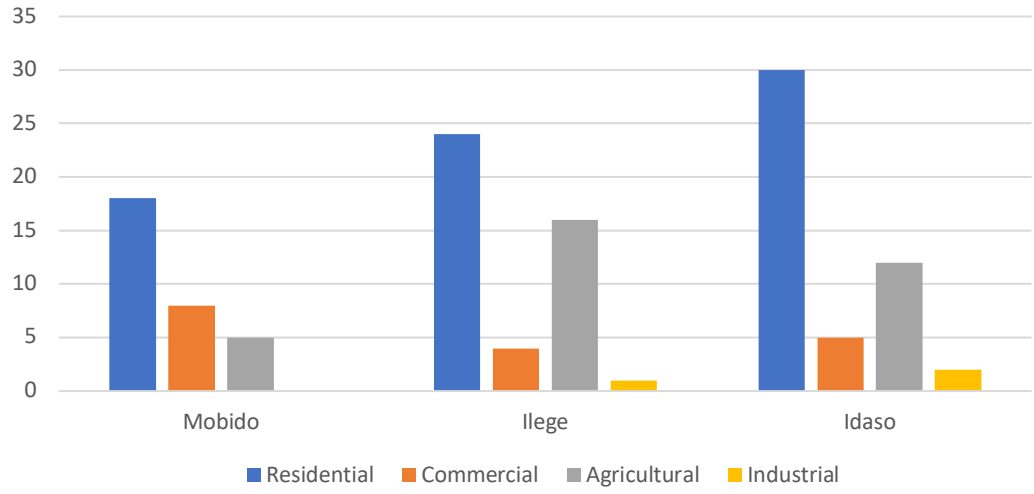
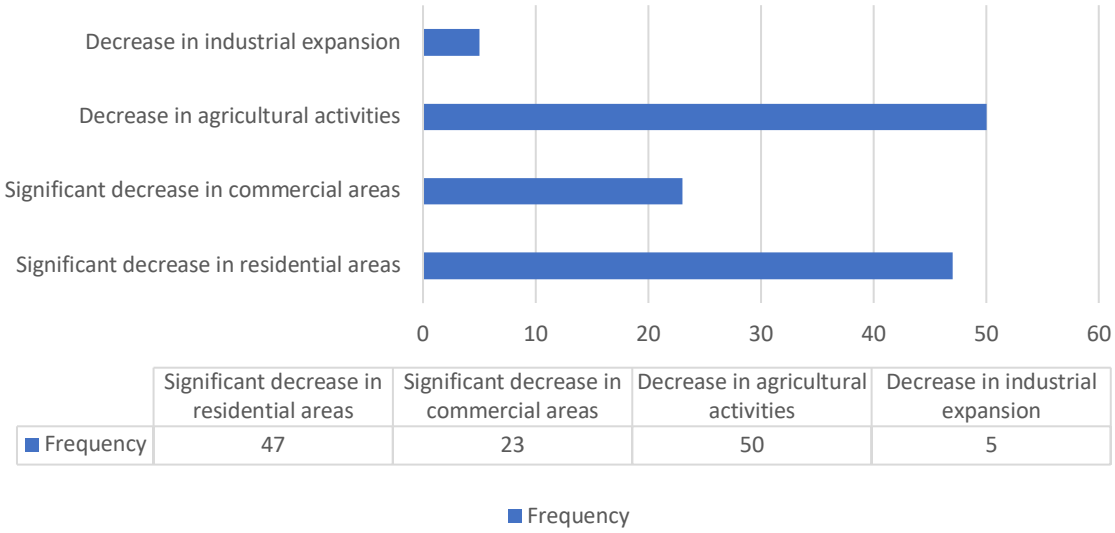


Fig.2 Observed land use types in the study area

The duration of residence data is evenly distributed, with the largest group (26.4%) having lived in the area for 6-10 years. This indicates a stable population that is likely familiar with the local environment and capable of observing long-term changes in land use. A stable, long-term population is crucial in peri-urban areas, as residents' knowledge of land use dynamics can provide valuable insights into how climate change is impacting the landscape.

Overall, the socio-economic characteristics of the respondents suggest a relatively well-educated, and middle-aged population with strong participation in informal economic activities. These factors are likely to influence

both the community's land use patterns and their ability to adapt to climate change. The prominence of trading and self-employment could drive increased demand for commercial and residential land, while their relatively high-income levels suggest that they may have the resources to invest in adaptation strategies for mitigating the effects of climate change.



	Significant decrease in residential areas	Significant decrease in commercial areas	Decrease in agricultural activities	Decrease in industrial expansion
Frequency	47	23	50	5

Fig.3 Perceived primary land use changed over the past 20 years

In response to the first objective which is to ascertain the various land uses in the study area. The results provide insights into the types of land use observed by residents in different areas of Ibeju-Lekki. For each area, Fig.2 shows the distribution of responses across four categories: Residential, Commercial, Agricultural, and Industrial. Overall, the data indicates that Residential land use is the most observed type across all three areas in Ibeju-Lekki. Agricultural use is also notable, particularly in Ilege and Idaso. Commercial and Industrial land uses are less prominent, suggesting that these types of land use are relatively less developed or less frequently encountered in these areas. The results reveal a clear pattern of land use distribution across the Ibeju-Lekki Local Government Area, as seen in the responses from the survey. The most dominant land use observed by residents across all areas is residential, which underscores the ongoing urbanization in the region. This trend is consistent with other peri-urban areas in Nigeria, where rapid population growth and urban sprawl are driving increased residential development (Olokeogun et al., 2014). Specifically, in Ilege and Idaso, residential land use is particularly prominent, indicating that these areas are experiencing significant housing demands, likely fueled by the proximity to Lagos and the expansion of the city into formerly rural areas.

Agricultural land use, though less dominant, remains notable in areas like Ilege and Idaso. The persistence of agriculture in these regions suggests that despite urbanization, some traditional farming practices continue, likely due to the dependence on agriculture for local food production and livelihoods. However, the lower presence of commercial and industrial land use points to the relatively underdeveloped state of these sectors. This may reflect the peri-urban nature of Ibeju-Lekki, where the focus remains on housing and agriculture, with commercial and industrial development lagging behind. Similar patterns have been observed in other coastal regions, where peri-urban areas function primarily as residential and agricultural hubs, with slower economic diversification (Adedire & Adegbile, 2018).

The data presented in Fig.3 illustrates the perceived changes in primary land use in Ibeju-Lekki over the past 20 years. The most notable change reported by respondents is a decrease in agricultural activities, with 40% indicating a significant reduction. This suggests a shift from traditional agricultural practices, possibly due to urbanization, land conversion, or environmental factors that make farming less viable. The data reveals that all 125 respondents (100%) observed a significant change in the primary land use within their communities in Ibeju-Lekki. This unanimous response underscores a widespread recognition of land use transformations,

suggesting that the area has undergone substantial shifts in its landscape. Such changes are likely influenced by both anthropogenic factors, including urban expansion and economic activities, as well as environmental pressures, particularly those related to climate change. The observed land use changes align with global patterns, where peri-urban areas, especially in developing countries, experience rapid land transformations due to urbanization pressures and economic development (Seto et al., 2011). In Ibeju-Lekki, the growing population and urban sprawl have likely contributed to the conversion of agricultural and natural lands into residential, commercial, and industrial uses. This is consistent with the findings from other studies in peri-urban regions of Lagos State, where the demand for housing, infrastructure, and commercial spaces has intensified land conversion (Folorunso et al., 2024).

Moreover, climate change may be accelerating these land use changes by making certain types of land, such as agricultural areas, less viable. For instance, increased flooding, coastal erosion, and other environmental challenges could be pushing communities to abandon traditional land uses in favor of urban development, which is perceived as more resilient or profitable in the long term (Folorunso et al., 2024). This dynamic is evident in other coastal areas of Nigeria, where climate-induced changes in land and water resources have led to shifts in land use patterns (Abija et al., 2020). The unanimous recognition of land use changes by the respondents also highlights the importance of local perceptions in understanding environmental transformations. Communities are often the first to experience the effects of land use changes and can provide valuable insights into the drivers and consequences of these shifts. This participatory approach to assessing land use changes is critical in developing context-specific adaptation and mitigation strategies (Turner et al., 2016). Respondents' perceptions in this study confirm that climate change is playing a crucial role in shaping land use. This is further compounded by the growing demand for housing as Lagos expands, pushing urban boundaries further into peri-urban areas like Ibeju-Lekki.

Type of Change Observed	Strongly agree [%]	Agree [%]	Disagree [%]	Strongly disagree [%]
Increased flooding in agricultural land use	6.4	32.0	44.0	17.6
Increased flooding in residential land use	9.6	44.8	27.2	18.4
Coastal erosion in residential areas	7.2	16.0	60.0	16.8
Coastal erosion in agricultural areas	5.6	5.6	69.6	19.2
Destruction of road infrastructure by erosion	7.2	16.0	62.4	14.4
Sea level rise	32.0	24.0	44.0	0.0

Tab.3 Perceived environmental changes and their impact on land use and infrastructure

To examine the extent to which climate change has affected land use in Ibeju-Lekki between 2003 and 2023 was the second objective of this study, Tab.3 presents the respondents' perceptions of various environmental changes, focusing on the impact of flooding, coastal erosion, destruction of infrastructure by erosion, and sea level rise. Increased flooding emerged as a critical issue, with 48 respondents agreeing or strongly agreeing that agricultural land has been affected by flooding, while 77 respondents reported flooding in residential areas. This indicates that flooding is a dominant environmental challenge, particularly in built-up areas where urban expansion may have exacerbated the problem due to inadequate drainage systems (Folorunso et al., 2024). Coastal erosion was perceived as less impactful, with only 29 respondents expressing concerns about its effects on residential areas, and even fewer (14 respondents) indicating it as a concern for agricultural land. This suggests that while erosion is a present risk, it may not yet be as widespread as other challenges, though it could increase in severity as sea levels continue to rise (Choukri et al. 2024). The destruction of infrastructure by erosion was acknowledged by 29 respondents, further highlighting the vulnerability of the region's transportation and public infrastructure to climate change. Erosion's impact on roads and bridges

could exacerbate economic challenges, hinder trade and mobility. Meanwhile, 70 respondents agreed or strongly agreed that sea level rise is a significant concern. This aligns with broader predictions of rising sea levels in coastal Nigeria, where low-lying areas are at heightened risk of inundation (Akiyode, 2024). These findings collectively demonstrate that flooding and sea level rise are the most critical environmental challenges affecting land use in Ibeju-Lekki, with potential long-term consequences for residential and agricultural land, as well as infrastructure. Land use allocations for development are severely affected by the possibilities of what a particular piece of land can achieve based on its topography. Whilst a particular portion of land may be needed for residential dwellings due to the high cost of accommodation in the urbanized areas of the city, it is practically impossible to address this need in a peri-urban location like ibeju-lekki due to the flooding issues faced by the community. It is important to note here that on-going developmental activities on the lekki free trade zone and Dangote estate are very high capital-intensive projects that can only be undertaken by the financially capable establishments and not individuals. The ibeju-lekki axis provides them with the needed space (land) at a cheaper ownership rate irrespective of the topography.

Impact on Livelihoods or Daily Activities	Percent
Reduced agricultural productivity	17.6%
Relocation due to flooding or erosion	44.8%
Increased cost of living	37.6%
Total	100.0%

Tab.4 Impact of environmental changes on livelihoods or daily activities

Tab.4 details the perceived impact of environmental changes on the livelihoods of the respondents. A significant proportion (44.8%) of respondents reported relocation due to flooding or erosion, indicating the displacement of communities as a major outcome of climate change in the region. Displacement is a common response to environmental hazards in coastal areas, where increased flooding and erosion make certain locations uninhabitable (Luederitz et al., 2015).

Land Use Types	2003 Land Use		2013 Land Use		Difference (2003-2013)		2023 Land Use		Difference (2013-2023)	
	sq. km	%	sq. km	%	sq. km	%	sq. km	%	sq. km	%
Water Body	13.235	3%	12.378	3%	-0.857	0%	16.107	4%	3.729	1%
Dense Vegetation	172.679	38%	162.86	36%	-9.819	-2%	124.69	27%	-38.17	-8%
Sparse Vegetation	100.889	22%	145.838	32%	44.95	10%	150.623	33%	4.785	1%
Bare Land	138.63	30%	61.216	13%	-77.414	-17%	60.868	13%	-0.348	0%
Built-Up Area	32.242	7%	75.38	16%	43.138	9%	105.381	23%	30.001	7%
Total	457.675	100%	457.672	100%	-0.003	0%	457.669	100%	-0.003	0%

Tab.5 Land use/land cover analysis of Ibeju-Lekki 2003, 2013 and 2023

Additionally, 37.6% of respondents reported increased living costs, which can be attributed to the economic strain imposed by environmental changes. As infrastructure deteriorates and agricultural productivity declines, the cost of goods and services in the region increases, placing additional pressure on local populations. This economic burden is particularly evident in the reduction in agricultural productivity, as reported by 17.6% of respondents. The loss of arable land due to flooding and erosion reduces the viability of farming, further

threatening food security in the region. These findings align with broader research on the socio-economic impacts of climate change, where vulnerable populations often bear the brunt of environmental challenges, experiencing both displacement and economic hardship (Akiyode, 2024). The results underscore the need for adaptation strategies that address both environmental and socio-economic vulnerabilities in Ibeju-Lekki.

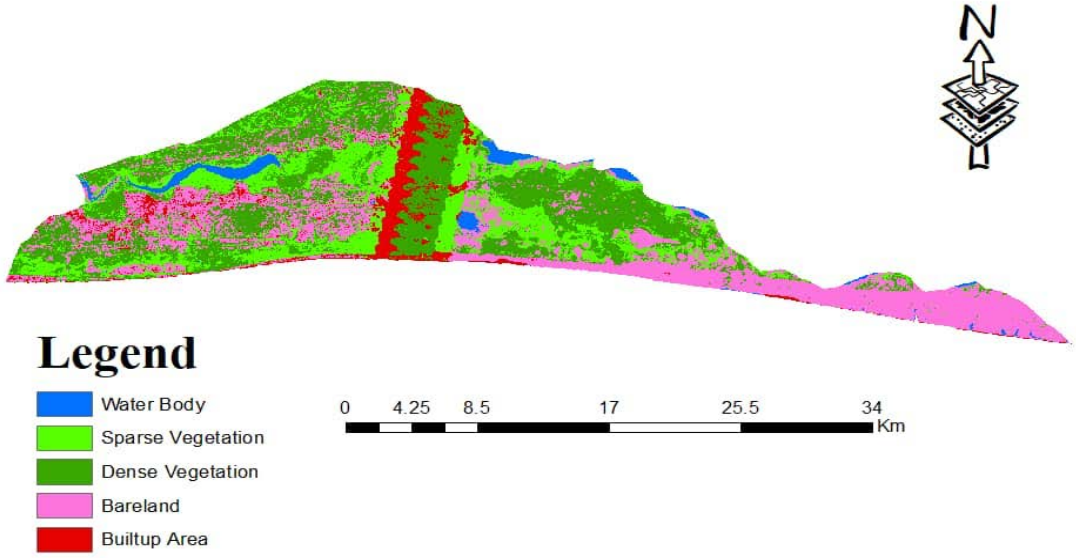


Fig.4 Land use/Landcover of Ibeju-Lekki for 2003

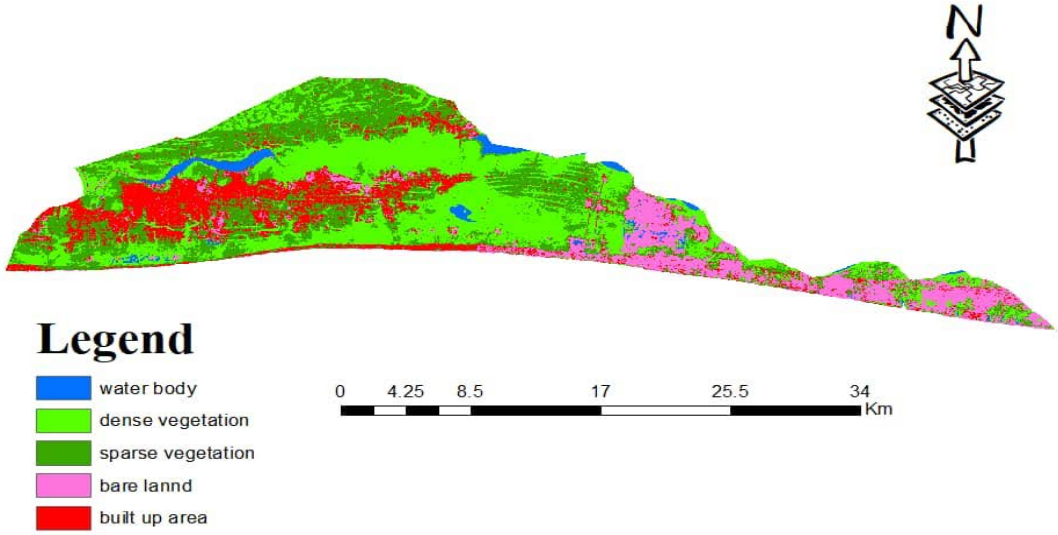


Fig.5 Land use /Landcover of Ibeju-Lekki for 2013

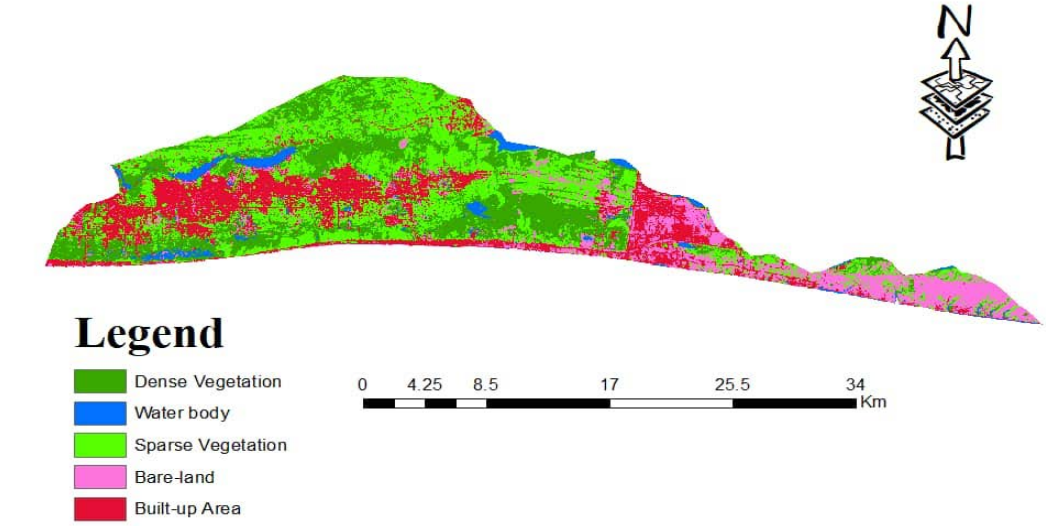


Fig.6 Land use /Landcover of Ibeju-Lekki for 2023

Tab.5 and Fig.4, 5 and 6 went on to show the comparative land use analysis between 2003 and 2023 revealing significant shifts in the landscape of Ibeju-Lekki. The data shows a sharp decline in bare land (-77.41 sq. km), accompanied by a substantial increase in built-up areas (+43.14 sq. km) between 2003 and 2023, reflecting rapid expansion/urbanization over the decade. These changes suggest a shift from rural to urban land use, driven by population growth and economic development in line with the study of Dahanayake et al., (2024) where environmental stressors like land reclamation, and excessive use of natural resources have been noted as a major contributor to the decline of bare lands. Furthermore, Ibeju-lekki currently embodies ongoing infrastructural projects such as the Free Trade Zone, numerous new housing estates and Dangote Refinery as mentioned earlier so it is not uncommon to see a sharp decline in bare land and increase in built up areas.
Sparse vegetation saw a significant increase of 44.95 sq. km in 2013 and a further 4.79 sq.km increase in 2023, indicating land clearance for development or agricultural purposes. This jump also suggests degradation of dense vegetation or abandoned agricultural lands. Meanwhile, dense vegetation declined by 9.82 sq. km in 2013, and even further in 2023 by 38.17 sq. km, representing the loss of forested areas, likely due to both human activity (conversion to industrial zones) and environmental factors such as deforestation and climate change. The reduction of natural vegetation is concerning, as it diminishes the region's ability to mitigate the effects of flooding and erosion (Ogundele et al., 2018; Nifosì et al., 2024). The reduction of natural vegetation has also been noted to reduce carbon sequestration thereby accelerating climate change, increasing local vulnerability to heatwaves, flooding, and ecosystem imbalance. Water bodies remained relatively stable, with a minor reduction of 0.86 sq. km in 2013 but however increased by 1% in 2023, suggesting that changes in water coverage were less significant during this period. However, the expansion of built-up areas highlights the need for careful urban planning to ensure that future development does not exacerbate the vulnerability of the region to climate-related hazards.

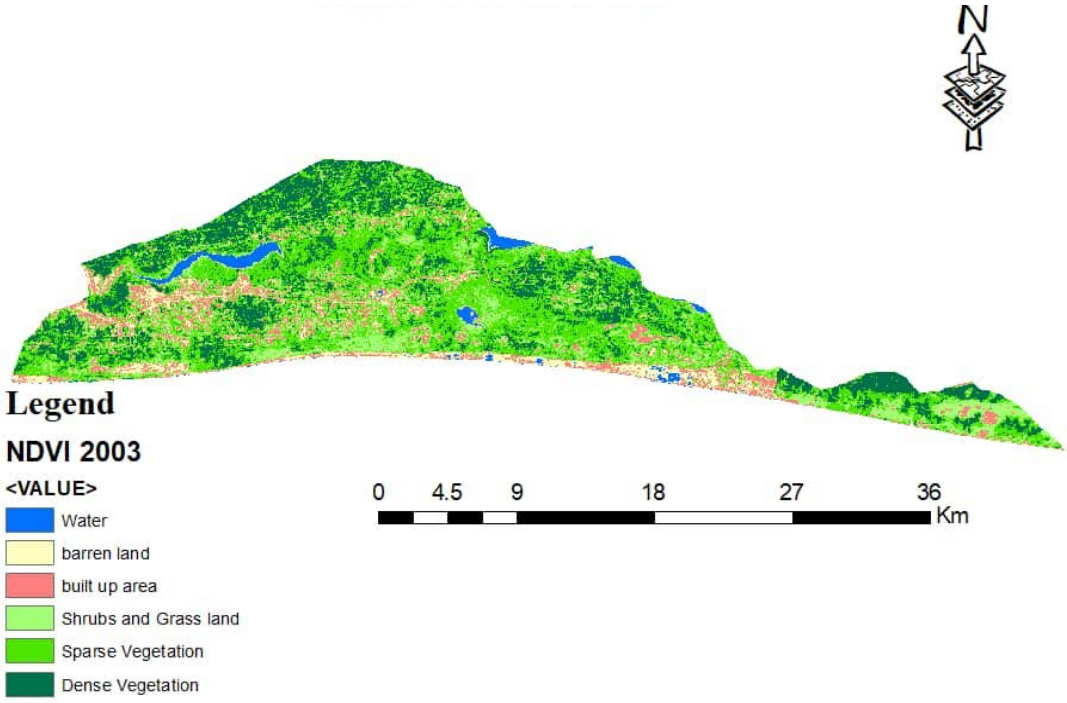


Fig.7 NDVI Analysis of Vegetation Change in Ibeju-Lekki: 2003

Fig.ss 7, 8 and 9 showed the Normalized Difference Vegetation Index (NDVI) values for the years 2003, 2013, and 2023 highlight significant changes in vegetation cover within the Ibeju-Lekki region. In 2003, areas with NDVI values between 0 and 0.3115, represented by green patches in Fig.7, indicate the presence of vegetated areas, predominantly shrublands and grasslands. Coastal regions during this period were still largely covered by marine shrub and grassland, with some areas showing NDVI values ranging between 0 and -0.1052,

reflecting bare surfaces and sandy regions. This observation aligns with the findings of Crippen (1990) and Bid (2016), which state that NDVI values near zero correspond to barren areas such as sand, rock, or snow, while positive values indicate varying levels of vegetation.

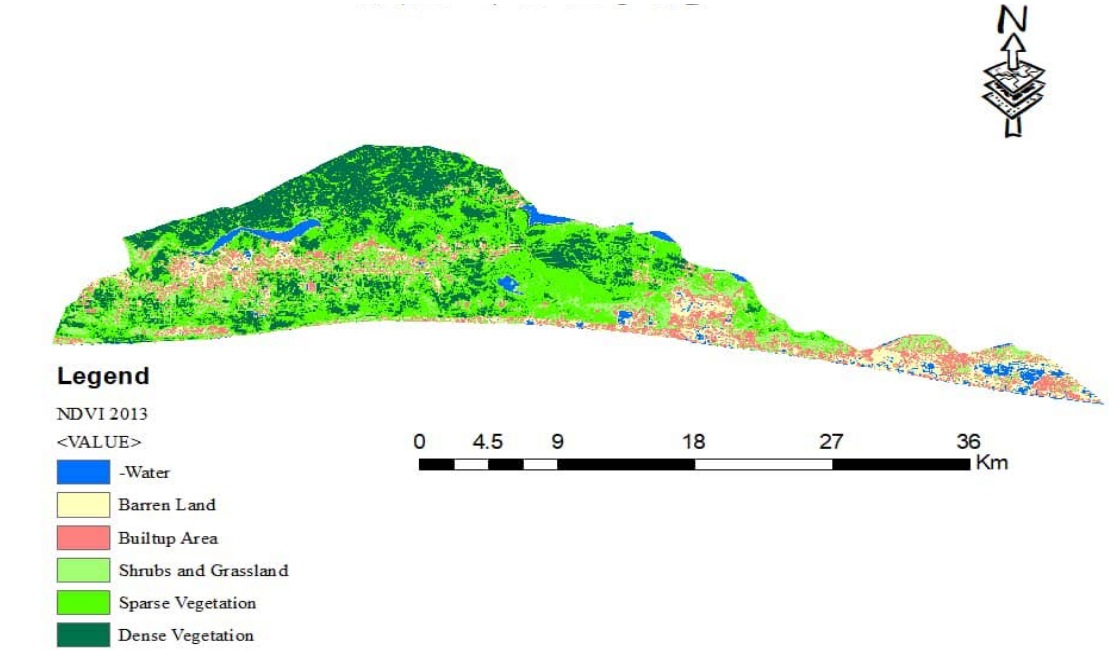


Fig.8 NDVI Analysis of Vegetation Change in Ibeju-Lekki: 2013

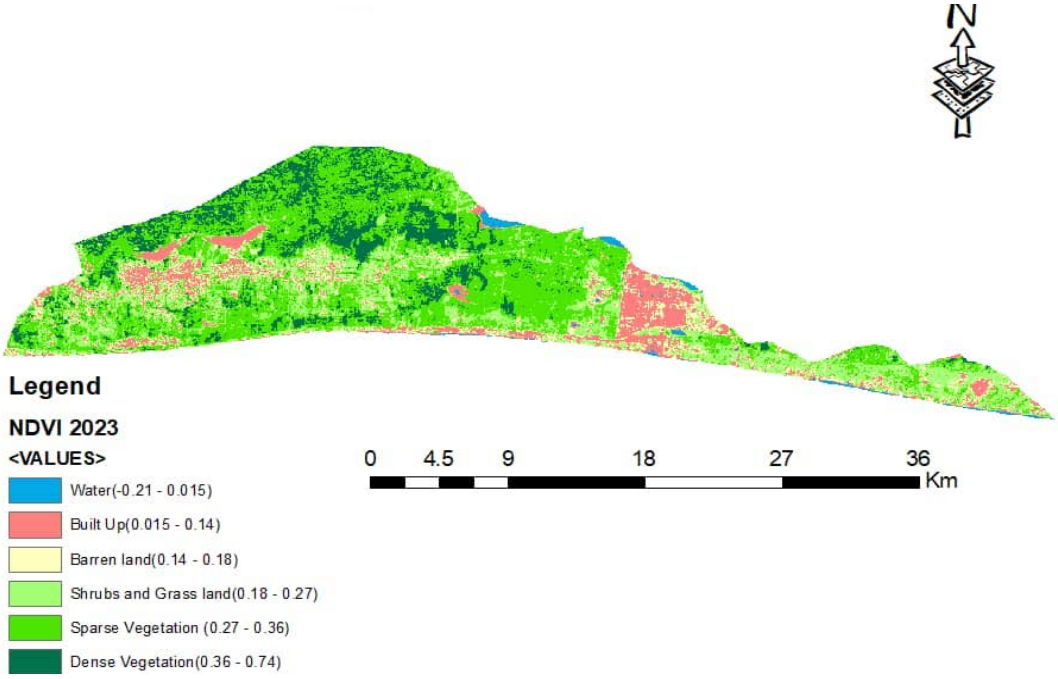


Fig.9 NDVI Analysis of Vegetation Change in Ibeju-Lekki: 2023

By 2013, as shown in Fig.8, the NDVI range expanded slightly, with values between 0 and 0.4270 indicating further degradation of vegetation, as urban expansion and infrastructure development became more prominent in the area. The reduction of shrubs and grassland is evident over the 10-year period, reflecting an ongoing shift towards more built-up areas. In 2023 (Fig.9), the NDVI values range from 0 to -0.0725, further emphasizing the significant loss of vegetation. This is attributed to increased urbanization, with built-up areas and bare surfaces occupying 52.67% and 12.9%, respectively, of land that was once covered by vegetation. Additionally, 0.36% of water bodies have been encroached upon by both urban and bare land as a result of population growth and migration. Over the span of two decades, the substantial reduction of vegetation, 95%

of which was replaced by urban development, indicating a rapid rate of deforestation and environmental degradation. The loss of vegetation has serious environmental implications for Ibeju-Lekki, a low-altitude region where vegetation serves a crucial role in mitigating surface runoff, erosion, and large-scale flooding. The continued depletion of vegetation in favor of urban infrastructure increases the area's vulnerability to these climate-related risks, undermining the ecological balance and contributing to worsening environmental conditions in the region.

Land Use Type	Vulnerable	Not Vulnerable	Total
Flooding			
Residential	50.40%	49.60%	100%
Commercial	40.00%	60.00%	100%
Agricultural	48.80%	51.20%	100%
Industrial	37.60%	62.40%	100%
Coastal Erosion			
Residential	50.40%	49.60%	100%
Commercial	40.00%	60.00%	100%
Agricultural	48.80%	51.20%	100%
Industrial	37.60%	62.40%	100%
Sea Level Rise			
Residential	26.00%	74.00%	100%
Commercial	25.60%	74.40%	100%
Agricultural	31.20%	68.80%	100%
Industrial	20.80%	79.20%	100%
Loss of Vegetative Cover			
Residential	8.00%	92.00%	100%
Commercial	5.60%	94.40%	100%
Agricultural	12.80%	87.20%	100%
Industrial	4.80%	95.20%	100%

Tab.6 Vulnerability to climate change impacts

The third objective, which is to assess the vulnerability of different land use types to climate change impacts illustrated (as seen in Tab.6) that residential areas were of the most concern regarding the perceived vulnerability to flooding. This highlights a significant variation in perceived risk across land use types, with industrial areas as the least. This finding aligns with existing literature that suggests residential areas are often more exposed to flooding due to their higher density and infrastructure vulnerability (Smith & Ward, 1998)
With regards to coastal erosion and sea level rise, the data reveals a consensus that coastal erosion is not a major concern for most land use types. Agricultural land, however, is slightly more perceived as vulnerable compared to other types. This observation underscores the need for enhanced awareness and preparedness regarding sea level rise, particularly for sectors heavily reliant on land and water resources (Nicholls et al., 2011; Boglietti et al., 2024). Tab.6 finally demonstrates that the loss of vegetation cover is perceived as a relatively minor concern across all land use types, though agricultural areas are seen as the most vulnerable. This perception may be linked to the significant role vegetation plays in agriculture, where deforestation and climate change could have pronounced effects. The lower concern for other land uses might indicate either a lower immediate impact or a prioritization of other pressing environmental issues (Lambin & Meyfroidt, 2010).

S/N	Strategies	Percentage
1	Relocation of Residential Communities	32.0%
2	Improved Agricultural Practices	24.8%
3	No Action	20.0%
4	Building Flood Defenses	15.2%
5	Reforestation/Afforestation	6.4%
6	Avoiding the Sea	1.6%

Tab.7 Current Adaptation Strategies for coping with flooding

S/N	Current adaptation strategies for coping with erosion, SLR and LVC	Erosion	SLR	LVC
1	Do Nothing/None	76.8%	70.4%	70.4%
2	Mitigation	2.4%	0.8%	0.8%
3	Planting Trees/Crops	0.8%	0.0%	0.8%
4	Avoiding Certain Areas (Sea Front/Building Near Sea)	0.0%	3.2%	0.0%
5	Clear Path/Return to Sea/Captured by Lake	1.6%	0.8%	0.0%
6	Encouraging Afforestation /Restriction from Cutting Trees	0.0%	0.0%	7.2%
7	Public Awareness/Prevent Indiscriminate Dumping	3.2%	3.2%	2.4%
8	Drainage and Flood Embankments /Creating Defences	0.0%	6.4%	1.6%
9	Other (Self-clearing, Road Construction, etc.)	15.2%	15.2%	16.8%

Tab.8 Current adaptation strategies for coping with erosion, sea level rise (SLR) and loss of vegetative cover (LVC)

In identifying the current adaptation and mitigation strategies to enhance the resilience of land use systems, Tab.7 and 8 reveal a broad spectrum of responses to climate change impacts among the surveyed population. As shown in, Tab.7, the predominant adaptation measures include the relocation of residential communities and improved agricultural practices. These strategies reflect a substantial effort to address climate challenges through significant infrastructural and operational adjustments. However, a noteworthy portion of the respondents indicated the absence of any adaptation strategies, suggesting a substantial gap in active climate response efforts. Other strategies, such as building flood defenses and reforestation/afforestation are less frequently implemented, indicating that while some areas are adopting targeted measures, others are lagging in proactive climate adaptation.

Tab.8 indicates a concerning trend regarding the adaptation strategies for erosion, sea level rise, and loss of vegetation cover. As illustrated, most respondents reported not employing any adaptive strategies, revealing a significant gap in proactive responses to these environmental challenges. Only a small fraction of respondents engaged in "Other" adaptive strategies, which include self-clearing of refuse or participating in local infrastructure improvements such as road construction and drainage activities. Minimal engagement was observed in more targeted strategies, such as afforestation or public awareness campaigns, with very few respondents adopting these measures. The predominance of inaction suggests a critical need for increased awareness and support to foster effective adaptation practices. The data highlights a clear opportunity for intervention to enhance adaptive capacity and resilience among the affected populations.

Anticipated land use changes over the next decade indicate that the next decade will bring significant land use changes in Ibeju-Lekki. Residential development emerged as the most significant anticipated change. This is likely a reflection of the region's expanding population and urbanization (Tab.9). Additionally, some of the respondents expect the development of green spaces and recreational areas, signaling an interest in improving the area’s environmental quality and livability. This finding aligns with broader trends seen in urban planning, where cities prioritize recreational areas to enhance the quality of life for residents, as highlighted in similar

studies by Ubani et al. (2024). Some respondents also foresee a decline in agricultural land, which may be attributed to the encroachment of urban development in rural areas, a trend corroborated by similar findings in (Molla et al., 2024). The anticipated expansion of commercial areas, as noted by a small portion of respondents, supports the region's growing economic significance, especially as Ibeju-Lekki is becoming a commercial hub with projects like the Lekki Free Trade Zone.

Anticipated Land Use Changes in Ibeju-Lekki Over the Next Decade	Frequency	Percentage
Decline in Agricultural Land	17	13.6%
Development of Green Spaces and Recreational Areas	34	27.2%
Expansion of Commercial Areas	16	12.8%
Growth in Sectors	20	16.0%
Increase in Residential Development	38	30.4%

Tab.9 Anticipated Land Use Changes in Ibeju-Lekki Over the Next Decade

Factors	Frequency	Percentage
Climate change impacts	45	36.0%
Economic development	19	15.2%
Government policies	30	24.0%
Population growth	18	14.4%
Technological advancements	13	10.4%

Tab.10 Factors Driving These Changes

Tab.10 suggests that climate change impacts are considered the most influential driver of land use changes. This finding is consistent with studies by Effiong et al. (2024) which emphasize the impact of changing weather patterns on land use decisions, especially in coastal regions and Ibeju-Lekki is not an exception. Government policies were also identified as another major factor. This reflects the importance of policy interventions in shaping land use outcomes, particularly with initiatives to boost housing and infrastructure development. In line with similar research by Assede et al., (2023), economic development, population growth, and technological advancements also play roles in driving land use changes, though to a lesser extent.

4. Conclusion and recommendations

This research underscores the profound impact of climate change and urbanization on land use patterns in Ibeju-Lekki. The rapid conversion of vegetation and agricultural land into built-up areas is driven by both population growth, economic development and environmental pressures such as ongoing infrastructural projects like the Free Trade Zone, numerous new housing estates and Dangote Refinery.

These land use changes have heightened the community's vulnerability to flooding, sea level rise, and other climate change impacts, making it crucial for stakeholders to prioritize sustainable land management practices. The decline in agricultural land poses long-term risks to food security and local livelihoods, while the continued expansion of urban areas without adequate climate adaptation measures increases the risk of environmental degradation. Furthermore, the community's lack of preparedness for climate change exacerbates these challenges, leaving them more susceptible to future environmental threats. It is imperative to note that while natural climate change impacts such as extreme weather events, decline in soil fertility/agricultural land drives the populace to seek adaptation, survival and adaptive strategies in turn become a human-induced (such as deforestation) driver of climate change and the cycle continues.

In summary, Sea level rise and flooding can displace coastal populations putting pressure on upland built-up areas. Varying rainfall patterns degrade dense vegetation thereby leading to an increase in sparse vegetation. Drought and extreme weather can turn a fertile land to bare or land leading to abandonment. Increase in temperature also changes crop viability which affects agricultural land use decisions. As climate change impacts worsens, feedback loops are created, causing further land degradation, deforestation as well as urban sprawl. The relationship can be termed as cyclical and mutually reinforcing, Land use in Ibeju-Lekki has evolved in ways that contribute to climate change, and climate change in turn is reshaping how land is used.

Based on the findings of the study, the following recommendations are made to enhance the resilience of land use systems in Ibeju-Lekki and mitigate the impacts of climate change:

1. Strengthening Infrastructure: The government through the Lagos State Physical Planning Permit Authority (LASPPPA) should prioritize the development of climate-resilient infrastructure to protect communities from the impacts of flooding and sea level rise. This includes enforcing improved drainage systems, flood defenses, rain gardens or buffer zones, permeable pavements and the construction of climate-proof buildings, particularly in vulnerable residential areas. This will help to manage stormwater, reduce urban heat thereby improving resilience.
2. Promotion of Sustainable Land Use Practices: It is essential to integrate sustainable land use practices into urban planning processes. This includes preserving green spaces, promoting afforestation, and preventing the overdevelopment of areas prone to climate risks. Authorities should implement stricter regulations on land use to protect agricultural lands from urban encroachment. Train farmers on Agricultural lands protection through practices like mixed faming systems, cover cropping and organic soil management.
3. Community Engagement and Awareness: There is a need for greater community awareness and involvement in climate change adaptation strategies. Local governments should engage residents in participatory land use planning and offer training programs on climate-resilient agricultural practices, environmental literacy programs on land stewardship, climate change impacts and flood mitigation techniques. Well-informed communities are more likely to participate in conservation and sustainable practices. This will also increase awareness of environmental costs of land misuse. Target groups such as religious institutions, schools and community development associations can be leveraged on.
4. Control Unregulated Land Conversions through Land Use Planning: The study highlights the need for comprehensive and forward-thinking land use planning that balances urban development with environmental sustainability. Land use policies should focus on long-term resilience, ensuring that future developments do not exacerbate environmental vulnerabilities. There is a need to enforce zoning laws to limit the illegal conversion of forested areas and agricultural lands to residential or industrial lands. This will protect green spaces and biodiversity.
5. Adoption of Climate Adaptation Strategies: Local authorities should encourage the adoption of climate adaptation measures, such as reforestation, coastal protection initiatives, and improved agricultural practices. Financial and technical support should be made available to farmers and landowners to implement these strategies effectively. For instance, local trees species can be planted along roads, in schools and other public places to restore and protect degraded areas. This will also reverse loss of vegetation, sink carbon, reduce heat and generally improve the quality of air.
6. Collaborative Efforts for Climate Resilience: Finally, the study recommends collaborative efforts between government agencies, private sector stakeholders, and local communities to build a more resilient Ibeju-Lekki. Public-private partnerships can be leveraged to fund climate adaptation projects and develop infrastructure that supports both economic growth and environmental sustainability. This can be done by promoting flood resistant designs and raised buildings in flood prone areas to reduce vulnerability to

coastal flooding intensified by climate change. A resilient infrastructure guideline can be developed through partnership with private developers in the Lekki-free trade zone.

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Assessing heat stress risk to inform urban heat adaptation. A method applied in the Friuli Venezia Giulia region, Italy

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Abstract

Urban areas usually experience higher temperatures than their surroundings, especially due to impervious surfaces that absorb and re-emit solar radiation. This phenomenon is called urban heat island and occurs mainly at night. People living in urban settings are therefore particularly exposed to potential heat-related health problems caused during the hot season due to prolonged thermal discomfort conditions. This situation is likely to worsen in the future due to climate change, possibly resulting in increased health costs and socio-ecological inequalities. The socio-demographic structure of the population is key in determining the vulnerability of the population to heat stress conditions, with the weakest and most socially and economically disadvantaged being the most vulnerable. To support more targeted adaptation interventions to improve urban resilience and reduce people's heat-related risks, this study develops a heat stress index that combines hazard, exposure, and vulnerability factors. The index is applied to the urban areas of the Friuli Venezia Giulia region (Italy), making it possible to identify risk hotspots that may be prioritized for reducing risk. The factors that contribute to determining the final risk condition are analyzed and discussed, together with the possible uses of the approach to support climate adaptation planning decisions at different scales and the risk mitigation solutions that may be implemented to this aim.

Keywords

Risk assessment; Urban Heat Island; Adaptation planning

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1. Introduction

Urban areas usually experience higher temperatures than their surrounding areas, a phenomenon that is especially evident during the night hours (Oke et al., 2017). This phenomenon is called urban heat island (UHI). It is caused by the significant presence of impermeable surfaces in urban environments, such as concrete and asphalt, which absorb heat from solar radiation during the day to a very much greater extent than vegetated and permeable areas. The stored heat is then released very gradually back into the atmosphere, contributing to increasing local temperatures and limiting the natural night-time temperature drop within built-up areas (Yu et al., 2020). The heat produced by vehicle combustion processes, industrial activities, and air conditioning systems also contributes to warming urban environments (Kim et al., 2022).

Since a large portion of the population is concentrated in urban settings that likely experience (more or less intense) heat islands, which exacerbate the negative effects of summer high temperatures, many people are overexposed to potential health problems (e.g., cardiovascular and respiratory disorders, heat stroke (Reiners et al., 2023)) caused by prolonged thermal discomfort conditions during the hot season.

This situation is destined to worsen in the coming years due to the progressive rise in temperatures caused by climate change, with Italy located in an area particularly sensitive to this problem. This could lead to an increase in both health costs and socio-ecological inequalities that make certain population groups more prone to heat-related impacts. These inequalities are notoriously linked to situations of disadvantage from both a social (i.e., people with disadvantaged socio-economic conditions) and an environmental (i.e., people living in areas prone to UHI) point of view.

On the one hand, the socio-demographic structure of the population has a significant influence in determining people's vulnerability conditions. The more vulnerable population groups during heat waves – also recognized by the Italian government (Italian Ministry of Health, n.d.) – include: the elderly, due to greater sensitivity to heat, a reduced thirst stimulus, and less efficient thermoregulation mechanisms; infants and children, due to a reduced capacity for thermoregulation and the inability to express any discomfort related to environmental conditions; the economically and socially disadvantaged people, as conditions of poverty (e.g., lower incomes) and isolation (e.g., language/cultural barriers) may reduce awareness of risks and limit the access to emergency/mitigation solutions (e.g., air-condition).

On the other hand, living in an urban area that is particularly prone to be affected by heat island phenomena makes the population of that area more vulnerable, as they are potentially exposed to higher temperatures for a longer time, given that this phenomenon maintains high(er) temperatures even during the night when they should naturally decrease to more tolerable levels. This leads urban populations to experience more prolonged heat stress/thermal discomfort conditions during summer hot periods with enhanced potential to suffer health impacts, since the longer the temporal exposure to heat stress conditions, the less the people's ability to cool off and the recovery time for the body (Logan et al., 2020). However, UHI may not only cause health impacts but also increase economic expenditure, since the longer the time with high ambient temperatures, the longer artificial air conditioning systems are required to function, leading to more energy consumption and energy bills increase (Santamouris, 2020).

It is therefore extremely urgent for Italian regions and cities to adopt and implement policies and measures aimed at mitigating the risks associated with heat stress due to the overheating of urban areas, which can be achieved through the reduction of the vulnerability condition of people and/or of the areas in which they live, for example through green spaces that counteract urban heat accumulation and provide cooler air flows to surrounding areas and high-albedo materials that better reflect solar radiation preventing surface overheating (Stiuso, 2025).

Within this context, this work aims to propose and test a spatially explicit risk index to determine the risk of urban populations being negatively affected by heat stress-related impacts. Climate-related spatial risk assessments are of undeniable importance to support adaptation policies, especially in the framework of

urban/spatial planning (e.g., Maragno et al., 2020), where the geographical dimension plays a key role in the spatial allocation of adaptation solutions and, consequently, their benefits and beneficiaries (e.g., Ceci et al., 2023). Various methods for developing risk indices (or variations of them, e.g., territorial vulnerability indices) exist and have been applied worldwide to various hazards (e.g., Jibhakate et al., 2023; Beltramino et al., 2022), including for assessing heat-related urban population risks in Italy and beyond (e.g., Longato et al., 2025; Ellena et al., 2023; Pappalardo et al., 2023).

The proposed index is developed according to the latest IPCC (i.e., Intergovernmental Panel on Climate Change) framework by accounting for the hazard, exposure, and vulnerability factors that concur to determine the risk condition of city inhabitants. Overall, the application of this index can provide an overview of the different risk conditions affecting people who live in an urban context and can therefore support decisions that target and prioritize risk mitigation interventions within high-risk hotspots, while unveiling the main socio-demographic and environmental conditions that most concur to the final risk condition. The index is applied to the urban areas of the Friuli Venezia Giulia (FVG) region, revealing which urban settings, and what specific areas within them, are characterized by higher risk conditions that deserve special attention for risk reduction strategies and adaptation interventions.

2. Method

2.1 Rationale and study area

The risk index is developed by combining the three factors that contribute to risk: hazard, exposure, and vulnerability.

According to the latest definitions proposed by the Intergovernmental Panel on Climate Change (IPCC, 2022), hazard refers to the possible occurrence of a physical event or trend (natural or human-induced) that may have negative consequences on exposed and vulnerable elements. Exposure refers to the presence of elements in an area that may be affected by such an event, i.e., they are exposed because they are located in a potentially hazardous area. Vulnerability refers to the propensity or predisposition of the exposed elements to be negatively impacted in light of the occurrence of the hazardous event.

In this case, the hazard is defined in relation to the occurrence of periods with (potentially hazardous) high temperatures, the exposure in relation to the amount of population exposed to potentially high(er) urban temperatures and heat stress conditions, and the vulnerability in relation to the degree of resilience and/or fragility (i.e., to heat stress) of the population itself and of the urban environment in which they reside. The geographical unit of reference for which the assessments are carried out is represented by the census unit areas (i.e., the so-called census sections in Italy) for which population data is collected.

The study area is represented by the FVG region, located in the north-eastern part of Italy. The regional area includes the Alpine region bordering Austria and Slovenia, the hilly karst area between the cities of Trieste and Gorizia, and a floodplain and a coastal area overlooking the North Adriatic Sea in which most of the population lives. Since located between the Alps and the Mediterranean, two climate change hotspot areas, its climate profile is characterized by above-average temperature increase and more and more frequent weather extremes, including heatwave periods resulting in thermal discomfort conditions, especially during summer, which are projected to worsen in the future (see ARPA FVG, 2018 and ARPA FVG, 2023 for more information). This makes the FVG region an appropriate illustrative example to test and apply the proposed risk index.

To limit the assessment to the areas that are plausibly exposed to potentially hazardous high temperatures during the summer season, it was decided to include only the urban settings located in the regional area characterized by an average maximum summer temperature of at least 25° (Fig.1) according to the historical data provided by the Regional Agency for the Environment (ARPA FVG, n.d). To do so, the selected census sections are the ones that intersect the urban footprint areas (according to the regional land use map) that

satisfy the above-defined temperature threshold and that are coded as "urban centres", "inhabited settlements", or "industrial zones", thus leaving out those classified as "scattered houses" that predominantly correspond to agricultural and/or non-inhabited areas.

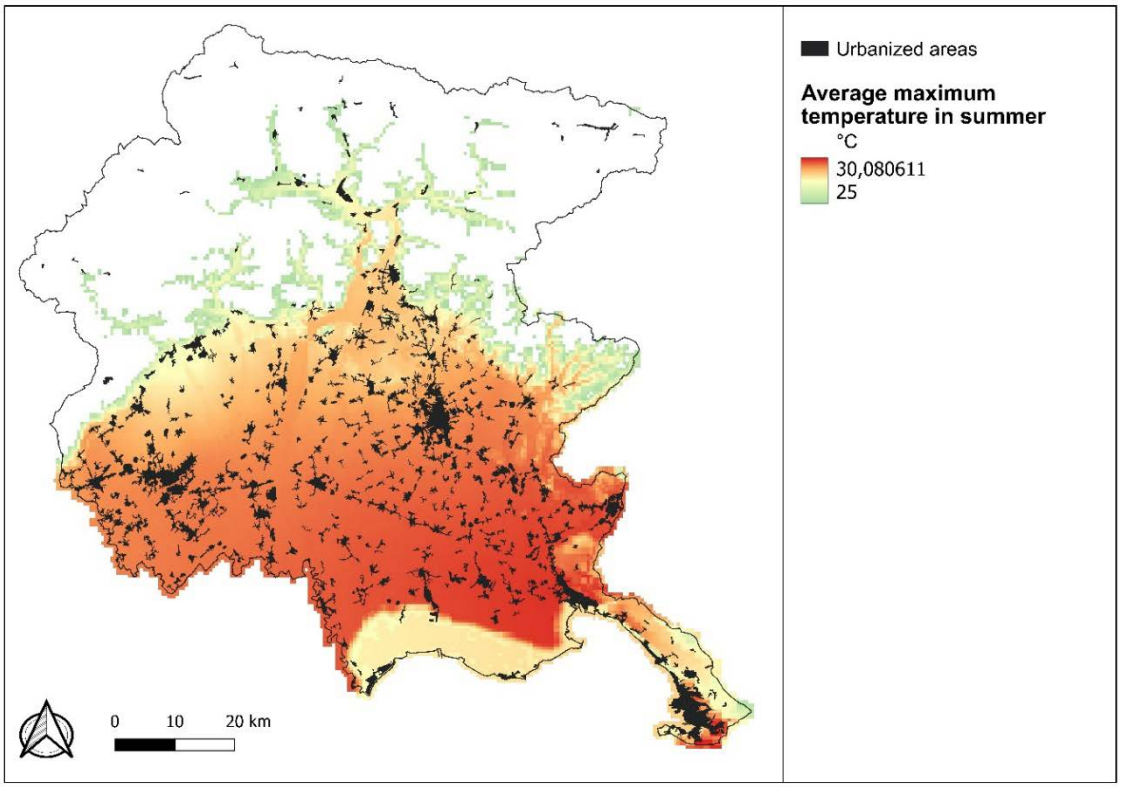

Fig.1 The territory of the FVG region characterized by an average maximum temperature during the summer period (i.e., months of June, July, and August) of at least 25° according to the 1991-2020 historical series. White areas are the ones characterized by temperature values below this threshold, corresponding to medium- to high-mountain regions. Source: Authors' elaboration based on monthly data produced by ARPA FVG (ARPA FVG, n.d.)

2.1 Hazard calculation

For the calculation of the hazard indicator $H_{clim.heat,j}$, it was used the average number of days per year with temperature exceeding 30° (Fig.2) as representative weather-climate hazard data, also known as 'hot days'. The formula (1) used for the calculation of the (normalized) indicator is as follows:

$$H_{clim.heat,j} = \frac{hot\ days_j\ -\ min(hot\ days_j)}{max(hot\ days_j)\ -\ min(hot\ days_j)} \quad (1)$$

Where $hot\ days_j$ represents the value of the average number of 'hot days' per year within the census section j.

2.2 Exposure calculation

The density of inhabitants, calculated using the data on the resident population of the last population census survey of 2021 by the Italian National Institute of Statistics, was used to determine the population exposure and calculate the related indicator $E_{pop,j}$. The variable 'density of inhabitants' was preferred to the total number of inhabitants because, due to the way census sections are geographically defined with the sections in urban core areas being very much smaller than the others, it provides more suitable information to define the concentration of the (exposed) elements in the territory (e.g., in cases of similar numbers of inhabitants in both a peri-urban census section and an urban core census section, the ones living in the peri-urban one are

spread over a much larger area, hence with a much lower density, which means that the exposed element - the inhabitants - is much less spatially concentrated than in the urban census section). The formula (2) for the calculation of the (normalized) indicator is as follows:

$$E_{pop,j} = \frac{dens_{pop,j} \; - \; min(dens_{pop,j})}{max(dens_{pop,j}) \; - \; min(dens_{pop,j})} \tag{2}$$

Where $dens_{pop,j}$ represents the value of the density of inhabitants (per hectare) within the census section *j*.

2.3 Vulnerability calculation

The vulnerability factor was assessed by taking into consideration both socio-demographic and environmental factors that may concur to influence the vulnerability profile of the exposed element, i.e., the inhabitants. Consequently, the vulnerability indicator $V_{pop.heat,j}$ was calculated by combining two sub-indicators, one relating to the vulnerability according to the socio-demographic profile of the population (i.e., social vulnerability) and the other according to the propensity to suffer from UHI effects of the area in which they reside that may exacerbate heat impacts on people. The formula (3) used to combine the two sub-indicators is as follows:

$$V_{pop.heat,j} = \frac{V_{soc,j} \; + \; V_{heat,j}}{2} \tag{3}$$

Where $V_{soc,j}$ represents the value of the social vulnerability indicator within the census section *j*, $V_{heat,j}$ represents the value of a purposely developed UHI-related vulnerability indicator within the census section *j*.
To calculate the social vulnerability indicator, several representative socio-demographic variables were calculated and combined to map the population groups considered most vulnerable to heat stress, according to the population information available in the 2021 national population census survey. These variables are: percentage of inhabitants considered vulnerable according to age (young children < 5 years and elderly people > 65 years); percentage of inhabitants considered vulnerable according to the economic profile (i.e., unemployed people in working-age); percentage of inhabitants considered vulnerable due to possible social isolation and language barriers (i.e., foreign people). The formula (4) for calculating the (normalized) indicator is as follows:

$$V_{soc,j} = \frac{\frac{V_{soc1,j} \; - \; min(V_{soc1,j})}{max(V_{soc1,j}) \; - \; min(V_{soc2,j})} + \frac{V_{soc2,j} \; - \; min(V_{soc2,j})}{max(V_{soc2,j}) \; - \; min(V_{soc2,j})} + \frac{V_{soc3,j} \; - \; min(V_{soc3,j})}{max(V_{soc3,j}) \; - \; min(V_{soc3,j})}}{3} \tag{4}$$

Where $V_{soc1,j}$, $V_{soc2,j}$ and $V_{soc3,j}$ represent the percentage values of the three selected social variables (above-mentioned) within the census section *j*.
To calculate the UHI-related vulnerability indicator, a qualitative pixel-based index was developed by combining the satellite-derived Land Surface Temperature (LST) data and a spatial simulation of the potential cooling effects provided by the surrounding natural and semi-natural ecosystems. This index (from now on called 'UHI vulnerability index') was proposed and tested by Longato & Maragno (2024) at the city scale to improve UHI analysis with remotely-sensed data since the use of LST allows the detection of Surface UHI (SUHI) only and is not (always) able to capture the potential flows of cooler air flowing from the surrounding ecosystems that can partly counteract heat islands. SUHI in fact only refers to surface temperatures, namely how hot is an object if you touch it, while what mostly influences thermal perception and discomfort for people is the temperature of the air above the ground, up to the level of buildings and tree tops, which is influenced

by several other factors besides surface temperatures, including near-surface air flows (e.g., Rocha et al., 2024). The proposed UHI vulnerability index thus integrates both a sensitivity – LST-derived SUSHI – and a coping capacity – potential cooling spatial effects of ecosystems – factor to account for multiple factors contributing to urban temperature variations.

Concerning the sensitivity factor, it was decided to use a historical series of LST (2013 to 2023). Using the Google Earth Engine Platform, which makes it possible to overcome traditional shortcomings concerning the use of large-scale and muti-temporal series of satellite data (e.g., time processing (Isola et al., 2023)) a script was used to automatically extract the pixel-based average LST value from the Landsat 8 satellite image series using as a reference period the summer months (i.e., June, July, and August) from 2013 to 2023. This way, it was possible to detect the multi-year average behaviour of surface temperatures during summer, avoiding using only one or a few images that could not have fully represented the LST spatial variability normally expected in summer. Moreover, given the regional scope of the analysis, it was possible to cover all the regional territory since the use of many images allowed to minimize the lack of LST data at the pixel level due to the (more or less frequent) presence of clouds. To this aim, the script was developed to mask out the pixels covered by clouds in each satellite image used for calculating the average value. A total of 303 satellite images (i.e., distributed across the tiles covering the case study area) were detected during the reference period and used to calculate the average value of LST. It is worth noting that not all the resulting pixel average values are calculated using the same number of satellite images due to the spatial variability and frequency of clouds that may have affected some areas more than others, reducing the number of usable satellite images in specific pixel areas.

Subsequently, the distribution of the LST values was used to identify five vulnerability classes (with scores from 1 – least vulnerable, to 5 – most vulnerable) according to five progressive temperature ranges obtained by categorizing the temperature values using the Natural Breaks statistical method. Given the large scale of the analysis, leading to a large variability of air temperature values, to account for the influence of air temperature variation on LST it was decided to subdivide the regional area into sectors and to categorize the LST values (for subsequently assigning the vulnerability classes) separately for each sector. This was done according to five different ranges of average maximum summer air temperatures (see Fig.1 for the spatial distribution), namely: areas between 25° (the lowest value for including an area into the analysis) and 26°; areas between 26° and 27°; areas between 27° and 28°; areas between 28° and 29°; areas above 29° (the maximum peak recorded in the region is slightly above 30°). Tab.1 shows the LST (range) classes and the corresponding vulnerability scores assigned according to the regional sectors identified.

	Sector 1: areas with air temp. 25° to 26°	**Sector 2: areas with air temp. 26° to 27°**	**Sector 3: areas with air temp. 27° to 28°**	**Sector 4: areas with air temp. 28° to 29°**	**Sector 5: areas with air temp. > 30°**	**LST-related vulnerability score**
1st LST class (lowest sensitivity)	< 28.02°	< 29.46°	< 32.06°	< 33.75°	< 34.46°	1 (least vulnerable)
2nd LST class	28.02° to 30.51°	29.46° to 32.10°	32.06° to 34.44°	33.75° to 35.93°	34.46° to 36.73°	2
3rd LST class	30.51° to 32.58°	32.10° to 34.48°	34.44° to 36.60	35.93° to 38.22°	36.73° to 38.51°	3
4th LST class	32.58° to 34.72°	34.48° to 37.94°	36.60° to 39.45°	38.22° to 41.24°	38.51° to 41.10°	4
5th LST class (highest sensitivity)	> 34.72°	> 37.94°	> 39.45°	> 41.24°	> 41.10°	5 (most vulnerable)

Tab.1 Land Surface Temperature (range) classes and corresponding vulnerability scores assigned in each regional sector identified according to air temperature variability

Concerning the coping capacity factor, first, the potential to provide cooling effects through the local climate regulation service was assessed for the regional ecosystems mapped in the regional Habitat Map using the scoring matrix developed by Burkhard and colleagues (2014). In this matrix, qualitative scores (from 0, no relevant potential, to 5, highest potential) are assigned to reflect the potential to supply ES by different ecosystems. According to the scores assigned to the local climate regulation service, the highest cooling potential (score of 5) is provided by woodlands, followed by shrublands and agricultural areas with significant natural elements, arable land, natural grassland, pastures, permanent crops, and urban green areas (i.e., see the ES potential matrix in Burkhard et al. (2014) for more details).
Second, the (omnidirectional) spatial extent of the cooling effects was determined using standard distances from the literature, namely a buffer of 100 linear meters from ecosystem patches smaller than 2 hectares and 250 linear meters from patches larger than 2 hectares (Geneletti et al., 2016). Each cooling buffer was assigned the corresponding cooling potential score of the providing ecosystem patch.
Third, the spatial intersection between the urban areas and these buffers was computed to identify the ones potentially benefitting from the cooling effects provided by ecosystems, accounting for the different ES (cooling) potentials and related scores (i.e., if an area benefits from more than one cooling effect, the ones with the highest potential – and score – is kept for that area) that are assumed to correspond to different cooling intensity potentials in the benefitting areas.
Finally, as done for the sensitivity factor, the spatial distribution of the cooling buffers was used to assign five vulnerability classes (with scores from 1 – least vulnerable; to 5 – most vulnerable) to the urban areas according to their potential to benefit (or not) from more or less intense cooling effects from the surrounding ecosystems, corresponding to, e.g., a null coping capacity (the most vulnerable situation) in case of not benefitting from any cooling effect; or the highest coping capacity (the lest vulnerable situation) in case of benefitting from the most intense cooling effect. Tab.2 shows the vulnerability scores assigned to the different situations concerning the coping capacity factor.

Cooling intensity potentials (qualitative score) benefitted by urban areas	**Vulnerability score**
Areas benefitting from cooling effects with very high (5) cooling intensity potential (highest coping capacity)	1 (least vulnerability)
Area benefitting from cooling effects with high (4) cooling intensity potential	2
Areas benefitting from cooling effects with medium (3) cooling intensity potential	3
Areas benefitting from cooling effects with low (1) to moderate (2) cooling intensity potential	4
Areas not benefitting from any cooling effect (null coping capacity)	5 (most vulnerable)

Tab.2 Cooling intensity potentials benefitted by urban areas (spatial intersection with cooling buffers) and corresponding vulnerability scores assigned

Once both the sensitivity and coping capacity factors were assessed, the pixel-based UHI vulnerability index was calculated by combining them using the weighted sum method and the weights proposed by Longato & Maragno (2024), namely a relatively higher weight of 0.6 for the sensitivity factor (i.e., LST-derived SUSHI) and a relatively lower weight of 0.4 for the coping capacity factor (i.e., the cooling intensity potential provided by surrounding ecosystems to the benefit of urban areas).
Using the computed UHI vulnerability index, the formula (5) for calculating the (normalized) UHI-related vulnerability indicator is as follows:

$$V_{heat,j} = \frac{V_{UHI,j} \; - \; min(V_{UHI,j})}{max(V_{UHI,j}) \; - \; min(V_{UHI,j})} \tag{5}$$

Where $V_{UHI,j}$ represents the average value of the pixel-based UHI vulnerability index calculated within the census section *j*.

2.4 Risk calculation

The hazard, exposure, and vulnerability indicators were combined to calculate the final risk index $R_{pop.heat,j}$ depicting the (urban) population heat stress risk using the formula (6):

$$R_{pop.heat,j} = H_{clim.heat,j} * E_{pop,j} * V_{pop.heat,j} \quad (6)$$

Where $H_{clim.heat,j}$ represents the value of the hazard indicator within the census section *j*, $E_{pop,j}$ the value of the population exposure indicator within the census section *j*, and $V_{pop.heat,j}$ the value of the population vulnerability indicator within the census section *j*.

3. Results

The map (Fig.2) of the distribution of the climatic variable used to calculate the hazard indicator (average number of days per year on which the temperature exceeds 30° (ARPA FVG, n.d.)) shows that the lowland areas, especially in the eastern part of the region, are those most affected (up to more than 50 days). However, the entire lowland and Karst areas experience a high number (>35) of days per year with temperatures above 30°.

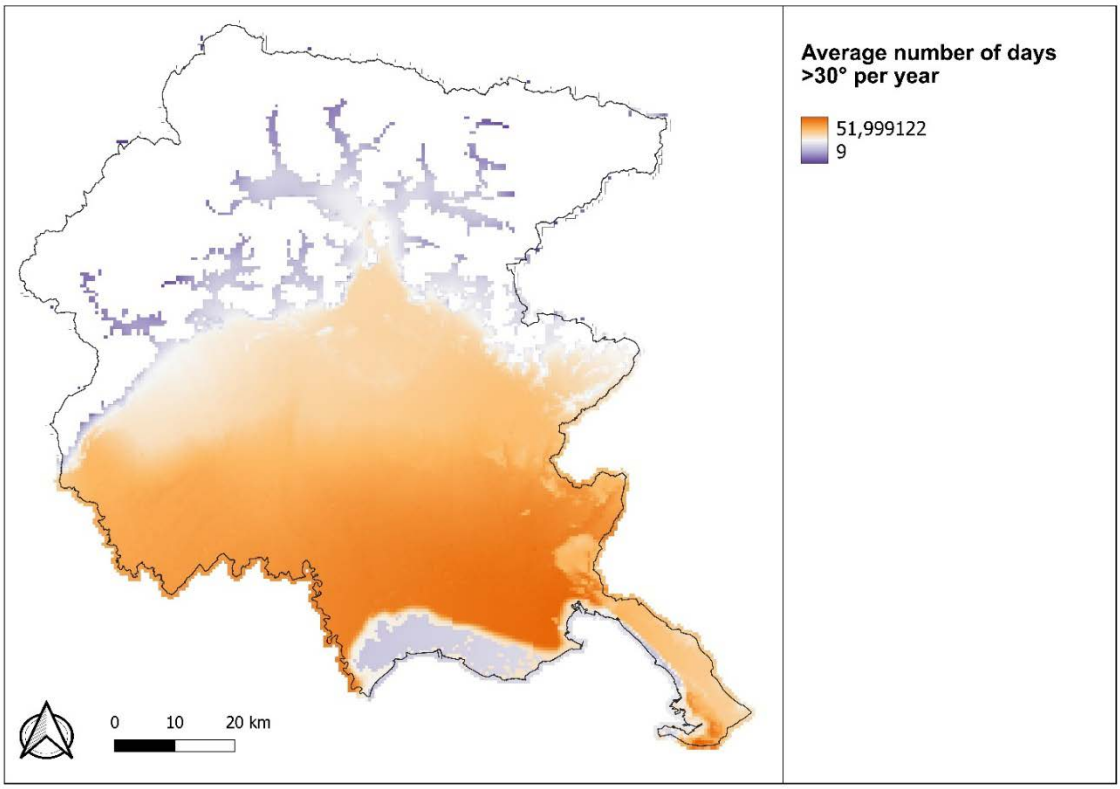

Fig.2 Distribution of the average number of days per year on which the temperature of 30° is exceeded (historical series 1991-2020; data used for calculating the hazard indicator). White areas are excluded from the analysis, corresponding to medium- to high-mountain regions. Source: Authors' elaboration based on the map produced by ARPA FVG (ARPA FVG, n.d.)

Concerning the variable used to calculate the exposure indicator (population density), it can be seen that this is commonly higher in the region's main cities (i.e., provincial capitals, but also in some medium-sized towns), with some differences in distribution from city to city (e.g., in Trieste the highest values are found in the most central areas, while in Udine especially in the first belt outside the historic centre) (Fig.3).The distribution of the variables used to calculate the social vulnerability indicator (i.e., % of inhabitants <5 years or >65 years, % of unemployed, % of foreigners) is instead more heterogeneous (Figures 4, 5, and 6), although in all the three cases there is a slight (regional-scale) tendency to concentrate the highest values towards the more

peripheral urban areas or, in any case, not within the most central census sections within the larger urban centres.

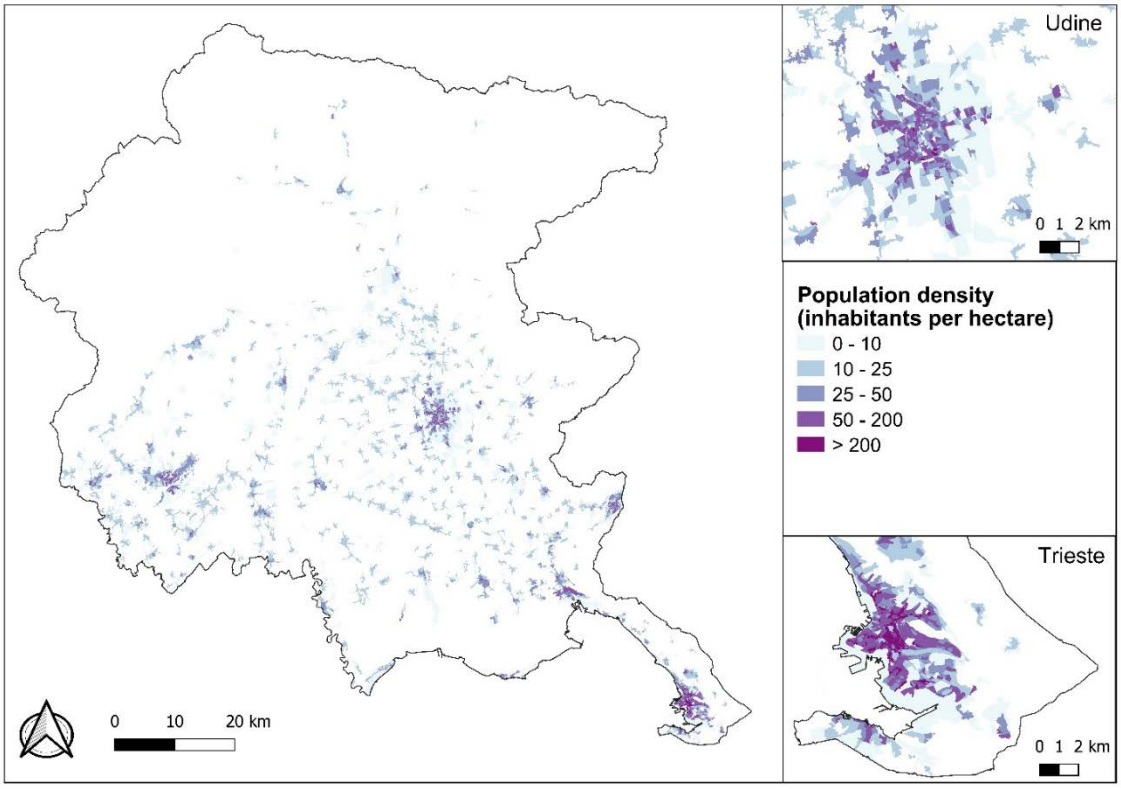

Fig.3 Distribution of population density by census section (data used for calculating the exposure indicator). Source: Authors' elaboration based on 2021 national census survey data

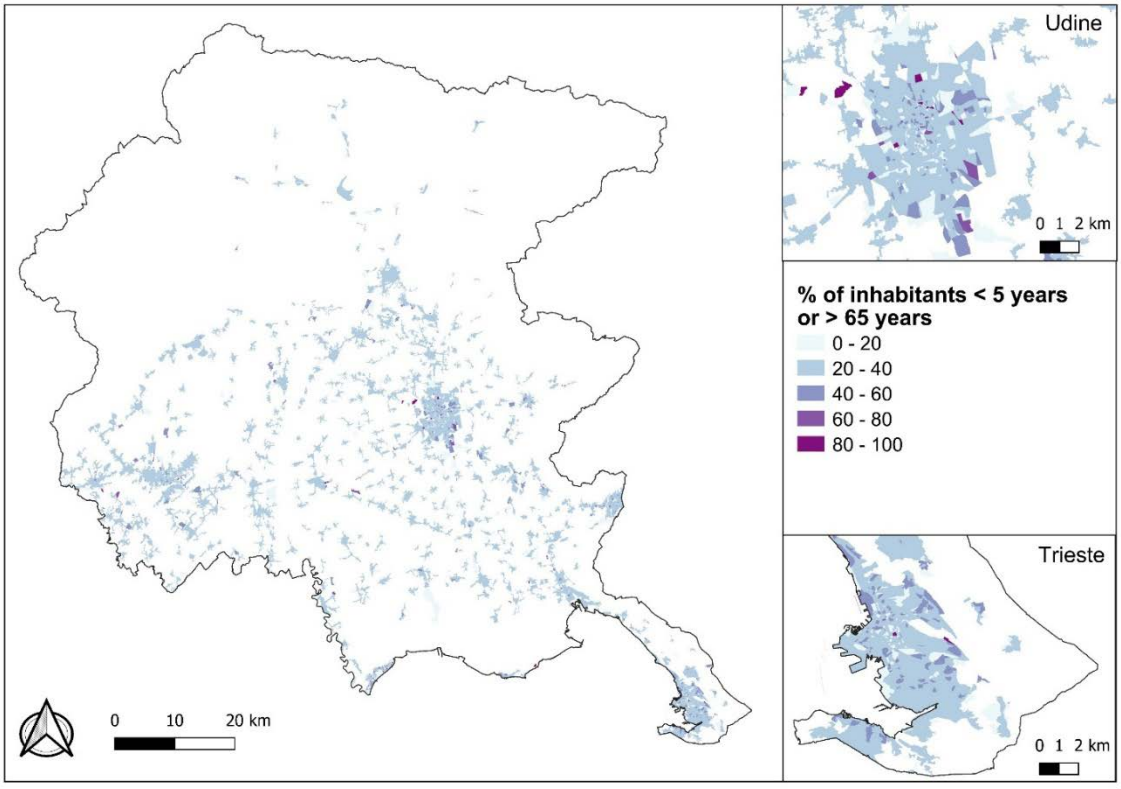

Fig.4 Distribution of the percentage of inhabitants considered most vulnerable according to age (children < 5 and elderly > 65 years) by census section (data used to calculate the vulnerability indicator). Source: author's elaboration based on 2021 national census survey data

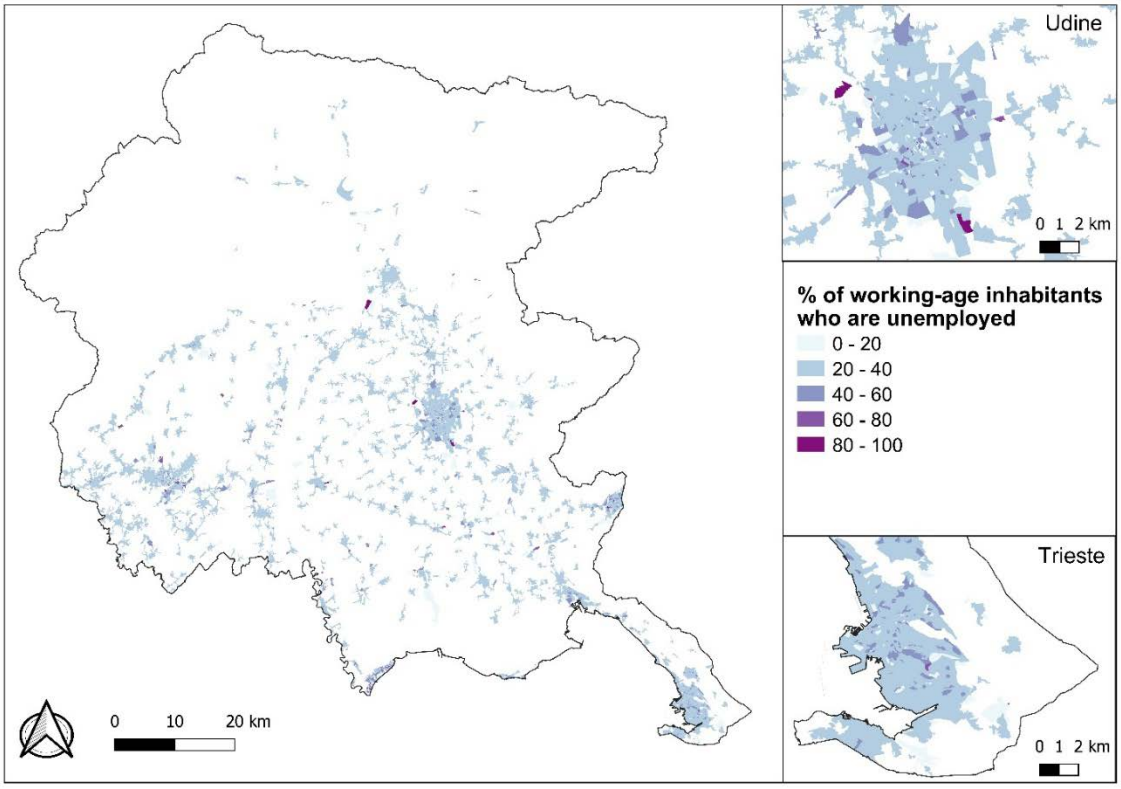

Fig.5 Distribution of the percentage of working-age inhabitants who are unemployed by census section (data used to calculate the vulnerability indicator). Source: author's elaboration based on 2021 national census survey data

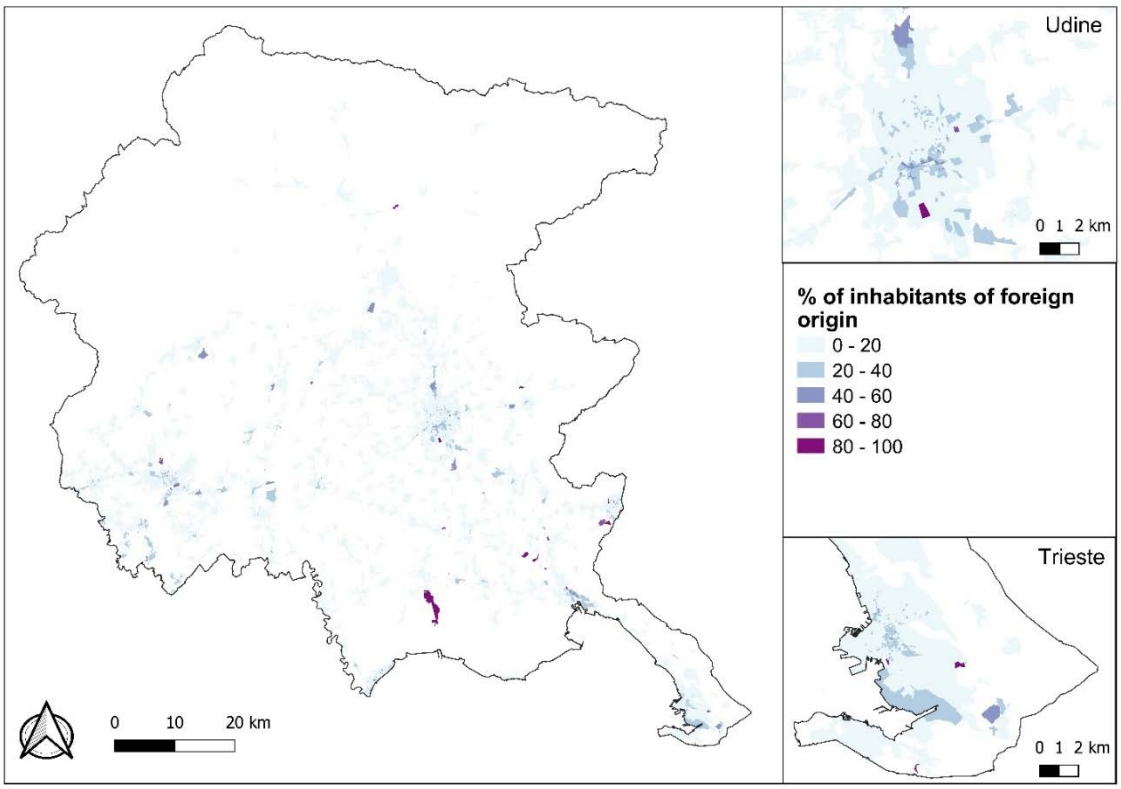

Fig.6 Distribution of the percentage of inhabitants of foreign origin by census section (data used to calculate the vulnerability indicator). Source: author's elaboration based on 2021 national census survey data

As regards the proposed index developed to calculate the UHI-related vulnerability (Fig.7), unsurprisingly the clusters of highest values are especially found in the larger towns with a dense urban fabric (e.g., Trieste,

Udine, Gorizia, and to a much lesser extent in Pordenone); moderate to high values are however also found in many smaller towns and urbanized areas, especially in the south-eastern part of the region and, less widely, in the south-western part.

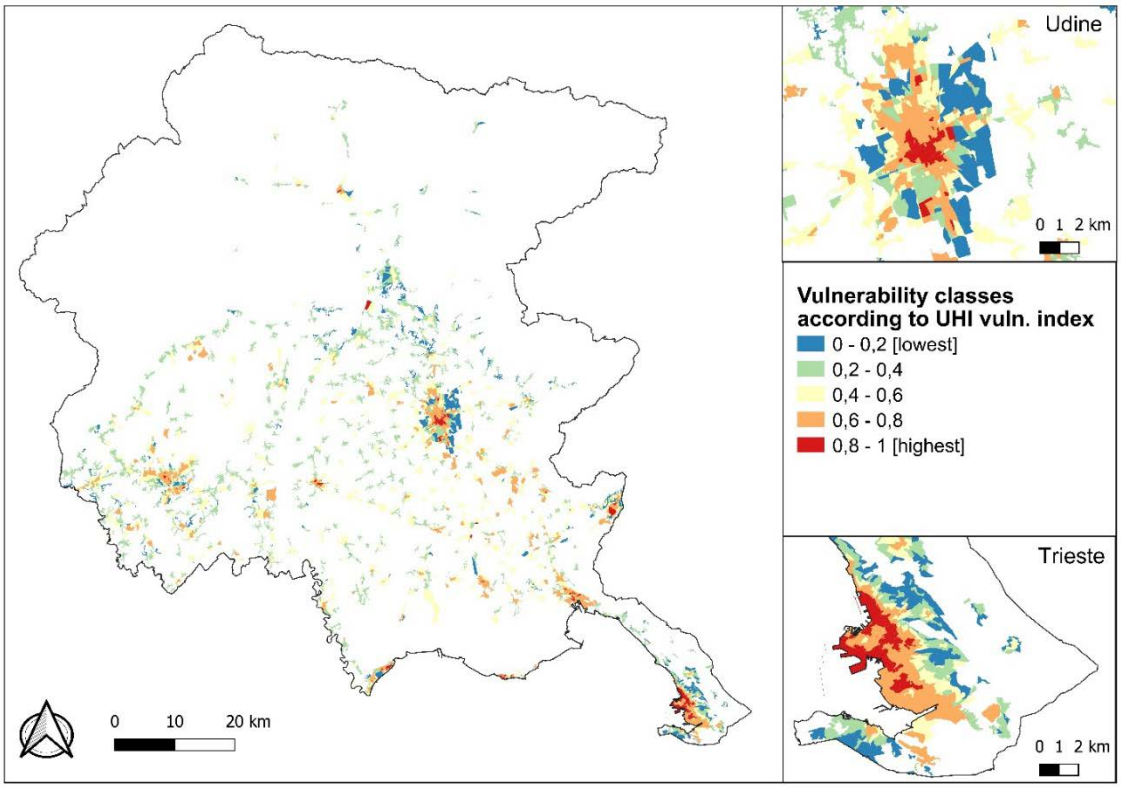

Fig.7 Distribution of the average value of the UHI vulnerability index by census section. Source: Author's elaboration

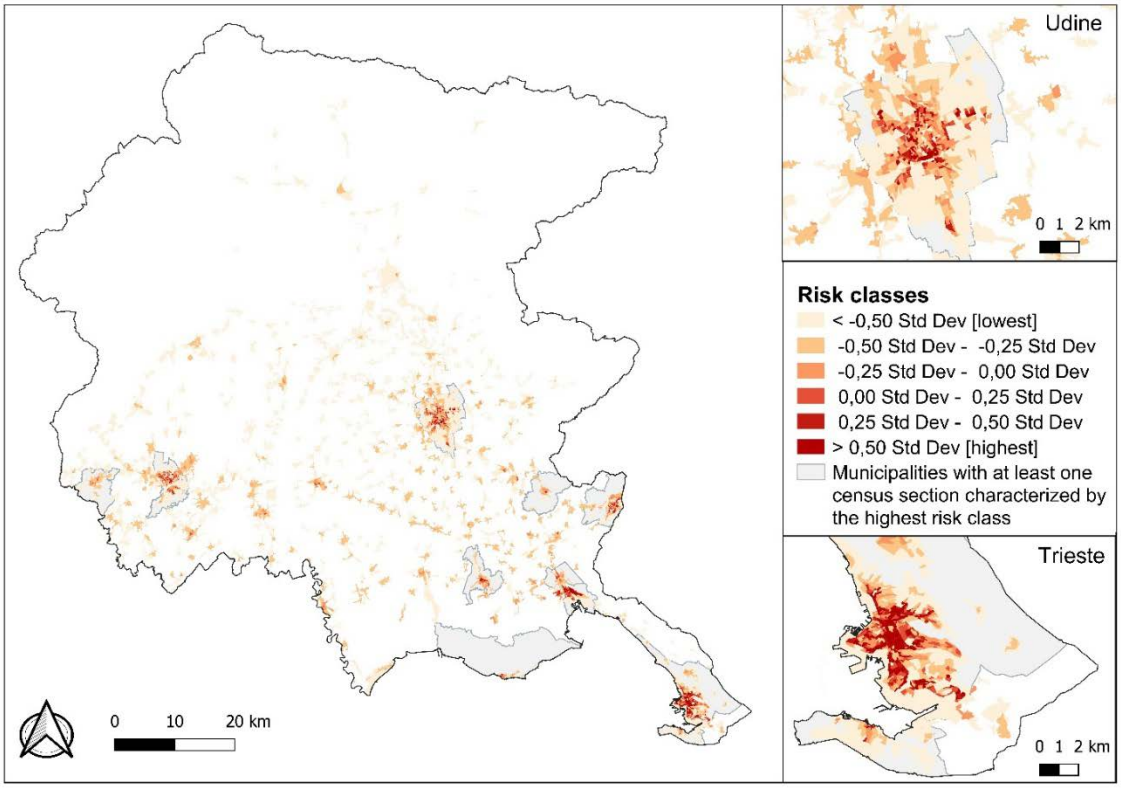

Fig.8 Distribution of the final risk classes/conditions by census section (based on the standard deviation from the average value of the risk index); the higher the standard deviation, the higher the risk condition. Source: Author's elaboration

Finally, the spatial distribution of the final risk index that combines all the variables and indicators presented above (Fig.8), in which the highest values (i.e., well above the standard deviation from the average) correspond to the highest risk conditions, makes it possible to identify the areas (census sections) in which the level of risk is potentially greater. These are concentrated within the largest urban areas (e.g., the four provincial capitals plus the medium-sized city of Monfalcone), but, in some cases, even relatively minor urban centres are characterized by at least one census section with the highest risk level (e.g., Grado, Cormons, and Ronchi dei Legionari to mention those with the smallest number of inhabitants).

4. Discussion and conclusions

This study presented a method to develop and test a risk index to assess the risk of urban populations being negatively affected by heat stress-related impacts, revealing the urban areas that show the major risk conditions according to both socio-demographic and environmental factors. The index is applied to assess the risk within the urban areas located in the FVG region, combining data and indicators that refer to the three risk components based on the IPCC framework: hazard (i.e., climate data), exposure (i.e., population distribution data), and vulnerability (i.e., people's socio-demographic characteristics and their potential to be affected by UHI effects). Main challenges and limitations of the proposed method that could affect its replicability and applicability include the availability of reliable input data needed to perform the assessment (e.g., fine-scale climate hazard data such as those available in the FVG region may not be available in other contexts) and the frequency with which they are updated. The latter aspect is especially valid for the socio-demographic data used to assess the social component of vulnerability, whereas, regarding UHI vulnerability, the use of satellite data ensures continuously updated information. Given the non-static nature of population dynamics, which may result in changes of the risk conditions and distribution over time, these types of assessment should indeed rely on regularly updated data, which are instead provided (in Italy) every 10 years through official national census surveys, often released several years after the reference year of the survey.

By combining hazard, exposure, and vulnerability metrics, the resulting risk index shows the spatial distribution of the major urban risk hotspots, which are the results of relatively high(er) hazard, exposure, and/or vulnerability conditions. However, these can contribute to the final risk in different terms across the various regional urban contexts, according to the local specificities.

To provide an overview of which variables related to the hazard, exposure, and vulnerability factors have a more or less systematic and strong relationship with the overall risk index (and, consequently, with the final risk condition), a correlation analysis (Pearson's method) was carried out between them and the final risk index. This was done at both the regional level and separately for the four capital municipalities as an example, to show how in different areas there may be different prevailing factors that determine the final risk condition (Tab.2).

Case study area analyzed	Climate hazard (days per year with T >30°)	Population exposure (population density)	Social vulnerability (% of young children and elderly)	Social vulnerability (% of unoccupied)	Social vulnerability (% of foreigners)	UHI-related vulnerability (UHI vulnerability index)
Whole region	0.0817	0.9471	0.0054	0.1154	0.2760	0.4367
Trieste	0.3551	0.9272	-0.1361	0.1225	0.5584	0.5200
Udine	-0.1199	0.9832	0.0250	0.2188	0.3822	0.4746
Pordenone	-0.1130	0.9663	0.1212	0.1689	0.2942	0.4284
Gorizia	-0.3070	0.9719	0.0011	0.1458	0.1352	0.5434

Tab.2 Correlation coefficients resulting from the correlation analysis (Pearson's method) between the value of the single variables and that of the final risk index. Negative values represent a negative correlation (the closer to the value of -1, the higher the negative correlation), while positive values represent a positive one (the closer to the value of +1, the higher the positive correlation). Values close to 0 represent a very low or almost null correlation

From the correlation coefficients obtained, it can be seen that the variable 'population density' is the one most correlated with the overall risk condition in all the cases analyzed (positive and highly significant correlation). It can therefore be stated that an increase in density almost always corresponds to an increase in the level of risk, a fact that well explains the role of exposure in determining the risk (e.g., an area may be located in a highly dangerous and vulnerable zone, but if the number of exposed elements is very low, the level of risk will also be relatively low), similarly to what found in other contexts in which a similar assessment method was applied (e.g., Longato et al., 2025). In contrast, at the regional scale, there is a very low correlation between the hazard variable and the final risk. At the municipal level, in the four municipalities analyzed, the trend is discordant and of variable direction. This confirms that if a place is located in an area with a higher climate hazard, this does not mean that the risk for that area is automatically higher than that of other places characterized by lower hazard conditions. As concerns the socio-demographic variables, the one that is most correlated (positively) with the final risk is generally the percentage of foreigners (higher in Trieste, lower in Gorizia), followed by the percentage of unemployed and that of young children and the elderly (the latter being insignificant in all cases and negative in Trieste). This means that, in almost all cases, one is more likely to encounter a higher risk condition when there is a relatively high percentage of foreigners compared to the other two variables. However, while these results may offer a general overview at the regional or whole city scale, further investigation of socio-demographic aspects and their contribution to the final risk condition are needed at the more local scale (i.e., intracity), since very different situations may exist from one city area to another such as already found in other similar contexts (e.g., Padova (Pappalardo et al., 2023)). Finally, vulnerability to the heat island phenomenon is always positively correlated in a moderately significant manner in all cases (almost always more significantly than the socio-demographic vulnerability), highlighting the importance of having climate-resilient places to decrease the population risk condition.

In this regard, in addition to social and economic policies and initiatives that can be deployed to support the most disadvantaged population groups (e.g., risk awareness raising activities, economic incentives for the installation/use of cooling solutions in buildings, the opening of climate refuges during hazardous weather conditions, etc.), the implementation of transformative adaptation interventions in cities to mitigate the heat island phenomenon represents one of the greatest challenges for urban/territorial plans and policies (Aflaki et al., 2017). To this aim, both green and grey interventions can be applied to cool down local temperatures and mitigate UHI. Through green interventions (i.e., nature-based solutions), generally speaking, vegetation is used to provide cooling through shading and evapotranspiration (Park et al., 2021). Examples of solutions of this type in urban areas include green roofs that lower temperatures in buildings during summer through enhanced insulation and evapotranspiration, and the creation or restoration of urban forests, parks, and green spaces that provide fresh air to the surroundings, among others. Grey solutions instead may include cool roofs and pavements that use specific surface materials characterized by a higher albedo compared with traditional ones, which consequently absorb lower rates of heat and attenuate the heat island effect.

The use of the proposed risk index could be useful above all to identify the priority areas where such interventions should be promoted with more urgency, concentrating resources and efforts so that they are as effective as possible in terms of reducing population risks and the associated social impacts and costs, a fundamental aspect in times of financial constraints and high competition between different land uses. Prioritizing the implementation of a solution in an area characterized by higher risk conditions may likely provide more benefits (than in less risky areas) in terms of, i.e., a higher number of exposed and/or vulnerable people that can benefit from it, reducing their risk and potentially more effectively decreasing the impacts - including health and economic - at the city scale once a hazardous event occurs. For this reason, the proposed index can be used to support the prioritization of adaptation interventions in relevant adaptation policies and decision-making processes.

The regional case study presented in this work aims to test the feasibility of applying the proposed method for assessing risk in large-scale areas, as well as to showcase its potential for multi-scalar applications. On the one hand, at the local scale, the proposed risk assessment can support municipalities in identifying the most problematic urban areas that are potentially characterized by higher population heat stress risks during heatwave periods, thus in prioritizing high-risk hotspot areas for planning and implementing adaptation solutions through local decision-making processes and planning instruments. To this aim, the risk index calculation could be rescaled at the municipal level to offer proper guidance to local practitioners, supporting them in concentrating policy efforts and investments for promoting adaptation actions in more risky areas (e.g., through retrofitting existing public spaces). On the other hand, at the regional scale, it can be used to support and inform policy and (co-)financing mechanisms for supporting adaptation interventions starting from concerted decision-making processes between the (superordinate) regional and municipal levels. Actually, the FVG Regional Spatial Plan explicitly envisages innovative forms of concerted planning between the regional and the municipal authorities for strategic themes such as the environmental ones through the so-called instrument of 'Territorial Projects'. These are 'the implementation tools of large-scale strategic themes that [...] have the task of transposing and evaluating on a suitable scale the major interventions in a way that will [...] have to foster positive effects on the local level' (Regione Autonoma Friuli Venezia Giulia, n.d.). Forms of preferential concertation between the Region and the municipalities affected by the major risk conditions can therefore be proposed (also) based on the evidence of spatially explicit assessments like the one proposed in this study to inform, guide, and prioritize the (co)financing and implementation of larger-scale interventions that may have tangible positive effects (also) at the local scale, in this case in terms of urban heat stress reduction. For example, the design and implementation of regionally-relevant ecological corridors (i.e., identified in the Regional Landscape Plan) or the proposal of supra-municipal parks (i.e., an instrument established by a regional law) can be fine-tuned in concerted planning processes to (also) maximize the provision of local cooling benefits in the urban areas identified as high-risk hotspots. Or prioritization criteria for accessing regional funding schemes that can be used to finance environmental and climate actions may be defined (also) based on risk hotspot identification.

However, it has to be noted that the proposed risk assessment is not meant to be the sole instrument for basing decisions but should be tailored and critically used by decision-makers together with other types of information and knowledge to reflect on the different factors concurring to determining the final risk condition and to consequently better inform spatial choices toward risk reduction (Kythreotis et al. 2024). For example, weighting/modulating factors can be introduced in the calculation and combination of the risk components (e.g., vulnerability, exposure) and related indicators to assign more/less relative importance to specific factors that local decision-makers want to emphasize or adjust to better reflect local peculiarities. Future research should focus on fine-tuning these practical aspects together with practitioners to test the applicability of the approach in real-world decision-making contexts, as well as on testing the replicability of the method in other regions/cities, also using different data (e.g., future climate scenarios, other socio-demographic characteristics of population, etc.) or integrating/expanding the scope of the assessment (e.g., including non-resident populations – such as workers – as exposure).

Finally, it is worth noting that, while the proposed assessment method is aimed at promoting sustainable planning decisions for people vulnerability/risk reductions, if a high-risk area is characterized by a significant presence of economically disadvantaged population groups, special attention should be paid since, especially in cases of green adaptation interventions that may trigger unwanted gentrification processes (e.g., Camerin & Longato 2024), these population groups may be displaced in other (more) deprived areas if no specific measures to prevent this situation are taken early on in the decision-making process. These could include the adoption of specific housing policies to counteract the likely increase of house prices and protect existing residents from displacement (Derickson et al., 2021). Or the implementation of diffuse green interventions

instead of fewer, big green areas, which has been claimed to be more effective and equitable in terms of social impacts, even if this action alone could not always be sufficient if not paired with strong housing policies (e.g., Bockarjova et al., 2020).

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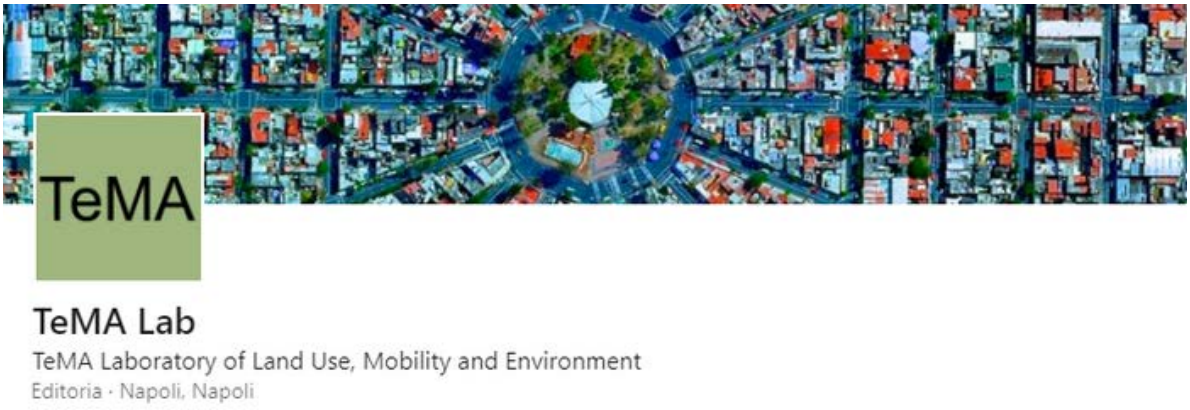

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Capacity assessment of the creation and development of regional brands in Guilan province

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Abstract
This study investigates the capacity for regional branding for Guilan province concerning the existing brands' identification, new brands' creation opportunities, and development obstacles. The current mixed-method study by using MICMAC analysis method describes the main variables affecting branding results. Its findings recognize tourism, agriculture, and horticulture as the most dominant existing brands and ecotourism, agritourism, and commercial tourism as having huge development potential. Inferior infrastructure, inadequate coordination among stakeholders, and lack of governmental support are major barriers. The study proposes practical solutions to overcome these barriers and to use regional assets effectively. The findings present critical views for policymakers and stakeholders toward the competitiveness and sustainable development of Guilan.

Keywords
Regional branding; Branding capacity assessment; MICMAC analysis; Regional competitiveness; Branding challenges

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1. Introduction

In the globalization context, different parts of the world face increased competition for resources, investment, tourism, and residents. The evolution of regional branding emerged as a vital method of enhancing competitive edge through the creation of distinct identities that are attractive to stakeholders. An effective regional brand will spur economic growth, attract investments, and promote tourism by leveraging the unique characteristics of a region (Kavaratzis, 2004; Rainisto, 2003). Recent studies such as (Carra et al., 2022) has determined that walkability, spatial access, and climate-responsive urban design have the potential to greatly add to the identity and branding potential of an area, particularly if implemented in line with local demands and daily experiences. In developed countries, branding approaches are extensively utilized and constantly refined through integrated planning frameworks and smart city strategies that align governance, infrastructure, and innovation (Gargiulo & Tremiterra, 2015); however, in less developed areas, these approaches frequently face considerable obstacles, such as infrastructural, administrative, and cultural difficulties (Björner, 2014; Shoaib & Keivani, 2015).

The province of Guilan with its favorable climate, rich cultural heritage, and strategic geographic position, has all the ingredients to become one of the greatest regional brands in Iran. Despite all its special resources, Guilan has problems with developing and sustaining competitive branding regarding infrastructure shortages, lack of support from the government, and poor coordination between stakeholders in the sector (Akhavan Foumani et al., 2022; Cheraghi & Moosavi Nadoshan, 2024). Addressing these problems is the key to using the capacities of the province to make it become a benchmark for regional development. This research aims to analyze the potential of Guilan in terms of regional branding by identifying existing brands, discovering new opportunities for brand development, and investigating barriers that impede progress. Using MICMAC methodology, the research examines key variables to provide realistic recommendations for decision-makers, stakeholders, and local governmental authorities on the basis of (Godet et al., 2008) and (Villacorta et al., 2014). The main purpose of the study is to propose viable strategies for overcoming problems and bring about sustainable regional development. The research is based on some research questions: (1) what brands are there in the Guilan province at the moment, and how do they help to improve local competitiveness? (2) What are the critical barriers to branding exercises in Guilan? (3) How can the branding of Guilan be used to build and develop sustainable regional brands?

2. Literature review

2.1 Branding theories and concepts

Branding theories have evolved significantly offering frameworks for understanding how regions, cities, and nations can craft and communicate their identities. One of the most prominent frameworks is Kavaratzis' Place Branding Framework (2004), which emphasizes the interplay of place identity, stakeholder engagement, and effective communication. This model highlights the importance of aligning regional characteristics with stakeholders' perceptions to construct a cohesive and competitive brand. Another widely utilized model is Anholt's Nation Brand Hexagon (2010) which delineates six dimensions of branding: tourism, governance, exports, people, culture, and investment. While developed for national branding, this model is adaptable to regional contexts providing a comprehensive approach to evaluating a place's strengths and weaknesses.

Van Ham's Branding as Diplomacy Approach (2008) posits that branding transcends mere marketing; it is a form of soft power that shapes perceptions and fosters economic and cultural relationships. This approach underscores the strategic role of branding in regional and international diplomacy emphasizing its potential in developing regions seeking investment and recognition. In the context of regional branding, Rainisto (2003) highlights success factors such as infrastructure, governance, and stakeholder collaboration. Meanwhile, Herstein (2012) explores the unique challenges faced by developing countries, including misalignment between branding strategies and local cultural or administrative practices. These theories underscore the necessity for

integrated strategies that account for social, economic, and political dimensions of branding. For Guilan province, these frameworks provide a theoretical foundation for identifying branding opportunities and addressing the barriers to effective implementation.

Title	Author(s), Year	Focus/Objective	Methodology	Key Findings
Factors and Stimuli Affecting the Conversion of Urban and Rural Places to Tourism Brands (Study: Guilan Province)	(Cheraghi & Moosavi Nadoshan, 2024)	Explores the potential for urban and rural areas in Guilan to become tourism brands.	Mixed-methods case study.	Identifies Guilan's unique attributes and challenges in tourism branding.
Place Branding: The State of the Art	(Van Ham, 2008)	Discusses branding as a form of diplomacy and its global implications.	Literature synthesis.	Branding shapes perceptions and fosters economic and cultural relationships.
Realization Path of Geographical Indication Branding of Agricultural Products to Boost Rural Revitalization	(Yang, 2024)	Investigates how GI branding enhances rural economies and local identity.	Case study on GI branding.	GI branding improves market positioning and fosters economic growth.
Methodology of Marketing Territory as a Factor of Socio-Economic Development	(Denisov & Chuvashlova, 2023)	Explores how marketing strategies can drive socio-economic development.	Qualitative analysis of marketing strategies.	Aligns branding with socio-economic goals for sustainable growth.
Regional Branding as an Effort to Promote a Sustainable Environment	(Munawaroh & Fajri, 2023)	Examines the integration of branding and sustainability in developing regions.	Case study approach.	Sustainable branding enhances eco-conscious appeal and competitiveness.
Challenges in Urban and Rural Place Branding	(Pasquinelli et al., 2022)	Explores barriers to branding across urban and rural contexts.	Systematic literature review.	Lack of cohesion and infrastructure limits effective branding in developing regions.
Territorial Branding in the Face of Society's New Challenges	(De-San-Eugenio & Ginesta, 2020)	Analyzes factors contributing to successful territorial branding.	Literature review.	Stakeholder collaboration is critical for successful branding.
The Development of a Sustainable Tourism Area for Borobudur Temple	(Soesanta et al., 2023)	Explores city branding themes linked to sustainable tourism.	Case study.	Sustainable tourism enhances competitiveness and cultural preservation.
Self-Branding of Grobogan District Through Mapping Superior Potential	(Astuti et al., 2023)	Maps branding opportunities for local products in Grobogan District.	SWOT analysis and mapping.	Emphasizes strategic use of local resources for regional branding.
Local Branding: Imperative Strategy Towards Sustainable Destination Competitiveness Through Social Media	(Kuswardani et al., 2023)	Highlights the role of social media in enhancing local branding and sustainability.	Social media content analysis.	Digital platforms amplify local branding and enhance destination competitiveness.
Urban planning for biodiversity: An assessment of green plans in Northern Italy	(Lazzarini et al., 2024)	Evaluates how urban green plans in Northern Italy incorporate biodiversity into planning processes	Qualitative assessment of policy documents and planning frameworks	Demonstrates that biodiversity-integrated planning enhances ecological resilience, improves quality of life, and supports the development of a distinct regional identity
Sustainable Branding for Local Products: Empowering Rural Economic Development	(Aesthetika et al., 2023)	Explores branding as a tool for economic development in rural areas.	Rural case studies.	Branding strategies empower communities and drive rural economic growth.

Tab.1 Literature review

2.2 Challenges in branding

Regional branding faces varied challenges across global and local contexts. Globally, key issues include governance complexity, stakeholder misalignment, and lack of long-term planning. Developing regions often struggle to adapt Western-origin branding models, which assume participatory governance and strong institutional frameworks (Björner, 2014; Casais & Monteiro, 2019).

A major barrier is infrastructure—poor transport, accommodation, and communications weaken branding impact (Rainisto, 2003). In Guilan, specific challenges include political instability, inadequate government support (Akhavan Foumani et al., 2022), and administrative inefficiencies. Cultural resistance and public skepticism further hinder progress (Pasquinelli et al., 2022), while limited budgets and reliance on public funding restrict private sector involvement. Environmental pressures add complexity, requiring a balance between development and preservation (Munawaroh & Fajri, 2023).

Despite extensive research, gaps persist for regions like Guilan. Most literature focuses on urban areas in developed countries (Kavaratzis, 2004; Rainisto, 2003), often overlooking the realities of rural, mixed-use, or resource-constrained regions (Herstein, 2012; Pasquinelli et al., 2022). Branding frameworks like Anholt's Hexagon and Kavaratzis' model rarely address operational challenges such as stakeholder fragmentation or lack of tailored strategies.

Sustainability is also underexplored, especially how to align branding with ecological priorities. This study bridges those gaps by adapting a mixed-methods approach to Guilan's context, offering practical guidance for branding in similar developing regions.

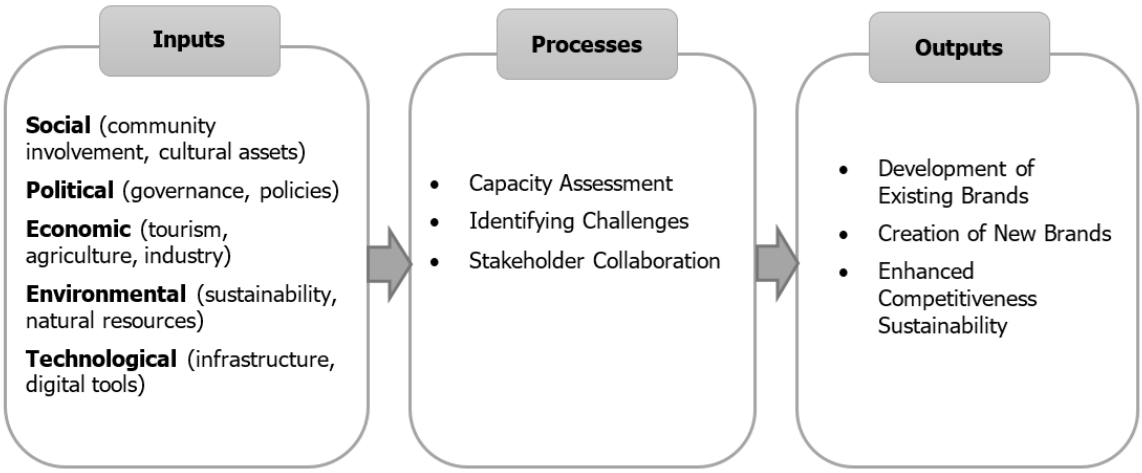

Fig.1 Conceptual Framework of Regional Branding Capacity Assessment

The proposed framework conceptualizes regional branding through three components: inputs, processes, and outcomes. Inputs encompass social, political, economic, environmental, and technological factors shaping the branding context. Processes include capacity assessment, identifying challenges (e.g., stakeholder misalignment), and promoting collaboration. Outcomes aim to enhance existing brands, create new ones, improve competitiveness, and support sustainable growth. This structure offers a holistic view of Guilan's branding potential aligned with the study's objectives.

2.3 International perspective on regional branding

Recent studies highlight the growing intersection between spatial planning and regional branding.

In northern Portugal, (Oliveira, 2015) shows how branding aligned with spatial planning through territorial identity and participatory governance, though long-term success depended on sustained political and cross-sectoral support.

Similarly, (Lucarelli & Heldt Cassel, 2020) examine Swedish Lapland's multi-municipality branding initiative, initially driven by collective discourse but later weakened by shifting agendas and fragmented governance.
These cases suggest that enduring branding efforts require strong institutional backing beyond initial momentum. For developing regions like Guilan, they underscore the need to embed branding within spatial planning frameworks to drive lasting, integrated development.

2.4 Geographic and spatial profile of the study area

Guilan Province, located in northern Iran along the Caspian Sea's southern shore, borders Mazandaran (east), Ardabil (west), and Zanjan and Qazvin (south). Spanning about 14,000 square kilometers, it features a rich geographic tapestry—coastal plains, wetlands, river deltas, and the forested northern slopes of the Alborz Mountains.
The province's humid, temperate climate sustains fertile lands and the ancient Hyrcanian forests, enabling rice, tea, and citrus cultivation. Rivers like Sefidrud play a vital ecological and economic role.
Rasht, the provincial capital, is the administrative and cultural hub, while cities like Bandar Anzali (a key maritime port) and Lahijan (a center for tea and horticulture) contribute to the region's distinct identity. Guilan's population, known for its unique language and customs, weaves a vibrant cultural fabric.
The economy is grounded in agriculture and fishing, with tourism on the rise. Guilan's strategic access to roads, railways, airways, and the Anzali Free Zone enhances its role as a trade corridor.
As Fig.2 illustrates, Guilan's unique mix of sea, forest, and farmland provides a strong spatial foundation for developing place-based regional brands. Understanding this geography is key to assessing its branding potential.

Fig.2 Location and topographical context of Guilan Province in northern Iran (based on Google Earth, 2024)

3. Methodology and data

This study was conducted in Guilan province (July 2023 - January 2024) using a mixed-method approach that combined qualitative and quantitative data from library research and fieldwork.

The methodology centered on two techniques: the Delphi method and MICMAC analysis, which together helped identify and classify key variables influencing Guilan's regional branding system.

3.1 Delphi method

The Delphi method, a structured consensus-building technique, was used to explore branding opportunities and challenges in Guilan.

A panel of 21 experts - including scholars, branding professionals, tourism officials, and government representatives—participated in two iterative rounds.

- In the first round, open-ended questions elicited key challenges and opportunities;
- In the second, panelists rated the importance and feasibility of these items using a Likert scale, facilitating consensus on the most critical factors.

This iterative process technique was chosen for its ability to synthesize divergent views, especially for contexts characterized by low a priori data, ensuring rich understanding of Guilan's branding dynamics (Arcade et al., 1993; Chine et al., 2017).

3.2 MICMAC analysis

MICMAC analysis was used to structurally map the key variables influencing Guilan's branding system. As outlined by (Arcade et al., 1993), the process includes:

- identifying critical variables via the Delphi method;
- analyzing interrelations using a cross-impact matrix;
- classifying variables into five categories: input, intermediate, output, excluded, and clustered (Godet et al., 2008).

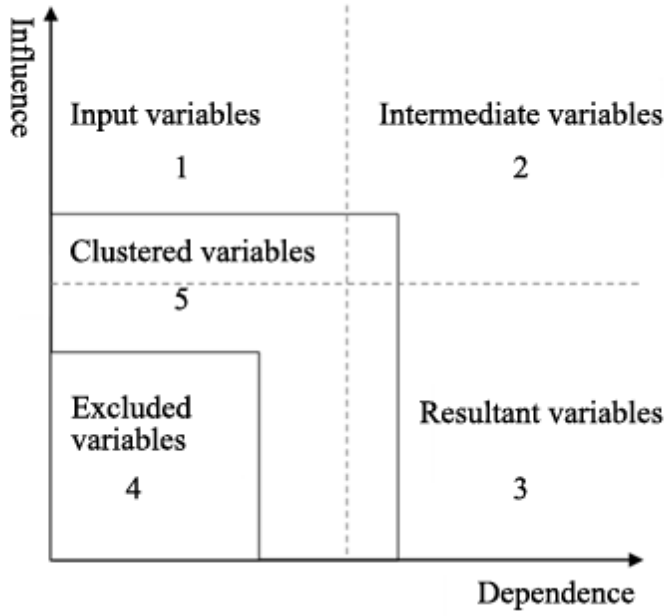

Fig.3 Classification of Variables Based on System Influence and Dependence (Authors' adaptation based on Godet et al., 2008)

The resulting diagram shows variables' influence (vertical axis) and dependence (horizontal), offering insights into strategic priorities (Nematpour & Faraji, 2019; Villacorta et al., 2014).

The classifications are:

- Input - highly influential, minimally dependent;
- Intermediate - both influential and dependent (Asan & Asan, 2007);
- Output - dependent, low influence;
- Excluded - low impact overall;
- Clustered - uncertain or overlapping roles.

3.3 Data collection

Data collection combined primary and secondary sources to provide a comprehensive view of regional branding in Guilan.

Primary data included:

- Semi-structured interviews with five experts (from tourism, fisheries, and academia) covering existing brands, regional potentials, and branding challenges;
- Expert surveys using structured questionnaires distributed to 21 professionals across academia, industry, and government.

Secondary data came from:

- Library research (books, articles, and reports, theses) to identify branding factors;
- Government and industry reports on development plans, policies, and tourism statistics.

3.4 Data characteristics

The dataset includes qualitative and quantitative data. Qualitative data derived from semi-structured interviews and open-ended survey responses. Quantitative data were collected using Likert-scale scoring in surveys, where variables were evaluated for importance and agreement. In Tab. 2 - 4 the results of the questionnaire are summarized.

Existing brands	Agreement (percent)/ Likert Scale					Importance (mean) (0-10)
	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	
Tourism	0.0	0.0	4.3	13.0	82.6	9.30
International Trade	0.0	4.3	21.7	39.1	34.8	7.30
Cellulose Industries	0.0	13.0	26.1	34.8	26.1	6.47
Agriculture	0.0	0.0	4.3	17.4	78.3	9.21
Horticulture	0.0	0.0	0.0	26.1	73.9	8.91
Fisheries	0.0	0.0	13.0	21.7	65.2	8.26

Tab.2 Results of Existing brands section of questionnaire (Authors analysis, 2024)

Potential brands	Agreement (percent)/ Likert Scale					Importance (mean) (0-10)
	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	
Pharmaceutical Industry	0.0	21.7	26.1	26.1	26.1	6.39
Ecotourism	0.0	0.0	4.3	30.4	65.2	9.30
Herbal Medicines	0.0	0.0	30.4	47.8	21.7	7.74
Agritourism	0.0	4.3	4.3	21.7	69.6	8.82
Domestic Maritime	0.0	0.0	26.1	43.5	30.4	7.69
Commercial Tourism	0.0	0.0	0.0	60.9	39.1	8.52
Foreign Marine Tourism	0.0	13.0	8.7	30.4	47.8	7.69
Beach Sports	0.0	4.3	13.0	34.8	47.8	8.65
Transit	0.0	4.3	4.3	65.2	26.1	8.21
Customs	0.0	0.0	17.4	52.2	30.4	8.00

Tab.3 Results of Potential brands section of questionnaire

Challenges and obstacles		Agreement (percent)/ Likert Scale					Importance (mean) (0-10)
		Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	
Political	Lack of sufficient government support for branding initiatives	0.00	13.00	8.70	30.40	47.80	8.00
	Political pressure regarding branding effectiveness	0.00	13.00	52.20	21.70	13.00	5.73
Economic and marketing	Long-term return on investment	0.00	8.70	4.30	56.50	30.40	7.52
	Deficiencies in infrastructure and facilities	0.00	0.00	13.00	21.70	65.20	8.78
	Budgetary and financial limitations	0.00	13.00	13.00	30.40	43.50	7.69
	Inability to reach target groups properly	0.00	21.70	17.40	34.80	26.10	6.69
	Difficulty selecting the best branding attribute	0.00	26.10	26.10	30.40	17.40	6.52
	Similarity to existing brands and unintelligent design	0.00	8.70	34.80	30.40	26.10	6.95
Administrative	Short management tenure	0.00	4.30	8.70	30.40	56.50	8.56
	Managers lack the necessary individual skills	0.00	4.30	21.70	17.40	56.50	7.73
	Complexity of administrative processes	0.00	8.70	4.30	34.80	52.20	8.39
Social and Cultural	Lack of positive public perception of the brand	0.00	8.70	56.50	13.00	21.70	4.82
	Imbalance between internal and external stakeholder interests	0.00	8.70	30.40	39.10	21.70	7.00
	Lack of proper coordination between the government and society	0.00	17.40	17.40	26.10	39.10	7.52
	Insufficient education for local communities to engage with investors	0.00	8.70	8.70	30.40	39.10	7.69

Tab.4 Results of Obstacle and Challenges section of questionnaire

4. Analysis

4.1 Inventory of variables

The MICMAC analysis began by identifying variables from the questionnaire responses, categorized into two groups: *Existing and Potential Brands* (13 variables reflecting Guilan's branding assets and opportunities), and *Challenges and Obstacles* (9 variables highlighting barriers to branding efforts).

	Variables	Short Label
Existing and Potential Brands	1. Tourism	Tourism
	2. Agriculture	Agri
	3. Horticulture	Horti
	4. Fisheries	Fishery
	5. Ecotourism	Ecotourism
	6. Herbal Medicines	Herbal med
	7. Agritourism	Agritouris
	8. Domestic Maritime Transport	In Mariti
	9. Commercial Tourism	Comtourism
	10. Foreign Marine Tourism	Out Mariti
	11. Beach Sports	Beach Sport
	12. Transit	Transit
	13. Customs	Customs

	Variables	Short Label
Challenges and Obstacles	1. Lack of sufficient government support for branding initiatives	Supportlac
	2. Long-term return on investment	InvestRetu
	3. Deficiencies in infrastructure and facilities	Infrastruc
	4. Budgetary and financial limitations	Budget
	5. Short management tenure	Duration
	6. Managers lack the necessary individual skills	SkillLack
	7. Complexity of administrative processes	Complexity
	8. Lack of proper coordination between the government and society	Coordinate
	9. Insufficient education for local communities to engage with investors	Education

Tab.5 Variables and Short Labels

4.2 Cross-Impact matrices

To assess relationships among key variables, two MICMAC cross-impact matrices were developed. The 13×13 Existing and Potential Brands Matrix identifies key drivers and dependencies among branding opportunities, while the 9×9 Obstacles and Challenges Matrix maps interdependencies among systemic barriers

4.3 Key variables for next steps

Based on Tab. 2 - 4, variables with ≥50% agreement and importance scores ≥7.5 were selected for deeper analysis. Key brand-related variables include tourism, agriculture, horticulture, ecotourism, agritourism, and commercial tourism. Key challenges include infrastructure deficiencies**,** administrative complexity, and branding support gaps—the latter involving lack of coherent policies, funding, and coordination.

4.4 Micmac analysis results

The MICMAC results are shown in Influence-Dependence Maps (Fig. 4), which categorize variables into: Drivers (high influence, low dependence), Outcomes (high dependence, low influence), Intermediate/Linkage Variables, and Excluded/Independent Variables.

The Direct Influence Graph illustrates how branding opportunities and challenges interact and identifies the most influential factors.

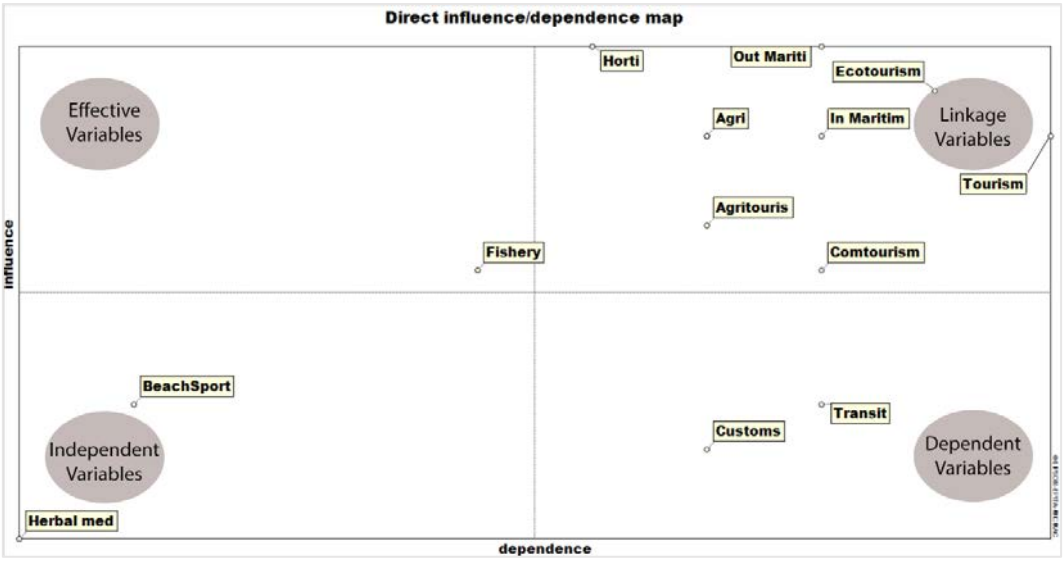

Fig.4 Influence-Dependence Map of Existing and Potential Regional Brands in Guilan (Authors analysis, 2024)

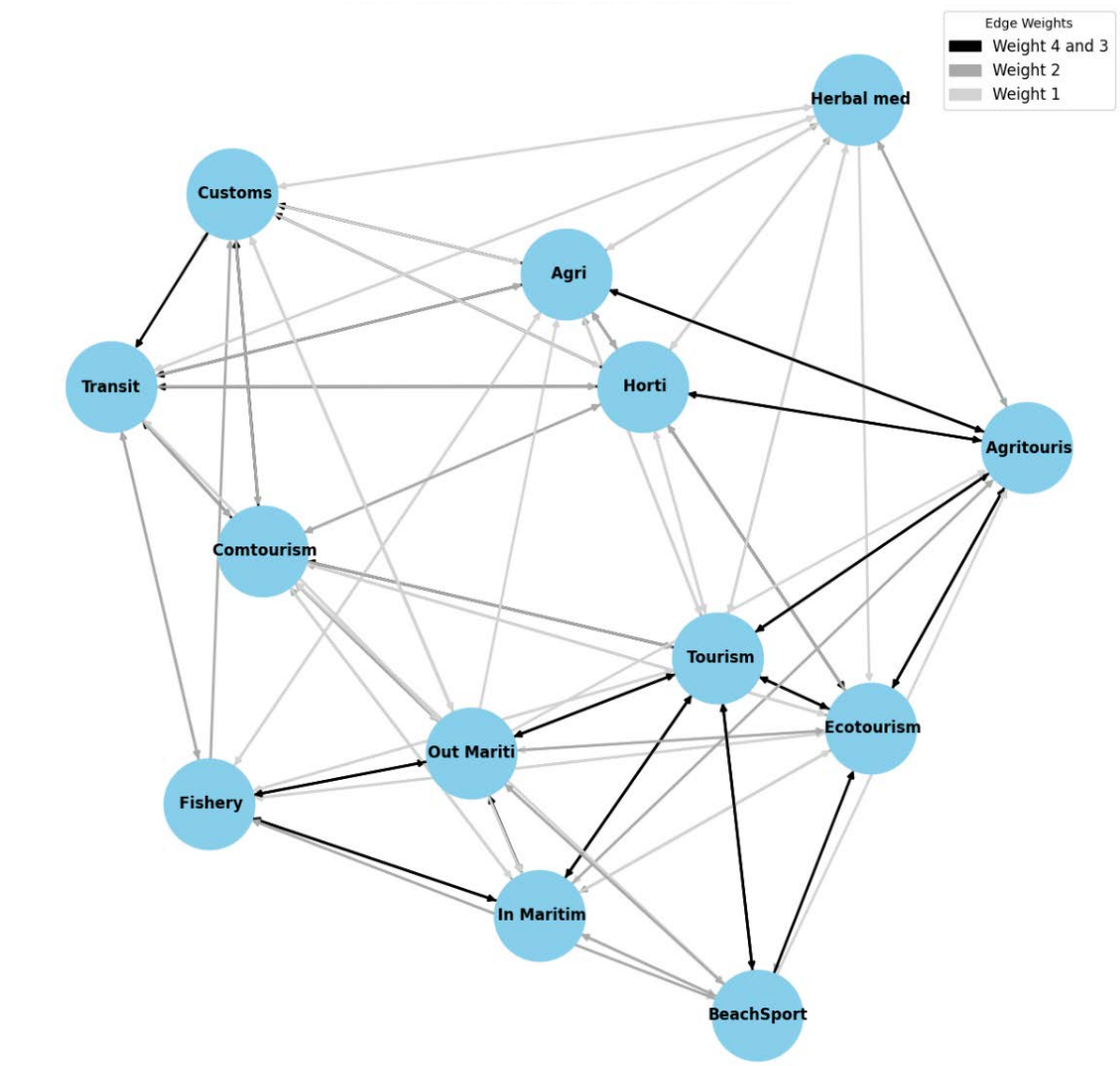

Fig.5 Network of Direct Influences Among Existing and Potential Regional Brands (Authors analysis, 2024)

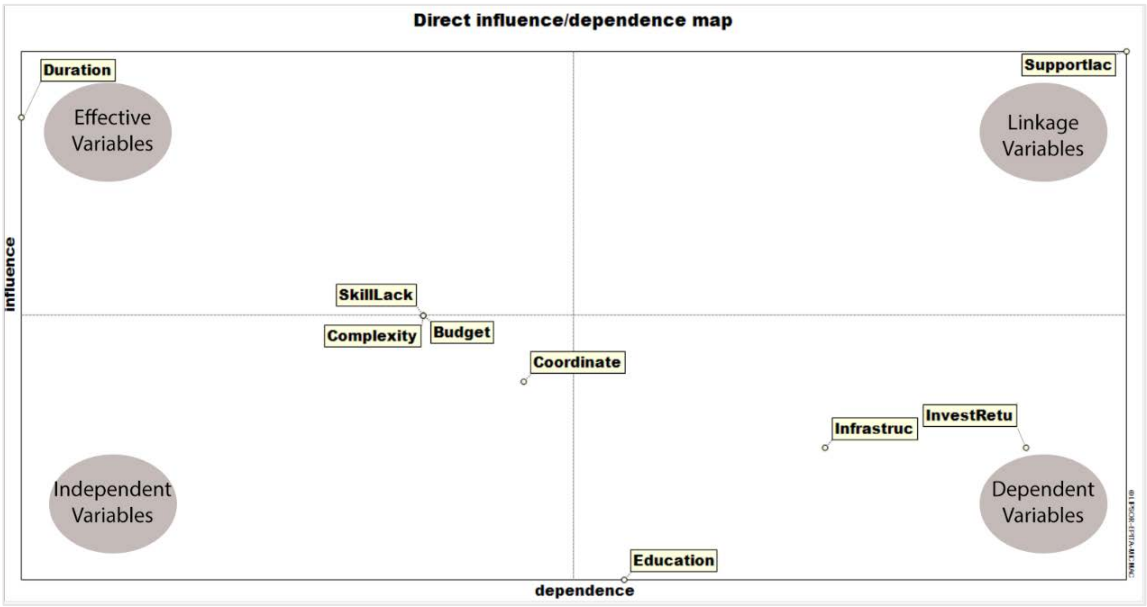

Fig.6 Influence-Dependence Map of Identified Obstacles and Challenges in Regional Brand Development (Authors analysis, 2024)

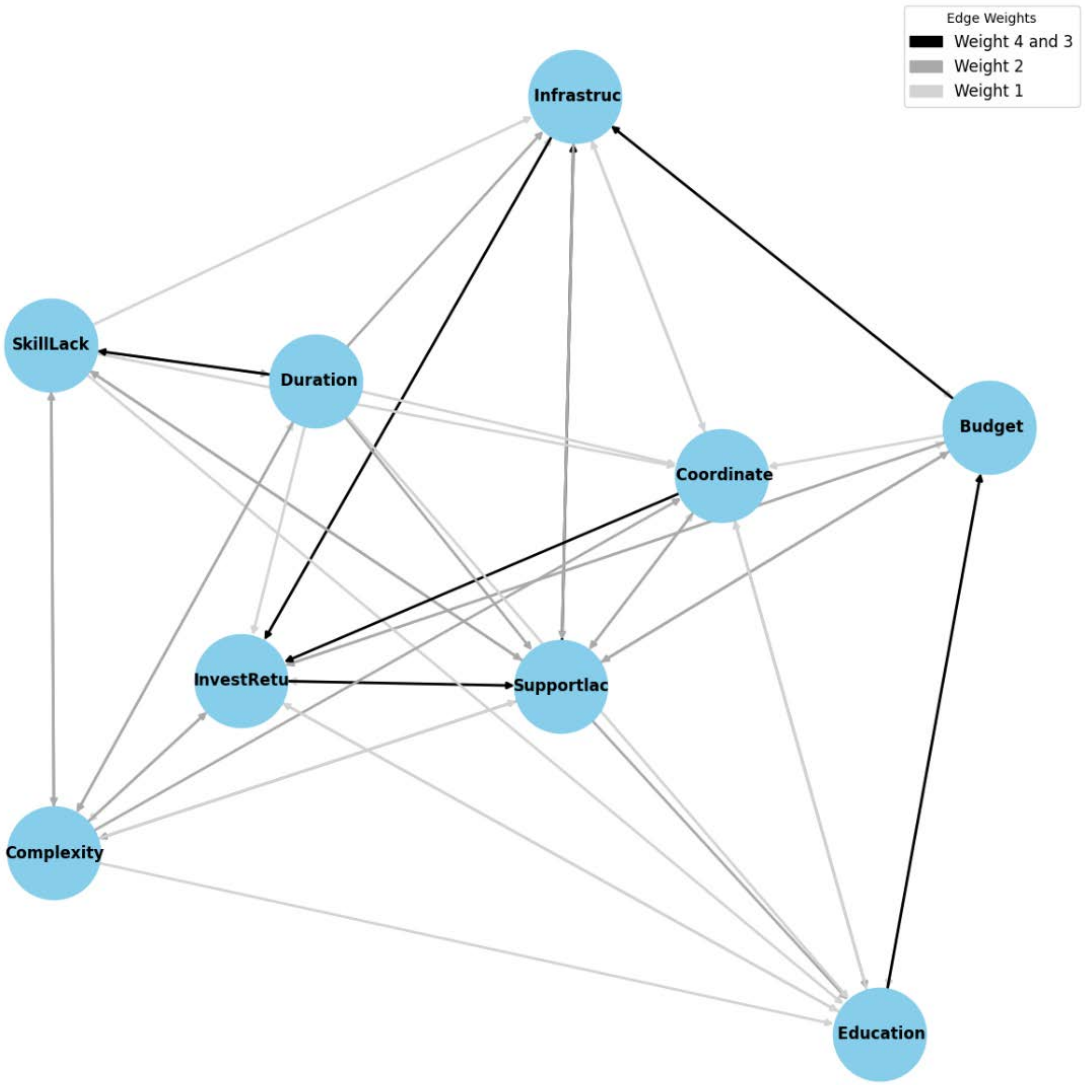

Fig.7 Network of Direct Influences Among Obstacles and Challenges in Regional Branding (Authors analysis, 2024)

5. Discussion

5.1 Key findings and interpretation

The MICMAC analysis identified tourism, agriculture, and ecotourism as the most influential drivers of Guilan's branding, reflecting its cultural, natural, and economic strengths. In contrast, infrastructure gaps, branding support deficiencies, and administrative complexity were major barriers limiting branding effectiveness.
These findings align with earlier research emphasizing tourism and agriculture as key to competitive branding (Huang & Yang, 2023; Kavaratzis, 2004). However, Guilan's challenges - especially fragmented stakeholder coordination and limited resources - are more pronounced than in branding studies from developed contexts (Pasquinelli et al., 2022).

5.2 SWOT analysis

The SWOT analysis evaluates the strengths, weaknesses, opportunities, and threats of Guilan's key brands. Existing brands include tourism, agriculture, and horticulture, while potential ones comprise agritourism, ecotourism, commercial tourism, domestic maritime transport, and foreign marine tourism. This framework helps identify strategic priorities, guide investment and marketing decisions, and support regional development planning.

	Strengths	Weaknesses	Opportunities	Threats
Tourism	- Natural, historical, and cultural landmarks - Favorable geography and climate - Abundance of local foods and products - A tourist-friendly culture - Enhancement of the built environment	- Absence of a designated authority for tourism development - Seasonal imbalance in tourist distribution - Insufficient amenities and accommodation facilities - Ineffective communication and advertising systems - Cultural conflicts between tourists and locals	- Encouraging private sector investment in the region - Generating employment and driving regional economic growth - Increasing focus on tourism planning and policy by officials	- Increased pollution and damage to the local ecosystem - Construction of residences and villas on forested slopes and areas rich in natural resources - Destruction of agricultural lands and fields - Rising land and service prices in the region - Negative impact on local culture
Agriculture	- Favorable geographic and climatic conditions for agriculture - High fertility and productivity potential of the land - Availability of various suitable water sources - A young and dynamic workforce in the region - Proximity to consumer markets and efficient transportation of products	- Use of inappropriate cultivation and supply methods, leading to significant agricultural waste - The current system is inefficient and has low productivity - Inefficient water usage due to outdated irrigation techniques - Absence of a coherent production chain, resulting in reduced incomes for farmers - Insufficient mechanization and outdated agricultural machinery	- Securing capital to develop conversion, processing, and packaging industries - Improving productivity through the use of modern designs and technologies - Potential for expanding markets and exporting agricultural products - Enhancing the attractiveness of agribusiness and rural livelihoods to encourage the younger generation to enter the sector	- Soil erosion and degradation resulting from unsustainable agricultural practices and overexploitation - Depletion of water resources due to misuse - Economic vulnerability of farmers, who are unable to sell products at their true value without profit-driven intermediaries - Lack of localized technology to enhance productivity
Horticulture	- Comparative advantage of horticultural products and economic value per unit of water used - Lower water consumption compared to traditional agriculture - Availability of suitable land for horticulture - Favorable climate and weather conditions for gardening	- High levels of waste and quality loss from harvest to distribution - Workers in the industry lack technical knowledge and skills - Insufficient funding and lack of investors - Absence of mechanization in gardening and inadequate facilities	- Potential to export products to neighboring countries and generate foreign currency - Utilization and restoration of degraded forests and pastures to establish gardens - Introduction of new foreign species and cultivars for export-oriented production - Preservation of resources and creation of employment opportunities	- A weak trade and export system, alongside limited expansion into foreign markets - Lack of coordination among research, laboratory, and educational activities - Inadequate infrastructure for transporting and storing horticultural products

Tab.6 SWOT analysis of key existing brands (Authors analysis, 2024)

	Strengths	Weaknesses	Opportunities	Threats
Agritourism	- Provides farmers with a second source of income - Enhancing commuting routes and infrastructure	- Low literacy levels among agricultural workers - Lack of knowledge and acceptance of this method of generating income among farmers	- Creating employment and attractiveness for farmers and rural residents - Familiarizing tourists with agriculture processes	- Increasing tourism in agricultural areas and potential environmental damage - An increase in undesired constructions - Lack of advertising and awareness campaigns

Ecotourism	- A wide range of ecotourism attractions are available in the region - Integrating natural and urban environments	- Lack of infrastructure and facilities in areas such as Asalem Road, Bojagh National Park, etc. - Tourists are unaware of ecotourism principles and environmental protection - Pollution and environmental damage	- Teaching ecotourism and tourism principles without harming the environment Science, research, and ecotourism tourists arrive in pristine and valuable environments - Sustainable development and environmental protection	- The government and residents are unwilling to allow tourists to enter pristine and protected areas due to the fear of environmental damage - Insufficient advertising for ecotourism
Commercial Tourism	- Anzali Free Zone with appropriate business facilities and locations - Bandar Anzali's proximity to Rasht Airport - A proximity to an industrial area	- Insufficient economic stability in the country, leading to a lack of investors	- Positive impact on other sectors of the tourism industry - Being located along the north-south transit route - Contribute to the creation of local jobs	- Sanctions and restricted access to goods and inputs - Risks associated with currency fluctuations
Domestic Maritime Transport	- Offering users an innovative and attractive mode of transportation - Capacity to transport cargo and goods safely and efficiently	- Insufficient equipment, infrastructure, and ports - A lack of coordination and custodial care - Degrading the environment	- Creating jobs and stimulating the economy - Reducing road traffic accidents and fatalities - Reducing the cost of road maintenance and repairs	- Insufficiency of specific and coherent shipping lines - Variation in atmospheric conditions, particularly during cold seasons, which can lead to unpredictable limitations
Foreign Marine Tourism	- Setting up a currency import source - Establishing a safe and attractive tourist route	- Sanctions and political problems - Insufficient tourism infrastructure and inadequate facilities for foreign tourists - Polluting the sea due to ship traffic and waste	- Difference in exchange rates between neighboring countries and potential for foreign tourists to be attracted to the country - Provide employment opportunities	- Cultural and legal restrictions that discourage tourists - Lack of coordination between neighboring countries and weak political relations

Tab.7 SWOT analysis of key potential brands (Authors analysis, 2024)

5.3 Integrating regional branding with spatial and land use planning

The SWOT analysis shows that Guilan's core branding assets - agriculture, natural landscapes, and cultural heritage—are inherently spatial. These strengths are geographically rooted and shaped by ecological and land-use patterns, making spatial and land use planning essential for meaningful branding. For instance, ecotourism branding requires concrete interventions like zoning, conservation, and infrastructure, while agricultural branding depends on land protection, irrigation, and rural services. Without spatial alignment, branding remains symbolic rather than transformative. As (Zecca et al., 2020) argue, spatial planning must adapt to behavioral and infrastructural realities—especially post-crisis. Similarly, Guilan's challenges—fragmented infrastructure, weak coordination, and administrative inefficiencies—are fundamentally spatial governance issues. Addressing them requires participatory planning, rural development strategies, and territorial policy coordination. Supporting this, (Gomes et al., 2024) call for governance-driven spatial planning to balance resource use and sustainability, while (Chen & Gong, 2025) emphasize adaptive spatial strategies to anticipate long-term challenges. Embedding branding within these frameworks can anchor identity-building in real, actionable development.

5.4 Spatial and statistical validation of findings

The Delphi-based results are validated through spatial and statistical evidence. As shown in Fig.8, Guilan features dominant agricultural lands, forests, wetlands, and coastal areas - aligning with expert rankings of

agriculture, ecotourism, and agritourism as key brand assets. This land use pattern confirms the region's natural branding potential.

However, the Delphi study also highlights infrastructure and accessibility as major constraints, echoed in the disconnection between inland agricultural/ecological areas and urban/coastal tourist zones, limiting integrated mobility and tourism development.

Tourism data further supports these insights. According to the Guilan Cultural Heritage, Tourism and Handicrafts Department, over 8.25 million domestic travelers visited during Nowruz 2024, a 4% increase from the previous year. Cities like Rasht, Bandar Anzali, and Astara saw 99% accommodation occupancy, reflecting the province's strong tourism pull. Together, the land use structure and tourist data empirically support the Delphi findings and underline the urgency of addressing infrastructure gaps to strengthen Guilan's branding potential.

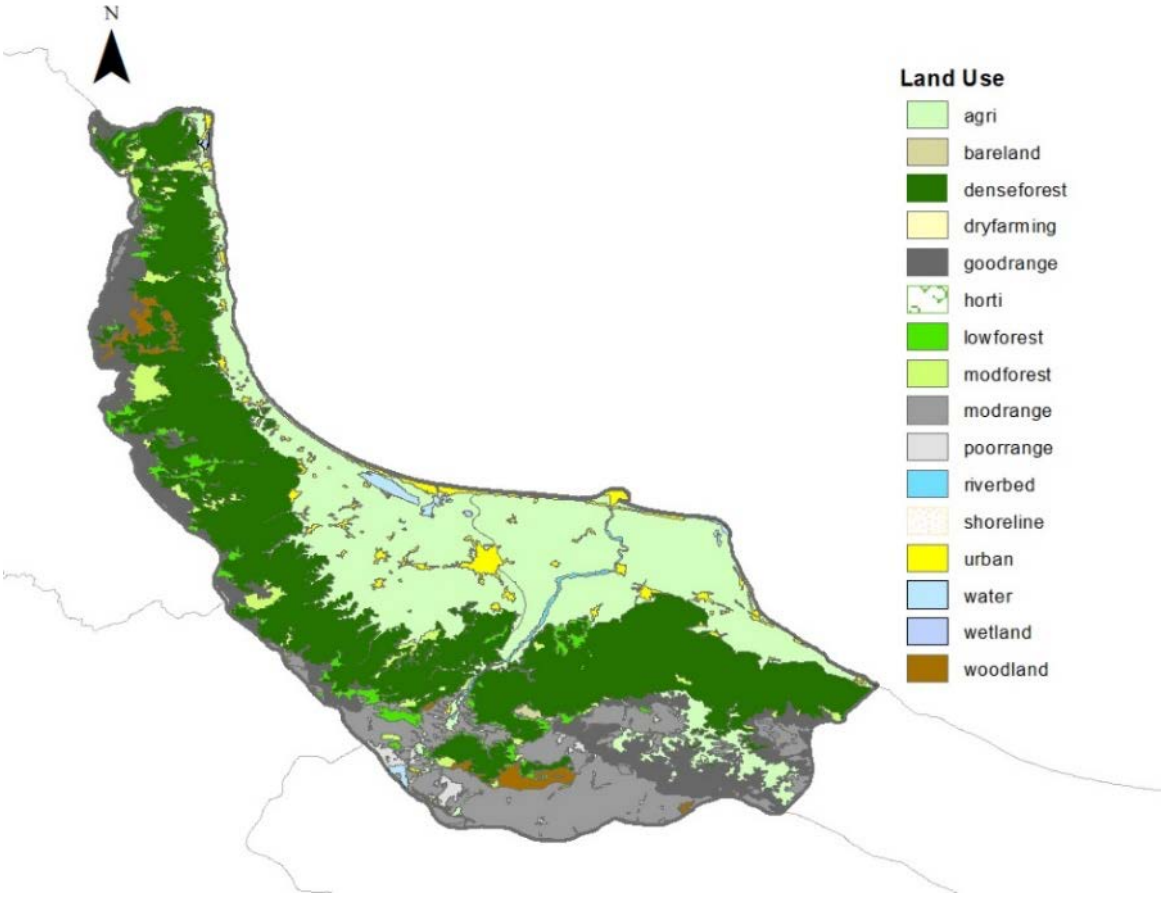

Fig.8 Land Use Distribution in Guilan Province (Authors analysis, 2024)

5.5 Addressing research questions

- *What brands are there in the Guilan province at the moment, and how do they help to improve local competitiveness?*

Guilan province's leading local competitiveness brands center on tourism, supported by its rich cultural heritage, natural beauty, and historic landmarks that attract both domestic and international visitors.

Tourism significantly contributes to the region's economy and identity. Complementing tourism, agriculture - particularly the cultivation of tea and rice using fertile land and traditional methods- remains a cultural and economic cornerstone. Additionally, ecotourism emerges as a strong branding opportunity, aligned with global sustainability trends and Guilan's diverse landscapes and biodiversity.

MICMAC analysis highlights tourism, agriculture, and ecotourism as key drivers of Guilan's branding success, defining regional identity and competitive advantage while fostering collaboration among stakeholders to enhance economic resilience. However, systemic challenges such as inadequate infrastructure, limited marketing resources, and fragmented governmental support hinder these sectors' full potential. Addressing these barriers through strategic investment, targeted marketing, and stakeholder cooperation is essential for strengthening Guilan's competitive position in regional and international sustainable development markets.

— *What are the critical barriers to branding exercises in Guilan?*

The study identifies critical barriers hindering Guilan's branding success, stemming from systemic, administrative, and resource-related challenges. Infrastructure deficiencies -particularly in road transport and tourism facilities- limit accessibility and detract from tourist experiences, thereby constraining the region's tourism potential.

A key obstacle is the lack of state-level support for branding initiatives. Insufficient funding, low policy prioritization, and weak government-stakeholder collaboration impede effective strategy development and execution, echoing prior research underscoring governance as vital for regional branding success.

Administrative complexity further hampers progress, with bureaucratic inefficiencies, protracted decision-making, fragmented management, and gaps in managerial skills undermining innovative campaign implementation. Financial constraints restrict investment in essential branding tools and marketing activities, limiting brand visibility locally and globally.

Additionally, negative public perceptions -rooted in limited awareness among local stakeholders - erode collective support for branding efforts.

These challenges demand strategic responses, including infrastructure investment, management capacity building, streamlined administrative processes, and stronger government commitment. Addressing these barriers is crucial for enhancing Guilan's branding ecosystem and realizing its potential as a competitive regional brand.

— *How can the branding of Guilan be used to build and develop sustainable regional brands?*

Based on the research findings, strategic recommendations for establishing sustainable regional brands in Guilan emphasize leveraging high-impact sectors -tourism and agriculture- to strengthen regional identity. Targeted capital investment in tourism infrastructure and the promotion of sustainable agricultural practices can significantly enhance these core drivers.

Addressing systemic challenges requires increased government funding and fostering public-private partnerships to resolve infrastructure gaps and improve branding support. Streamlining administrative processes will facilitate greater stakeholder engagement and more efficient branding initiatives.

Exploiting Guilan's unique assets, such as ecotourism and agritourism, offers further branding opportunities. Initiatives like developing eco-trails, promoting organic farming experiences, and marketing local products (e.g., herbal medicines) can position Guilan as a leader in sustainable tourism and local enterprise.

Engaging communities through educational campaigns and training to align stakeholders with branding objectives will strengthen local ownership of the regional brand. Additionally, integrating digital marketing - social media, virtual tours, and other platforms- can expand Guilan's reach among tech-savvy tourists.

Together, these strategies can foster a coherent, sustainable regional brand that highlights Guilan's distinctive cultural, natural, and economic strengths while overcoming existing challenges.

5.6 Implications

This study provides important theoretical and practical contributions to regional branding, especially in developing regions like Guilan Province. Theoretically, it demonstrates how MICMAC analysis can clarify the interconnections among drivers, intermediates, and outcomes in branding systems.

Practically, it underscores the need to prioritize high-impact variables, improve infrastructure, and involve local communities to build brand ownership.

These findings align with (Marinelli et al., 2022), who emphasized that infrastructure gaps and spatial fragmentation were major barriers to territorial development in post-seismic Italy, and that local engagement was key to building resilience.

By tackling these systemic challenges, Guilan can establish a sustainable and competitive regional brand with long-term global potential.

5.7 Limitations and future research

Considering the research focuses on expert opinions and in a short-term period, the geographical scope has been limited to Guilan province. Future studies should investigate the long-term effects of branding strategies or expand to other regions with similar conditions. Adding quantitative measurements of branding performance might be able to strengthen the findings further.

6. Conclusion

This study identified key existing brands in Guilan - tourism, agriculture, and horticulture - and emphasized the need for strategic development to leverage these assets. The findings align with (Cheraghi & Moosavi Nadoshan, 2024; Monem Lafmejani et al., 2022), who also highlighted tourism as Guilan's core brand. Emerging opportunities include agritourism, ecotourism, commercial tourism, inland waterway transport, and foreign cruise tourism, all of which suggest strong potential for sustainable growth.

The SWOT analysis confirms Guilan's strengths - natural and cultural richness - and aligns with (Moroz et al., 2020) on sustainable tourism's role in regional branding. While challenges such as infrastructure gaps, administrative complexity, and limited government support persist, they can be addressed through strategic use of existing strengths.

Barriers identified include bureaucracy, limited managerial skills, and short tenures. Solutions include streamlining processes via IT, investing in training and teamwork, and designing long-term strategies, as noted by (Mariutti & Giraldi, 2021). Strengthening collaboration between governance and branding stakeholders is also vital, echoing the insights of (Beran et al., 2016; Johnson et al., 2020).

By tackling these issues, Guilan can enhance its branding system and serve as a model for regional development in similar contexts.

Theoretically, this study highlights the interplay of influential and dependent variables in branding systems, contributing to the literature on branding in emerging economies.

Future research should explore the long-term impact of these strategies and their applicability to other regions with comparable socio-economic conditions.

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Image Sources

Fig.1: Authors, 2024;

Fig.2: Authors, based on Google Earth (2024);

Fig.3: Adapted from (Godet et al., 2008);

Fig.4: Authors analysis, 2024;

Fig.5: Authors analysis, 2024;

Fig.6: Authors analysis, 2024;

Fig.7: Authors analysis, 2024;

Fig.8: Authors analysis, 2024.

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The Axis Contract for the regeneration of fragile territories. An experiment along the Civitavecchia Capranica Orte railway line

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Abstract
The article explores the revitalization of Italy's "inner areas" - fragile territories facing challenges such as depopulation, abandonment, and a lack of essential services, primarily due to limited mobility. The enhancement of secondary and disused railways is proposed as a tool for territorial rebalancing, to be achieved through multilevel governance that integrates spatial planning, interinstitutional cooperation, and the strategic allocation of financial and economic resources. This approach aims to move beyond sectoral perspectives on infrastructure networks.
The *Axis Contract* is introduced as an integrated framework linking urban planning and mobility, centered on the right to mobility and the empowerment of local communities.
The article is structured into three parts: the first examines the relationship between territory, mobility, and infrastructure policies; the second analyzes the French *Contrat d'axe* model and its applicability in Italy; and the third presents the results of an interdisciplinary study on the reactivation of the Civitavecchia - Capranica - Orte railway line.
The findings confirm that the *Axis Contract* is an effective tool for integrating urban and mobility planning, addressing accessibility needs, and promoting the sustainable rebalancing of territories.

Keywords
Sustainable mobility; Urban planning; Inner Areas

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1. Introduction[1]

This article examines the reactivation of Italy's "internal areas," fragile territories affected by depopulation and abandonment due to socioeconomic challenges, including insufficient essential services and mobility barriers that undermine the "Right to Mobility" (Amato, 2021).

In this context, a strategy focused on secondary railway lines—many facing decommissioning—can support territorial rebalancing policies. This requires a multilevel governance framework that integrates territorial and urban planning with interinstitutional cooperation, leveraging financial resources and voluntary coordination tools.

International debates highlight the need to move beyond a sectoral approach to infrastructure, advocating for strategic urban, territorial, and mobility planning that aligns with evolving economic, settlement, and governance dynamics.

This article focuses on the Axis Contract, an integrated urban/mobility planning tool tested in the reactivation of the Civitavecchia-Capranica-Orte railway. The study is structured in three parts: the first explores the relationship between territory, mobility, and infrastructure policies; the second analyzes the French "Contrat d'axe" as a reference for adapting the Axis Contract to Italy; the third presents findings from interdisciplinary research conducted since 2021 at Roma Tre and Sapienza Universities.

Results confirm that the Axis Contract serves as a platform for integrating urban and mobility planning, providing concrete, shared responses to the Right to Mobility and fostering sustainable territorial balance.

2. Secondary railways and fragile territories

2.1 Settlement phenomena, mobility models and territory

There is a strong connection between infrastructure, mobility, and territory, recognized since the 1980s through national research[2]. Today, more than ever, an integrated approach is essential to rebalance the territory and achieve the green, ecological, and inclusive transition central to EU policies in the post-COVID era. Accessibility is a key issue in this context.

In Italy, 48.5% of the 7,901 municipalities, covering 59% of the national territory, are significantly distant from essential services (education, health, and mobility) (Barca et al., 2014). Since 2014, these have been classified as "inner areas" by the National Strategy for Internal Areas (SNAI)[3]. These areas have long suffered from depopulation, which between 2014 and 2024 reached -5.0% (compared to -2.2% nationally)[4]. This decline has impacted secondary railways, which serve as the backbone of these areas but have lost passengers over time, fueling a vicious cycle exacerbated by evolving settlement patterns since the post-war period.

After World War II, Italy's infrastructure reconstruction, particularly railways, required massive investment. This period, driven by the Marshall Plan, coincided with the global spread of new mobility models centered

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1 This contribution is part of ongoing research exploring the relationship between infrastructure and territory. Key projects include:
- "Railway policies, Territory and Mobility," coordinated by the author, involving the University of Roma Tre, CONICET (Buenos Aires), and UBA (Jorge Blanco), with results published in 2012 and 2015.
- "Paths of resilience: Reuse and relaunch of minor railways for fragile territory regeneration," led by Chiara Ravagnan and funded by Sapienza in 2018, involving several universities, with results published in 2020.
- "Right to mobility and contemporary city: The role of rail infrastructures in territorial regeneration strategies," coordinated by the author and funded by Sapienza in 2019, with results published in 2021.
- "Mobility infrastructures: New paradigms for European cities' resilience," coordinated by Bruno Monardo, involving multiple universities and published in 2024.

2 Among these, the multi-year research program "ITATEN Investigation of the transformations of the national territorial assets", conducted by A. Clementi, G. Dematteis and P. Palermo and the research program "RETURB Large networks and urban transformations in Italy", coordinated by A. Clementi, both in the Nineties.

3 The definition of "inner area" is linked to the levels of accessibility, calculated on the basis of travel times from the centroid of a municipality to reach, by car, the municipalities that are service provision centres (the "poles").

4 Data ISTAT National Institute of Statistics 2022-24; Department for Cohesion Policies and the South, 2024.

around automobiles. Enrico Menduni identifies three key events between the mid-1950s and mid-1960s that sparked a transformation in mobility and living patterns: the launch of RAI's television broadcasts in 1954, the debut of the FIAT 600 in 1955, and the construction of the Autostrada del Sole in 1956. Television played both a cultural and commercial role, spreading the American model and boosting consumerism, while highways facilitated the shift from rail to road travel.

These changes led to urban sprawl and suburbanization, with cities expanding to accommodate internal migration, while small towns, particularly in the Apennines and the South, were increasingly abandoned. The 1950 Agrarian Reform failed to resolve agricultural inefficiencies, further accelerating depopulation (Fabbri, 1983). The decline of railways, especially secondary lines, was exacerbated by national policies that reduced investments, leading to declining accessibility, service reductions, and increased vulnerability to natural risks due to the loss of local stewardship.

To counteract these trends, the Department for Development and Cohesion Policies (DPS) was established in 1998, later renamed the Department for Development and Economic Cohesion in 2006. However, it was not until 2013, under the Monti government and Minister Fabrizio Barca, that the Agency for Territorial Cohesion[5] was created, launching SNAI. Inner areas are primarily served by secondary railways, representing 56% of Italy's railway network. Unlike main lines, which are crucial for high-demand travel, these lines ensure territorial connectivity for scattered populations. However, they suffer from technological gaps, with 54% being single-track and 30% non-electrified[6].

Fig.1 Civitavecchia - Capranica - Orte railway line

Affected more by unsustainable policies and mass motorization than actual obsolescence, secondary railways have faced continuous cuts since the 1950s. Between 1950 and 1999, 4,028 km of secondary railways were

[5] The Agency for Territorial Cohesion is abolished in 2023 and replaced by the Department for Cohesion Policies and for the South, Ministry for European Affairs, the PNRR and Cohesion Policies.

[6] Source: RFI Italian Railway Network, 2024.

decommissioned[7], leading to the closure of over 1,100 stations. Since 2000, an additional 1,694 km have been closed or had service suspended, totaling a loss of over 5,700 km - nearly 24% of the 1936 railway network (Sellari, 2011). This has severely impacted inner areas, increasing their fragility.

The transformation in mobility is evident in transport usage data. Since 1971, pedestrian mobility has plummeted, private car use has nearly tripled, and public transport usage has halved[8]. These trends reflect a shift towards dispersed living near large cities and the abandonment of historic centers in small municipalities (Estanqueiro & Cerasoli, 2018). The appeal of automobiles, coupled with deteriorating public transport, has both shaped and responded to these changes.

Since the 1990s, the EU has sought to address the rail crisis and territorial imbalances. Directive 91/440/EEC (1991) aimed to open national rail networks to international services in an integrated, competitive infrastructure system. However, its economic focus overlooked the territorial impacts of market liberalization and the varying interpretations in national legislation. Many EU countries prioritized profitable main lines, particularly high-speed rail, benefiting only a small portion of the population. This has deepened disparities between "fast" and "slow" territories, contributing to an unplanned redistribution of populations and economic activities in a context of pseudo-liberalization (Cerasoli, 2012; Cerasoli, 2020).

2.2 Right to mobility for inner areas. Towards an integrated approach

Today, Italy's abandoned railway heritage comprises over 8,000 km of disused or underused lines (Marcarini, Rovelli, 2018). Like uprooted roots, their cessation has stripped territories of economic and social vitality. These broken links in the secondary railway network must be repurposed to support sustainable mobility, integrating innovative transport solutions tailored for inner areas - such as mobility sharing, on-demand services, and intermodal hubs - redefining catchment areas and enabling the sustainable reactivation of basic services.

Both "top-down" European and national policies (2007-2013, 2014-2020) and National Recovery and Resilience Plan (PNRR)[9] investments, along with "bottom-up" community mobilization, highlight the potential of repurposing this heritage. Citizens, associations, and local administrations demand strategic reuse solutions that address community needs, particularly in marginal and internal areas where rail services have been withdrawn.

As highlighted in recent studies (Ravagnan & Amato, 2020), interventions in fragile, low-density areas should be guided by three key principles: promoting intermodality and multiscalarity to connect peripheral areas with larger infrastructure networks; integrating digital, cultural, and social dimensions to foster innovation and heritage valorization; and enhancing ecosystem services to support ecological regeneration and risk mitigation.

In Italy, processes of integrated redevelopment have been implemented in recent years, aligning with current trends in integrated planning that promote cycle tourism and the creation of slow mobility routes as drivers for the valorisation of inner areas (Pinto, Fossati, 2020). A particularly significant example is the *Via Verde Costa dei Trabocchi* (Fig.2), which runs from the station of Ortona to Vasto Marina. This project has enhanced the accessibility of a highly valuable coastal area, generating positive effects on land protection, the promotion of sustainable local economies, and the reduction of mobility-related air pollution. Another relevant example is the Caltagirone-S. Michele di Ganzaria Linear Park, developed by NOWA Studio along the disused Dittaino-Caltagirone railway line. The project includes the creation of a greenway and the establishment of cultural and recreational activities along its route.

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7 These are both standard gauge and narrow-gauge lines, managed by Ferrovie dello Stato, by the Regions or Autonomous Provinces or by concessionary companies.

8 Source: ISTAT & ISFORT Higher Institute of Training and Research for Transport, 2021.

9 Mission 3 "Infrastructure for Sustainable Mobility" 25.4 billion euros for interventions to improve the railway network, especially secondary; Mission 5 "Inclusion and Cohesion" 19.86 billion - to which are added the funding of the Complementary Fund. Source: Chamber of Deputies, Parliamentary documentation (www.temi.camera.it), 2024.

Additional cases concern underutilized railway lines situated in areas of notable cultural and environmental interest, where services have been reactivated - often with a tourism-oriented approach - within the legal framework established by Law No. 128 of 9 August 2017. A noteworthy example is the *Avellino - Rocchetta Sant'Antonio* line, where the *Irpinia Express* initiative seeks to valorize the region's historical and environmental heritage. This intervention contributes to a renewed narrative and accessibility for territories historically affected by economic and demographic decline [10].

Fig.2 Via Verde Costa dei Trabocchi

This and others European experiences demonstrate that mobility infrastructure transformations should align with broader urban and territorial regeneration strategies, integrating morphological, functional, and environmental reconfigurations with socio-economic planning. These approaches reinforce the concept of the Right to the City (Harvey, 2012), extending to the Right to Mobility - encompassing accessibility, spatial justice, fair tariffs, sustainability, and liveability (Amato, 2021).

Since the 1980s, mobility has been recognized as a social issue crucial to individual and collective opportunities (Panato, 2013; Pucci, 2014; Pucci & Vecchio, 2018). The Right to Mobility entails both the freedom of movement and the ability to make informed choices about mobility options, considering accessibility, quality, costs, and social equity (Kaufmann et al., 2004; Colleoni, 2019). It also highlights urban planning's role in addressing emerging social needs through an integrated approach, overcoming sectoral divisions in mobility and urban planning. This strategy fosters inclusive and sustainable cities and revitalizes small centers, making them welcoming for people, attractive for innovation, supportive of businesses, and resilient community hubs.

3. From the contrat d'axe to the axis contract. A *transit oriented* regeneration for the right to mobility

3.1 The French *contrat d'axe* for a strategic densification

In line with what has been expressed so far, it is essential to identify shared and participatory tools that can support complex projects capable of rebalancing the territory, starting from a public transport infrastructure, capable to revitalize abandoned context (Dody et al., 2025). This involves systematizing the various competent and interested actors and offering clear rules, costs, and timelines related to field transformations.

[10] These and other case studies have been analysed within the framework of the international research project Resilience paths. The reuse and relaunch of minor railways for the regeneration of fragile territories. Experiences in Italy and Spain, founded by Sapienza University (Ravagnan & Amato, 2020).

In this sense, the French *Contrat d'axe* represents a strategic tool for pursuing the integration of infrastructural development and urban planning, guaranteeing the Right to Mobility for all territories (Ravagnan, Amato, 2019; Amato, 2021; Amato, 2022).

The *Contrat d'axe* is a negotiated planning tool aimed at integrating urban and transport development. It reconciles urban densification interventions and directs mobility demand toward alternatives to the private car. This is done by intervening on the urban form as a key factor in the use of different travel modes, thus encouraging behavioral changes in terms of private mobility.

This tool was developed in the early 2000s during the revision of the *Plan de Déplacements Urbains* (PDU) of the Metropolitan Area of Toulouse. Its goal was to control urban growth and ensure coherence between urban planning and transport organization (Bentayou et al., 2015).

A similar approach was undertaken in Grenoble, by the Mixed Public Transport Union (SMTC[11]) with the support of the Urban Planning Agency of the Metropolitan Area, where the *Contrat d'axe* was signed in June 2011, linked to the construction of the fifth tram line (Fig.3). By 2014, this tool had led to the construction of approximately 1,500 housing units along the tram line and revisions to the *Plan Local d'Urbanisme* (PLU) to incorporate "urban densification" principles.

By 2013, five *Contrats d'axe* had been signed in Toulouse, and a total of about twelve had been completed across France by 2014.

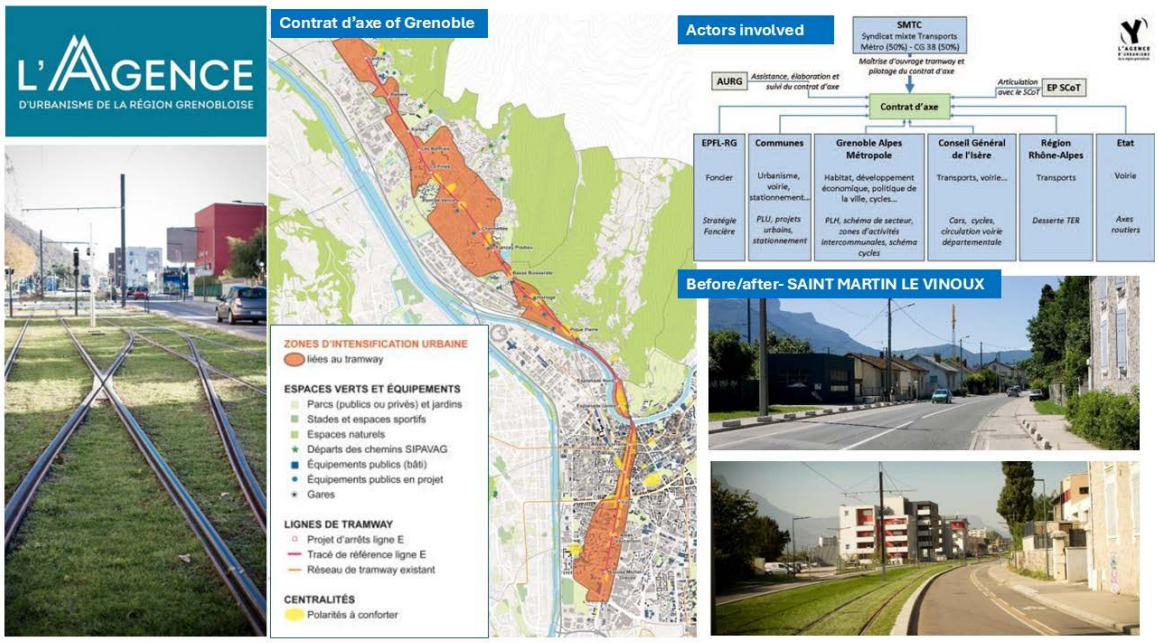

Fig.3 *Contract d'axe* for the "E" tram line in Grenoble

The Contrat d'axe currently being developed in France represents a unique experience in terms of the integration between urban development - still closely linked to a logic of controlled "expansion" - and mobility and infrastructure planning, in terms of skills, responsibilities, and programming. This result is achieved by bringing together the various institutional actors involved in urban transformation and coordinating their efforts and objectives toward a common and clear goal: to encourage as many people as possible to use the public transport infrastructure specified in the contract.

The Contrat tool also aims to enhance the effectiveness of public policies by transcending the sectorization of urban planning documents (PLU, PDU, etc.), ensuring coherence in strategic and sectoral choices.

In France, the implementation of *Contrat d'axe* follows five key phases:

[11] Today is SMMAG Syndicat Mixte des Mobilités de l'Aire Grenobloise, Mixed Union of Mobility of the Grenoble Area.

- A territorial diagnosis to identify urban development forecasts and evaluate the effects on public transport and mobility habits;
- Calibration of transport demand development scenarios based on expected demographic and urban growth, assessing socio-economic feasibility and costs/benefits of public transport;
- Formalization of the Contract, with explicit commitments from all parties involved;
- Integration of development forecasts into the urban and strategic planning tools of the municipalities;
- Monitoring of the contract's progress to ensure commitments are met on time and with expected results.

The *Contrat d'axe* is embedded within the *SCoT* (Schéma de cohérence territoriale), a strategic urban planning document that ensures coherence across multiple municipalities, particularly in terms of residential development, mobility, and environmental planning.

Specifically, some differences can be found in the use of *Contrat d'axe* in the French cases analysed, in relation to the contexts in which they were drafted. In urban and peri-urban areas, it focuses on controlling urbanization and regulating movements, as seen in Toulouse and other cities. In more intermediate areas, such as Béarn, the emphasis shifts to landscape protection and the "désenclavement" (opening up) of territories. In some cases, such as the Béarn region, the *Contrat d'axe* is also used in cross-border projects, like the reactivation of the Pau-Canfranc-Zaragoza railway line, fostering collaboration between regional actors and beyond (Region Aquitaine, 2013; Amato, 2019).

3.2 The proposal of an Axis Contract for an integrated approach

The strategic role of the *Contrat d'Axe* tool in linking urban development and mobility, as well as its potential for strategic inter-municipal coordination and community participation, presents opportunities for integration within the Italian urban planning landscape.

Much like "River Contracts"[12] for environmental planning along river sections or "Landscape Contracts"[13] for territorial landscape enhancement, the Axis Contract can be introduced as a negotiated planning tool. Its purpose is to coordinate actions aimed at urban regeneration and sustainable mobility development along an infrastructural axis, involving multiple stakeholders and leading to a shared strategic commitment.

A key aspect of the proposed Italian Axis Contract is its focus on the coherence and coordination between urban and mobility planning, within procedures that benefit both transport services along the axis and the territories they traverse. The goal is to define areas for Axis Contracts within Territorial Coordination Plans (PTC) [14], focusing on main public transport routes that require creation, enhancement, or strengthening. Each area will be evaluated for objectives, strategies, and actions, establishing the foundation for a participatory process leading to the Axis Contract.

The "axes to be implemented" refer to projects that are at various planning stages, with the goal of connecting them to territorial structures - both for sustainable mobility and green infrastructure - ensuring consistency in the development choices along these areas. These projects will be implemented through sustainable planning, assessing socio-economic and environmental impacts, and ensuring the infrastructure contributes to community cohesion and ecosystem integration.

The "axes to be strengthened" are those whose services have been reduced or suspended due to mobility dynamics, where strengthening or reactivating the service is strategic. Economic sustainability will require increased building density and a mix of uses, alongside major urban service projects that will generate

12 Article 68-bis "River Contracts" of Legislative Decree 3 April 2006, n. 152 "Environmental regulations".

13 European Landscape Convention. Pilot case "Landscape Contract in the mountain territories of Foligno, Trevi and Sellano", Umbria Region, Regional Council Resolution no. 1005 of 07.30.2012.

14 The Territorial Coordination Plan PTC is an urban planning tool at a supra-municipal scale provided for by the National Urban Planning Law n. 1150 of 1942 and still in force, even if at a regional level it may have a different name.

significant traffic along these axes. This will be coordinated with sustainable mobility alternatives, such as interurban buses or consortium shuttles, to serve a broader catchment area.

The "axes to be valorized" include operational infrastructures that can drive territorial regeneration, through rethinking network nodes in cultural-identity terms and integrating them with sustainable mobility systems, including pedestrian and cycle paths linked to parks and green areas. These areas form the foundation for launching the Axis Contracts.

The Axis Contracts are negotiated planning tools involving multiple actors to create a shared formal commitment. The process begins with establishing an inter-institutional Working Table, which can be initiated by regional, provincial, or municipal authorities, often led by the mayor of the involved municipality. Stakeholders include local authorities, the infrastructure owner, transport service providers, mobility services, area property owners, and private entities interested in the project's development.

The Working Table follows phases similar to those of a River Contract, including:

- Drafting a shared Intent Document;
- Conducting a cognitive analysis of the Territorial Plan, supplemented by further investigations if needed.
- Creating a Strategic Document and Action Program outlining long-term objectives, strategies, and intervention phases;
- Holding a participatory process with thematic workshops, engaging the local community to gather feedback and refine the framework of objectives and strategies;
- Revising the Strategic Document and Action Program based on community input;
- Finalizing and signing the Axis Contract, which outlines the roles, commitments, timelines, costs, benefits, risks, and sustainability of interventions;
- Publishing the Contract in the Official Journal and disseminating it via local information channels;
- Implementing a monitoring system to track progress and ensure compliance with the commitments.

The commitments outlined in the Axis Contract will then be incorporated into the local planning of the municipalities involved.

4. An Axis Contract for the Civitavecchia-Capranica-Orte railway

4.1 The railway line: between lost opportunities and future scenarios

The Axis Contract has been tested in the context of reactivating the Civitavecchia-Capranica-Orte railway (Fig.1), located in the southern Tuscia region, north of Rome. The rationale behind reactivating this railway is not sector-specific, but stems from an integrated territorial vision, closely tied to the concept of "territorial rebalancing." The region, rich in natural and cultural resources, is sparsely populated, with a catchment area of less than fifty thousand inhabitants. From a purely financial perspective, this region would not justify such an infrastructure, but the Lazio Region recognized its potential and included the project in the Regional Mobility, Transport, and Logistics Plan, approved in December 2020, proposing it for funding under the National Recovery and Resilience Plan (PNRR). However, it was excluded due to uncertainties regarding the start of works by 2026.

The construction of railways should be driven by regular planning efforts by the State and Regions, not only by emergency needs. This approach reflects the foundational logic behind the construction of the railway in the late 1920s. The Civitavecchia-Capranica-Orte railway was part of a broader territorial strategy aimed at connecting the ports of Civitavecchia (on the Tyrrhenian Sea) and Ancona (on the Adriatic), as well as serving key industrial sites such as the Ronciglione ironworks (16th century), Terni steelworks (19th century), Fabriano paper mills (18th century), and agricultural areas rich in high-quality crops like olives and hazelnuts.

The railway originated from a project dating back to 1860, under the Papal States, with the goal of connecting Civitavecchia to Orte, where it would link to existing rail lines to Rome, Ancona, and Florence. After several revisions, the final project was approved in 1922, with the line inaugurated in 1928 and fully operational by 1929. The 85.8 km line, characterized by steep gradients, a single track, and partial electrification, was built to connect industrial and agricultural zones. Despite various challenges, the line remained in operation until the 1960s when motorization and the increasing use of cars led to its gradual degradation, culminating in partial closure in 1961 due to a landslide.

Despite being decommissioned[15] in 2011 and various attempts at restoration, the project has never fully materialized. In 2017, the railway was included in the list of disused lines with cultural, landscape, and tourist value, but today it is in poor condition, with much of the track removed or abandoned. Nevertheless, the reactivation of the line has remained a goal for local citizens and administrators for thirty years. Restoration costs are estimated between 400 and 800 million euros[16], but despite Lazio Region funding, work has not yet commenced.

Reactivating the line could stimulate the local economy, which includes sectors such as agriculture (producing oil, hazelnuts, wine, potatoes, and beans) and industrial manufacturing (e.g., Socofer's factory in Gallese, exporting high-tech railway tracks worldwide). Furthermore, freight transport is evolving toward new models, such as small-scale distribution[17], which could be easily integrated into secondary lines like the Civitavecchia-Capranica-Orte. These smaller stations could serve as local distribution hubs or even host lockers for parcel collection. Although freight transport is crucial, passenger transport should remain the primary goal for reactivation. Offering a variety of services, such as regional trains, fast regional trains, and intercity options, could reduce road traffic, lower pollution, and improve accessibility for both tourists and residents.

To implement this vision, a comprehensive strategy is needed to reorganize local mobility systems in ways that complement rail transport. Cooperation among small municipalities and the reintegration of "thresholds" for public services would be essential to maximize efficiency, especially in low-density areas[18]. Reactivating the railway as part of a broader territorial policy would reconnect this area to the national network, promoting tourism, industrial and artisanal production, quality agriculture, and improving local services.

4.2 The experimentation: a hypothesis of territorial Masterplan and Axis Contract

The Axis Contract hypothesis has been developed through various research studies and presented at numerous conferences and publications (Ravagnan & Amato, 2020; Amato, 2021; 2022). This research is complemented by educational experiments carried out since 2021 within the Urban Planning Laboratory at the Department of Architecture, Roma Tre University, and the Urban Planning II course at the Faculty of Architecture, Sapienza University of Rome. Additionally, three master's theses in Architecture have focused on defining a "Territorial Masterplan and Axis Contract for the abandoned Civitavecchia-Capranica-Orte railway line." These simulations involved the "Committee for the Reactivation of the CCO Railway" and were supported by several municipal administrations along the line.

As part of various urban planning courses, detailed analyses were conducted on the territory intersected by the railway, from Civitavecchia to Orte. These analyses took into account the infrastructure and mobility

15 It's noteworthy that in the same year the Civitavecchia-Capranica-Orte railway was closed, the last remaining ironworks in Ronciglione, dating back to the Farnese family era, also shut down. The Farnese family had constructed a canal in the 15th century to supply water from the nearby Lake Vico, which powered the ironworks.

16 Source: Committee for the Reopening of the CCO Railway; Italferr, 2024.

17 In response to the growing demand for fast, small-package freight transport, Ferrovie dello Stato launched the Mercitalia Fast division in 2018. This division utilizes ETR500 high-speed trains, modified to carry Unit Load Devices (ULD), small containers used for loading goods onto aircraft. These trains operate between Bologna, a key logistics hub in Northern Italy, and Maddaloni-Marcianise in the South, a major logistics gateway.

18 Until 1934, Italy's administrative system divided Provinces into "Circondari," which were further divided into "Mandamenti," each consisting of several municipalities. These divisions ensured the provision of basic territorial services. However, this structure was abolished by a local authority reform implemented by the Fascist regime.

system, the settlement structure, the historical and environmental systems, as well as demographic and socio-cultural factors. This allowed for the development of a multi-scale functional model that addressed all the key aspects of the area, identifying both its resources and challenges.

From this, a "territorial project" was designed, starting with the Italferr project for the reactivation of the Civitavecchia-Capranica-Orte railway (2012). It was translated into a territorial Masterplan that outlined regeneration strategies aimed at reactivating and making the affected areas more resilient. This plan included both tangible and intangible interventions in mobility, housing, and historical and natural landscapes to maximize the positive impact of the railway within a network framework.

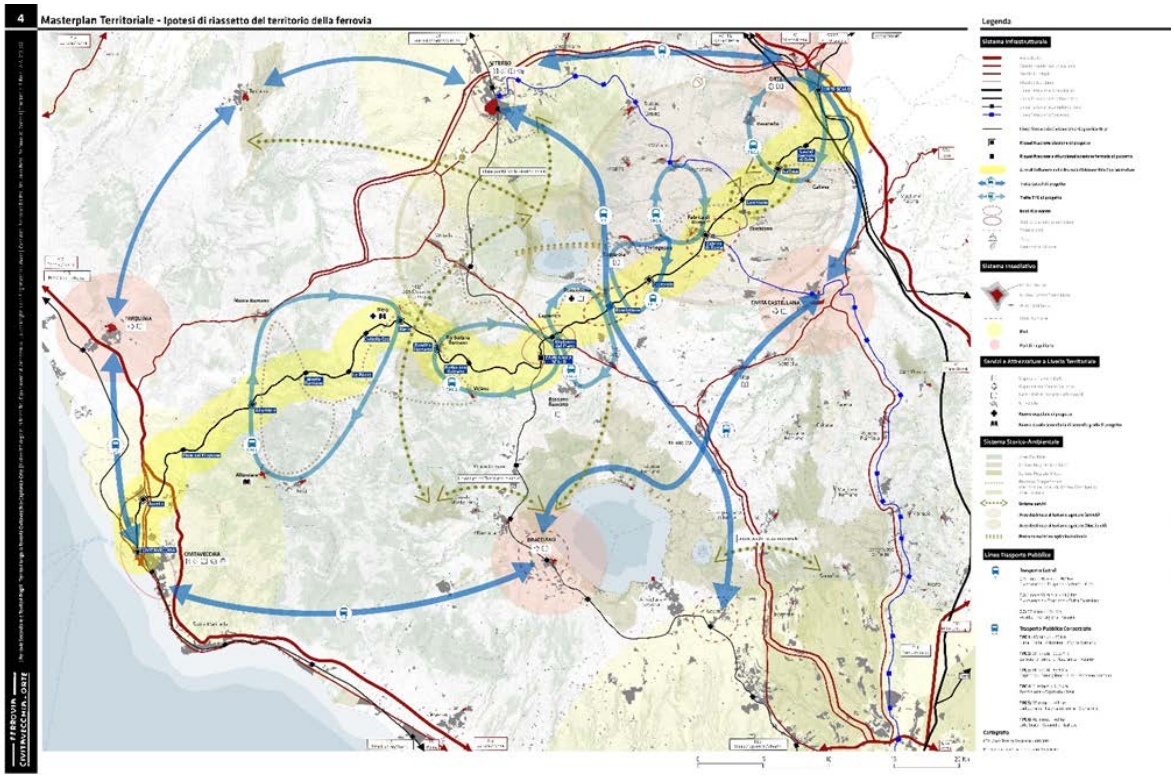

Fig.4 Hypothesis of a territorial master plan

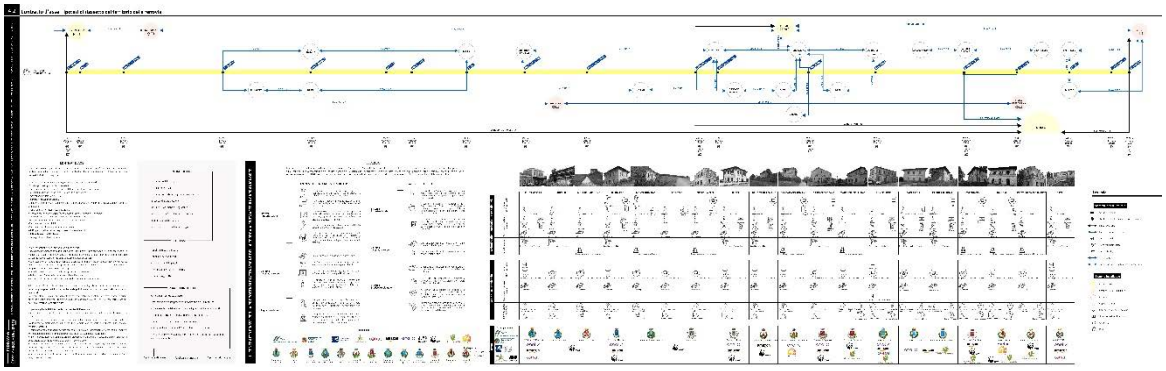

Fig.5 Hypothesis of a territorial master plan. Excerpt from the Axis Contract

The Masterplan, in particular, redefined mobility hierarchies by redesigning regional road transport, currently operated by Cotral (Lazio Region). It also proposed a local public transport system on a consortium basis to connect the various municipalities and railway stations. It integrated and networked supra-municipal public services, with a focus on higher education and local healthcare, and proposed interventions for the recovery, redevelopment, and urban and socio-economic regeneration of residential areas. The plan also sought to enhance and expand the network of protected natural areas, woods, lakes, and waterways, as well as the region's numerous archaeological, architectural, and artistic heritage sites.

The territorial Masterplan thus used the Axis Contract as an implementation and management tool, identifying the various actors involved in the project strategy. These included territorial and local authorities (Lazio Region, Viterbo Province, Metropolitan City of Rome, municipalities along the line, and heritage Superintendencies), public transport companies (Cotral), cultural associations, businesses in the region (Italia Nostra, Legambiente, Enel X), and specialized actors involved in projects like micro-logistics (Amazon) and sustainable hazelnut farming (Ferrero). For each of these actors, the terms of the "Contract" were defined, binding all parties involved (Fig.ss 4 and 5).

To achieve this, multiple meetings were held with key stakeholders in the area, simulating the process and results[19].

As part of the multi-scalar experimentation underpinning the integrated strategy of the Territorial Masterplan, the territories of the 11 municipalities along the Civitavecchia-Capranica-Orte railway underwent an in-depth analysis. The outcomes, in the form of Integrated Programs, were publicly presented in Barbarano Romano (November 2024) and later in Gallese (February 2025), the lead municipality of the railway consortium, in the presence of local administrations and representatives of the Committee for the Reopening of the C-C-O Railway (Fig.ss 6 and 7).

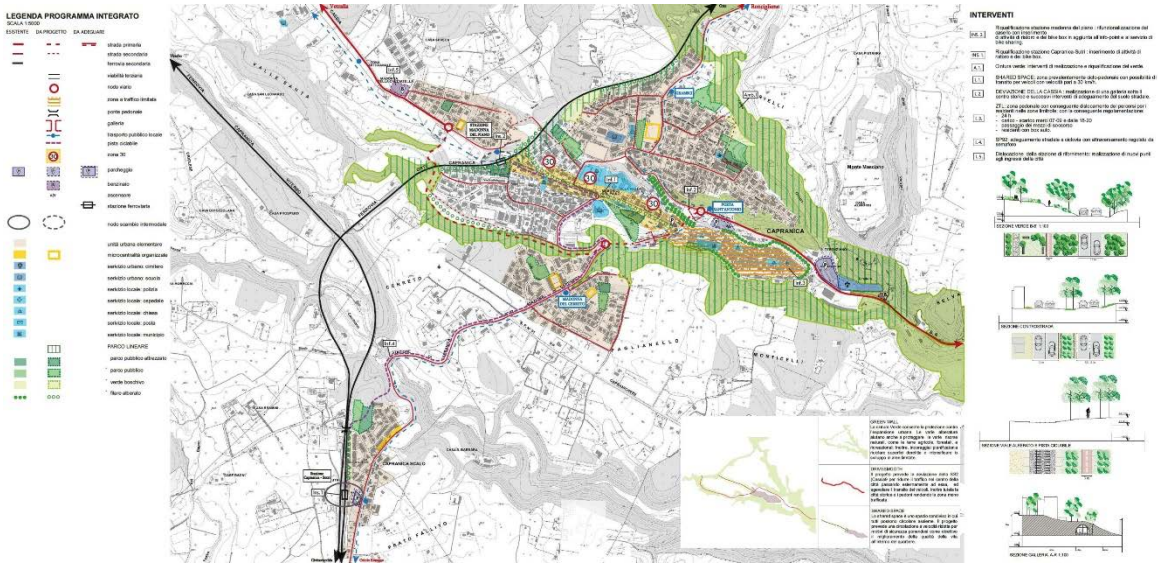

Fig.6 Integrated Program proposal for the Municipality of Capranica

Aligned with the overarching Masterplan, each Integrated Program identified a set of plans, policies, and projects aimed at maximizing the benefits of railway reactivation. These address key issues such as mobility - through the redesign of local public transport routes and, where necessary, road and rail infrastructure; urban and environmental quality - via the renewal of public and green spaces; and the preservation, restoration, and enhancement of the built heritage.

This experimentation refined several structural aspects of the Axis Contract tool. While it directly draws from the French Contrat d'Axe, it differs in key foundational aspects, including its objectives, the actors involved, and the territories covered.

[19] As part of the Urban Planning Laboratories (Master's Degree in Architecture-Urban Planning, Department of Architecture, Roma Tre University, academic years 2020/21 and 2021/22) and the Urban Planning II Course (Single-cycle Master's Degree in Architecture, Faculty of Architecture, Sapienza University of Rome, academic year 2024/25), held by Cerasoli, a *Seminar on the Civitavecchia Capranica Orte Railway* was held on March 24, 2021, with the participation of the "Committee for the reopening of the CCO Railway", and the study-day "*Secondary railways and fragile territories. An axis contract for the reactivation of the territories along the Civitavecchia-Capranica-Orte Railway*", on April 13, 2022, at the the Department of Architecture of Roma Tre University. Finally, a public meeting with the Mayors of the line, which was held at the Municipality of Barbarano Romano (Viterbo), on November 5, 2024.

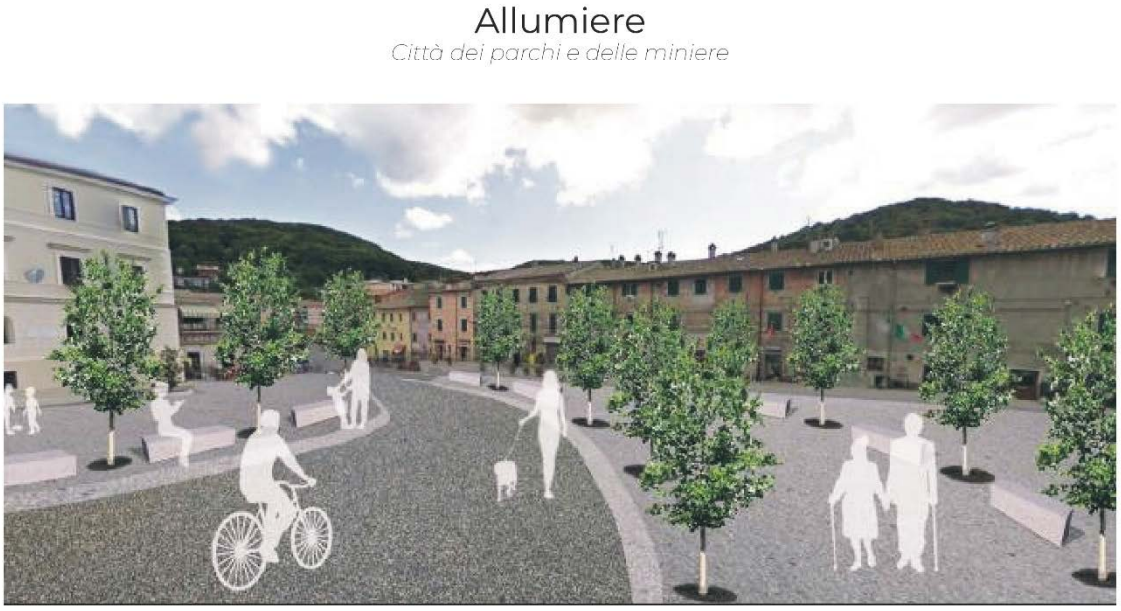

Fig.7 Integrated Program Proposal for the Municipality of Allumiere: redesign of local mobility and public space project, photo insertion

One area for reflection concerns the fact that, while the French Contrat d'Axe primarily focuses on transport and settlement development aimed at selective densification - which can increase land consumption, traffic, and settlement pressure - the Italian version adopts a more holistic approach. Its goal is to guide the regeneration and redevelopment of existing areas, integrating social and environmental interventions with those focused on mobility, and promoting the conversion, reuse, and revitalization of abandoned and underutilized spaces, as well as the redevelopment of public spaces.

Another point is the geographic scope, which already constitutes a strategic and programmatic action. Unlike the French approach, which is confined to the immediate vicinity of the infrastructure, the Italian proposal extends to areas impacted by the infrastructure, including its catchment area. This broader scope takes into account the effects of the infrastructure, which can influence the performance of the mobility service.

A third difference lies in the integration of the Axis Contract within urban planning. While in France the link between the tool and urban planning is weak, the Italian version is deeply integrated into a strategic planning process. This process spans multiple scales, encompassing both territorial-metropolitan and local dimensions, with a strong focus on the "Right to Mobility." It connects strategic, structural, operational, and regulatory planning levels (Amato, 2024).

Finally, the process and stakeholder involvement differ significantly. One of the weaknesses of the French Contrat d'Axe is that its definition relies primarily on the technicians of the local administration and the transport service provider, excluding local communities and active stakeholders such as associations and private companies. In contrast, the Italian version is more inclusive, with a broader engagement of local actors. It is conceived as an evolved "program agreement" (L. 241 of 1990) that combines the benefits of joint planning and inter-institutional consultation with the establishment of a "permanent territorial table" (Cerasoli, 2012).

Nonetheless, it is important to recognize that the Axis Contract remains primarily a regulatory and methodological framework designed to facilitate the reuse or reactivation of railway lines. As such, it must be shaped and enriched according to the specific territorial context in which it is applied. This is particularly relevant when dealing with minor urban centers, inner areas, and territories distant from metropolitan areas, which often possess distinct historical trajectories, cultural phenomena, socioeconomic dynamics, and - most importantly - divergent future prospectives. These local specificities require careful and case-by-case investigation to ensure that the contract effectively supports context-sensitive regeneration processes.

4.3 Methodological tools and process in case study analysis

The methodology of this case study combines theoretical research, educational experiments, and practical applications in urban planning and infrastructure development. The conceptual framework is based on the Axis Contract hypothesis, focusing on a specific case: the creation of a "Territorial Masterplan and Axis Contract for the abandoned Civitavecchia-Capranica-Orte railway line." These projects, carried out in collaboration with the "Committee for the Reactivation of the CCO Railway" and supported by municipal administrations along the railway line, laid the foundation for developing the methodology applied in this study.

A crucial aspect of the methodology was the active participation of key stakeholders throughout the experimentation process. This included multiple rounds of meetings with local authorities, businesses, cultural associations, and other regional actors.

Through these discussions and simulations, the structural aspects of the Axis Contract tool were refined, deepening the understanding of how stakeholders perceive infrastructure's role in regeneration and how they can collectively contribute to the planning process.

The involvement of local actors was particularly important in identifying the needs and priorities of communities affected by the railway's reactivation. This comprehensive engagement provided a broad range of perspectives, contributing to a more robust, context-sensitive design for the proposed infrastructure.

The data collection process incorporated both quantitative and qualitative approaches to provide a holistic view of the challenges and opportunities presented by the railway’s reactivation.

Quantitative data were collected from regional and national transport authorities, identifying trends in mobility, such as shifts in travel behavior and regional transport demand. Geographic Information Systems (GIS) mapped existing infrastructure and transport networks along the railway line, offering a spatial understanding of how proposed changes would impact the region.

Qualitative data were gathered through interviews with a wide range of stakeholders, including local citizens, government representatives, transport companies, and community organizations. These discussions provided valuable insights into the social and cultural context of the project, shedding light on mobility needs, sustainability concerns, and implementation barriers. GIS tools also helped visualize these data, particularly in understanding the spatial distribution of settlements and transport networks.

Focus Area	Actions and Tools	Strategic Outcomes
Stakeholder Engagement	Roundtables, interviews, community forums	Shared vision among actors; identification of local needs and conflicts
Quantitative Data Analysis	Transport datasets, GIS spatial analysis	Mobility trends; regional connectivity; mapping of underserved areas
Qualitative Data Collection	Interviews, workshops, local narratives	Insight into socio-cultural dynamics; identification of sustainability concerns
Participatory Planning	Simulation of Axis Contract governance mechanisms	Testing coordination tools; refining co-decision processes
GIS Integration	Mapping of infrastructure, settlements, mobility services	Visualization of disparities and development potentials
Territorial Masterplan	Synthesis of Italferr plan with new regeneration strategies	Multi-sectoral project integrating mobility, housing, landscape, and public services
Policy and Planning Tools	Axis Contract hypothesis, multi-scalar territorial planning frameworks	Prototype of contract-based governance for inner area regeneration

Tab.1 Strategic Priorities and Outcomes

The qualitative data were analyzed to identify key themes and issues raised by stakeholders, helping to clarify priorities and concerns of local communities and identify areas of potential conflict or collaboration.
Based on this analysis, the study developed a "territorial project," starting with Italferr's 2012 plan for the reactivation of the Civitavecchia-Capranica-Orte railway. This plan was expanded into a broader Territorial Masterplan, outlining strategies to regenerate and revitalize the affected areas. The Masterplan integrated interventions across mobility, housing, and preservation of historical and natural landscapes to maximize the railway's impact on the region.
The iterative process of stakeholder engagement, data collection, and analysis refined the planning strategies, ensuring they were context-sensitive and aligned with broader sustainability and regional revitalization goals. Through this approach, the study presents a model for integrating infrastructure development with territorial rebalancing, emphasizing stakeholder engagement, multi-scale planning, and sustainability in regenerating inner areas.

5. Perspectives

The impact of infrastructure on inner areas has become an increasingly important topic in recent Italian scientific discussions (Amato, 2022). The growing focus on these "fragile territories" and their transformation from abandoned or underused spaces to areas of ecological revitalization and territorial rebalancing has also been central to national policies in recent years. This shift has highlighted the essential role that mobility infrastructure plays in fostering territorial cohesion and social equity, especially in the context of Italy's post-COVID recovery and the EU's green, ecological, and inclusive transition policies.
The 2020 pandemic marked a turning point, even in public opinion, regarding the unsustainability of life in large contemporary metropolises and the growing importance of rediscovering new rhythms and lifestyles, often found in smaller towns (Cerasoli & Mattarocci, 2020). This shift led to renewed attention on infrastructure - particularly railways - within Italy's Recovery and Resilience Plan (PNRR), which has positioned the improvement of railway networks in inner areas as a key driver for economic recovery. The PNRR emphasizes not only the construction and adaptation of rail infrastructure but also the integration of sustainability into infrastructure design, aligning with national and European objectives for ecological transition and inclusive development (MIMS, 2021).
However, despite significant innovations regarding the environmental sustainability of infrastructure projects, challenges remain in developing objective methodologies and indicators to assess the social and economic sustainability of infrastructure within territories. To address this, Ferrovie dello Stato, through Italferr and the FS Research Centre, is developing a Territorial Impact Assessment methodology. This approach aims to update the frameworks for evaluating the socio-economic and environmental impacts of railways in an integrated territorial context (Tartaglia et al., 2024). These efforts underscore the need for more effective tools in multi-scale, interdisciplinary governance, capable of assessing both the direct and indirect effects of infrastructure on urban and territorial transformations.
This study has also emphasized the importance of repurposing Italy's disused railway heritage, representing over 8,000 km of abandoned or underused lines. These disconnections have contributed to the depopulation and fragility of inner areas, which have long suffered from reduced accessibility. Integrating innovative transport solutions, such as shared mobility, on-demand services, and intermodal hubs, can revitalize these regions and provide sustainable alternatives to private car usage. Moreover, the growing focus on "tourist railways" through initiatives by the FS Foundation and local associations offers an exciting opportunity for local economic revitalization, as these projects provide both transportation and cultural enrichment.
The concept of *Right to Mobility* - which encompasses not only the freedom of movement but also the accessibility to sustainable, equitable, and socially inclusive transport options - remains central to this discussion. A comprehensive and integrated approach that combines urban planning, mobility strategies, and

environmental sustainability is necessary for fostering resilient communities in Italy's inner areas. Models like the French *Contrat d'axe*, which aims to integrate urban densification with public transport infrastructure, offer valuable lessons for Italy, highlighting the potential of infrastructure as a tool for territorial rebalancing and regeneration.

In conclusion, the transformation of infrastructure in fragile territories must consider both environmental and social sustainability, leveraging integrated planning to reconnect these areas to broader economic and social systems. By addressing the specific needs of inner areas and investing in innovative mobility solutions, we can promote a more inclusive and sustainable future, revitalizing not only transport networks but also the communities they serve. The combination of strategic territorial planning, stakeholder engagement, and an integrated approach to infrastructure can pave the way for a more balanced and equitable territorial development in Italy.

Note

The article is the result of the strong collaboration of the two Authors. Specifically, Chiara Amato edited: § 2.2, 3, 4,2 and 4.3; Mario Cerasoli edited: § 1, 2.1 and 4.1. The § 5 is the result of joint work.

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Image Sources

Fig.1: Civitavecchia - Capranica - Orte railway line (source: author's photo)

Fig.2: Via Verde Costa dei Trabocchi (Source: Ebiketravel.it)

Fig.3: Contract d'axe for the "E" tram line in Grenoble (Source: L'Agence d'Urbanisme de la Region Grenobloise, 2022);

Fig.4: Hypothesis of a territorial master plan (Marianna Petti, Francesca D'Uffizi, 2024 - revision and integration by prof. dr. Cerasoli, Department of Planning, Design and Technology of Architecture, Sapienza University of Rome. Graphic processing by Sandra Morcate Rizo);

Fig.5: Hypothesis of a territorial master plan. Excerpt from the Axis Contract (Marianna Petti, Francesca D'Uffizi, 2024 - revision and integration by prof. dr. Cerasoli, Department of Planning, Design and Technology of Architecture, Sapienza University of Rome).

Fig.6: Integrated Program proposal for the Municipality of Capranica (Urban Planning II Course, Single-cycle Master's Degree in Architecture, Faculty of Architecture, Sapienza University of Rome, academic year 2024/25).

Fig.7: Integrated Program Proposal for the Municipality of Allumiere: redesign of local mobility and public space project, photo insertion (Urban Planning II Course, Single-cycle Master's Degree in Architecture, Faculty of Architecture, Sapienza University of Rome, academic year 2024/25).

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GIS-based bikeability approach as a tool in determining urban bicycle infrastructure capacity for Eskisehir, Turkey

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Abstract
Urban transportation systems are rapidly evolving to meet contemporary challenges such as traffic congestion, environmental concerns, and sustainable mobility demands. Cycling is increasingly recognized as a viable mode of sustainable urban transportation due to its environmental, economic, and health benefits. However, determining the adequacy and capacity of bicycle infrastructure remains a key challenge for urban planners.

This study assesses the bicycle accessibility of Eskisehir, Turkey, by analyzing both existing and planned bicycle infrastructure using GIS-based methods. The research employs three established methodologies: Bicycle Stress Level (BSL), Bicycle Suitability Score (BSS), and Bicycle Level of Service (BLOS) to evaluate the urban road network and bicycle paths. These methods consider various factors including traffic conditions, road geometry, and infrastructure quality. The results reveal a disparity: while the BSS indicates that a large portion of the road network is "Suitable" or "Highly Suitable" for cycling, the BSL identifies significant "High Stress" areas for cyclists. Similarly, BLOS analysis shows that most of the network functions at "Level B," suggesting a reasonable environment for cycling, yet this contrasts with the high stress levels indicated by the BSL. The study highlights a critical issue where infrastructure classified as suitable may still present considerable stress for cyclists. The GIS-based approach provides a valuable tool for urban planners to identify areas needing improvement, aiming to create more bicycle-friendly cities. Ultimately, the research underscores the necessity for a comprehensive strategy that goes beyond basic assessments to effectively mitigate factors contributing to cycling stress, thereby fostering sustainable urban mobility.

Keywords
Bikeability; Bicycle infrastructure; GIS; Urban mobility; Sustainable transportation

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1. Introduction

Urban transportation systems are undergoing significant transformations to address contemporary challenges such as traffic congestion, air pollution, and the urgent need for sustainable mobility options. Cycling has emerged as a significant sustainable transportation mode due to its numerous benefits, including environmental sustainability, cost-effectiveness, and positive health impacts (Pucher et al., 2010; Mateu & Sanz, 2021). Research indicates that cycling not only reduces carbon emissions but also promotes physical health and well-being, making it a vital component of urban mobility strategies (Yang et al., 2021). The increasing use of bicycles, particularly in European bicycle-friendly cities, underscores the potential for cycling to contribute to sustainable urban transport (Castanon, 2024; D'Amico, 2023). For instance, cities like Utrecht, Münster, and Copenhagen have reported average bicycle usage reaching 35 %, reflecting a cultural shift towards cycling as a primary mode of transportation (Stults-Kolehmainen & Sinha, 2013). This shift gained unprecedented momentum during the COVID-19 pandemic, as cities worldwide accelerated bicycle infrastructure projects to promote safe and socially distanced mobility (Fenu, 2021).

To align with the European Union's 2030 and 2040 environmental targets, efforts must be made to enhance the bikeability of urban areas. This involves raising awareness of cyclist rights, improving safety measures, developing cycling infrastructure, and promoting bike-sharing schemes (Blanc & Figliozzi, 2016; Van Dyck et al., 2012). Integrating cycling into transportation frameworks underlines the determination and improvement of the bikeability of cities (Banister, 2008; Ewing & Cervero, 2010; Rodrigue, 2016). A bikeable city provides safe and comfortable cycling options for both commuting and recreational purposes, necessitating a cultural shift that recognizes cycling as a viable transportation mode (McNally et al., 2022). Bikeability has various definitions and generally refers to the assessment of an urban environment in supporting and encouraging cycling (Lowry, 2016) through a diversity of factors including the availability and quality of cycling infrastructure, safety measures, connectivity of bike paths, accessibility, and supportive policies (Hardinghaus, 2021; Lowry et al., 2012). Improving bikeability goes beyond infrastructure; it also requires creating a cultural shift toward recognizing cycling as a viable and desirable mode of transportation.

Still, the physical environment and availability are of critical significance regarding their key role in supporting bicycle transportation. The assessment of physical convenience is realized through the adoption of different approaches and methods to determine the suitability of the physical and environmental conditions of the geographical context for bicycle transportation.

Name of the Method	Acronym	Reference
Bicycle Safety Index Rating	BSIR	Davis (1987)
Bicycle Stress Level	BSL	Sorton & Walsh (1994)
Road Condition Index	RCI	Epperson (1994)
Hazard Interaction Score	HIS	Landis (1994)
Bicycle Suitability Rating	BSR	Davis (1995)
Bicycle Suitability Score	BSS	Turner et al. (1997)
Bicycle Compatibility Index	BCI	Harkey et al. (1998)
Bicycle Suitability Assessment	BSA	Emery & Crump (2003)
Rural Bicycle Compatibility Index	RBCI	Jones & Carlson (2003)
Compatibility of Roads for Cyclists	CRC	Noel et al. (2003)
Bicycle Level of Service	BLOS	Zolnik & Cromley (2007)
Bicycle Environmental Quality Index	BEQI	San Francisco Public Health Department (2009)
Bicycle Quality Index	BQI	Birk et al. (2010)

Tab.1 Methods used for determination of the bicycle transportation conditions (Pareek & Parbhakar, 2018; Callister & Lowry, 2013; Duc-Nghiem, Tung, Kojima & Kubota, 2017)

The literature on bikeability has evolved to encompass various interdisciplinary fields, including urban planning, transportation studies, public health, and environmental psychology. Murphy & Owen (2019) highlight the multifaceted nature of bikeability, emphasizing the need for comprehensive assessments that capture infrastructure quality, safety, accessibility, and convenience. Forsyth et al. (2013) further elaborate on this by presenting a conceptual model that integrates physical, social, and perceptual factors influencing cycling. Their model underscores the importance of both objective measures, such as the presence of bike lanes, and subjective experiences, such as perceived safety and comfort, in shaping cycling behavior. Methodologically, a variety of approaches have been employed to measure bikeability, ranging from qualitative assessments to complex quantitative indices. Geographic Information Systems (GIS) have become a common tool for analyzing spatial data related to cycling infrastructure and urban form (Ahmed et al., 2024). For example, Fonseca et al. (2023) introduced a multi-criteria analysis method for evaluating and designing bicycle networks in a Portuguese city, which is similar to the methodology applied in our study. In addition, field surveys and observational studies have been instrumental in evaluating cycling conditions and cyclist behavior, as evidenced by Dill & Carr's (2003) research in Portland, which established a positive correlation between high-quality cycling infrastructure and increased cycling rates. This article also aligns with studies such as Ahsan et al. (2023) that emphasize the importance of perceptual factors by examining barriers to walking in urban areas.

This study deals with the assessment of the environmental features that enable cycling in a city, commonly put forward through bikeability or other similar indexes. The study focuses on Eskisehir, one of the most livable cities in Turkey, known for its modern approach to urban planning and development. Eskisehir's relatively flat topography and compact urban form, with an urban population of approximately 810,000 inhabitants according to 2023 data, make it naturally suitable for cycling. However, investments in cycling infrastructure and efforts to promote this mode of transportation provide an interesting case study for examining the implementation and impact of bikeability initiatives. The goal of this study is to provide an overview of the possibilities of measuring how suitable the existing and planned bicycle roads in the Odunpazarı and Tepebası regions of Eskisehir province are for cycling. In this context, the most frequently used methods in the literature were used to measure bikeability. The visualization of the results provides guiding results for case studies conducted in the study area. The main contribution of this study is to reveal the urban bicycle transportation capacity with the perspective of bicycle accessibility with selected methods. An advantage of the transportation capacity presented is that it provides ideas for measuring the suitability of routes for existing or planned bicycle paths and making these lines efficient. The approach used is also useful for detecting inconveniences in road networks with different spatial coverage.

2. Material and methods

2.1 Study area

The study area comprises the urban areas of Odunpazarı and Tepebası districts, which are the central districts of Eskisehir province. Eskisehir is located in the northwest of Turkey, between 29-32 degrees east longitude and 39-40 degrees north latitude (Fig.1), spreading over 13,925 km². According to 2024 records, the province hosts 922.538 inhabitants, of whom 89.52 % live within the study area boundaries.

The basic information about the demographic and topographic structure of the study area highlights cycling potential in the city. According to the demographic data, 21.3 % of the population in the study area is under the age of 15, and 11.9 % of the population is over 65. The median age is 35.5, and the young population is predominant (Turkish Statistical Institute, 2024). The study area has a slope varying between 1-9 %, which is considered close to flat, providing a relatively suitable topography for bicycle transportation (Fig.2). In other words, the city has significant potential for bicycle transportation due to its topographic structure.

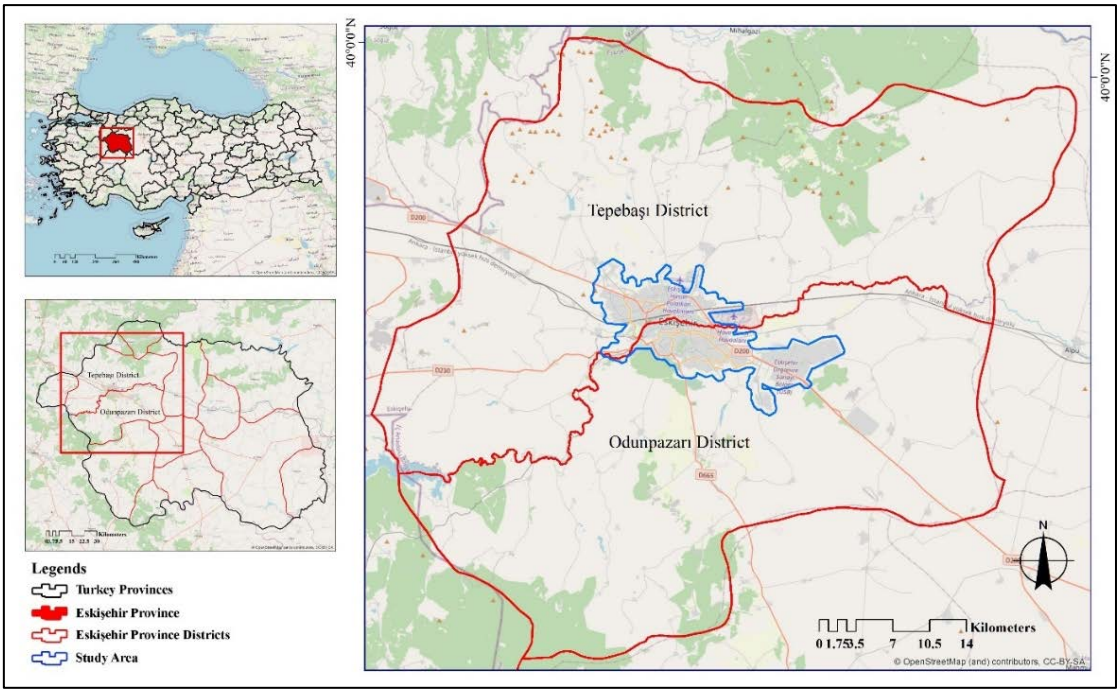

Fig.1 Location and boundaries of the study area

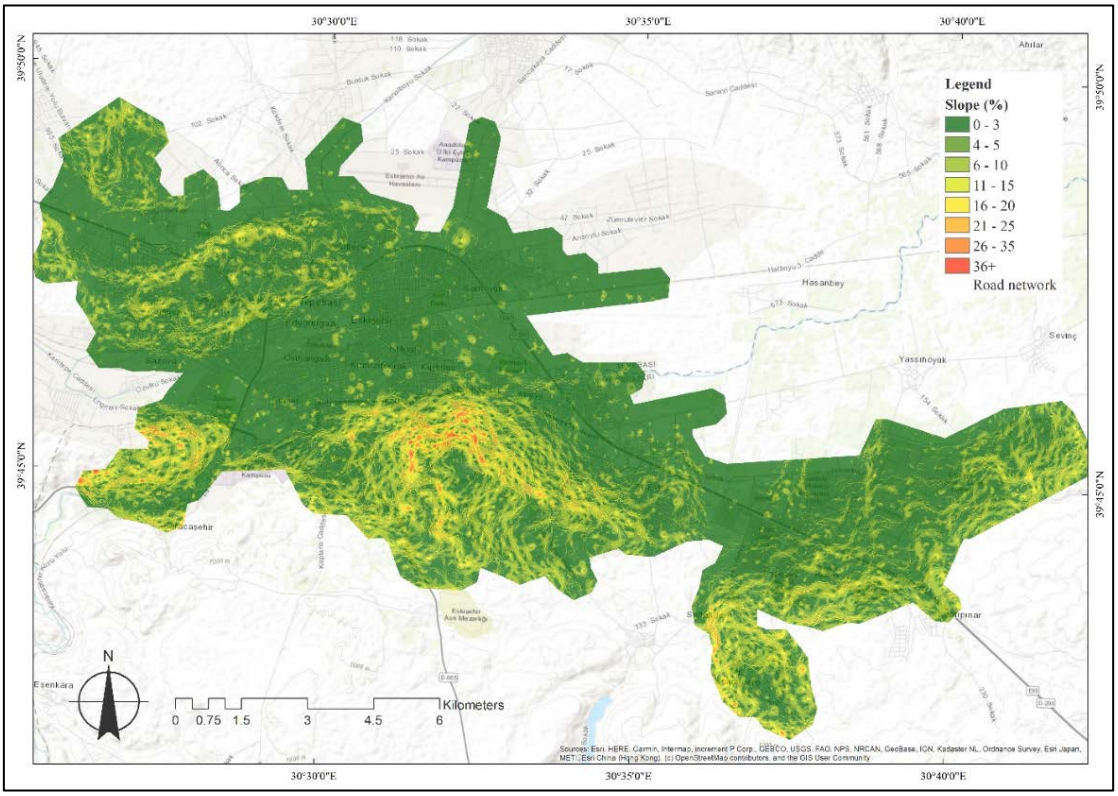

Fig.2 Slope map of the study area

This situation has given way to encouraging bicycle transportation in the study area to some extent. There are 64.5 km of existing and 30.3 km of planned bicycle roads in the study area (Fig.3). 13.3 km (20.7 %) of the existing bicycle roads are shared bicycle roads, and the remaining 51.2 km (79.3 %) consist of separated bicycle paths (İstanbul Technical University Transport and Transportation Vehicles Application Research Center, 2017). Separated or shared bicycle roads do not meet the Bicycle Roads Regulation, TS 9826, and TS 10839 standards. Furthermore, there are no provisions for intersection layouts, signaling, marking, cycling

bridges, or tunnels to merge bicycle lanes, vehicular highways, or pedestrian walkways. In 2024, the study region had a car ownership rate of 23.5 %. This ownership is 17 % in Turkey (Turkish Statistical Institute, 2024). While this situation shows that the individual car usage rate in Eskisehir province is above the national average, it can also be interpreted as a negative situation in terms of sharing urban transportation infrastructure for cyclists.

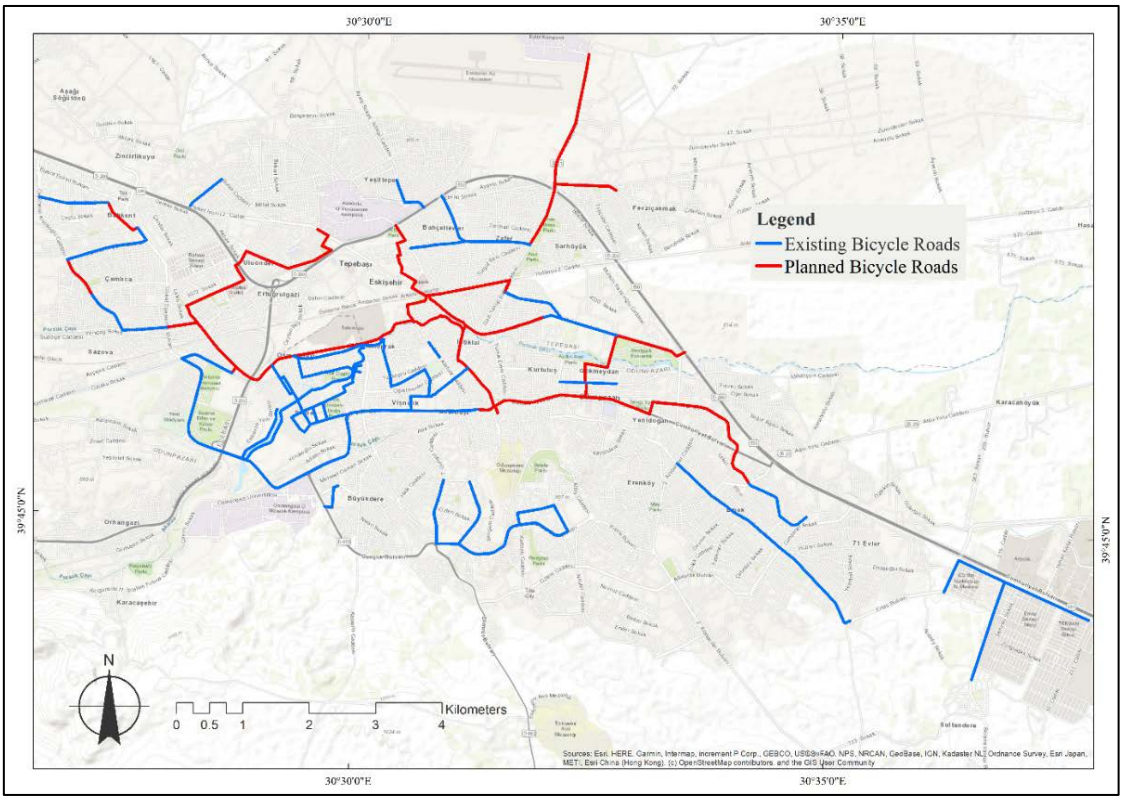

Fig.3 Existing and planned bicycle roads in the study area

2.2 Data Sources

This research was designed as a case study. The material of the study consists of vector data, satellite images and street images. Tab.2 summarizes the primary data used and their sources.

Data Name	Type	Source
Road network map and attribute data	Vector data and attributes	Digitization (originally produced using Arcgis 10.7 software)
Existing and planned bicycle road networks	Vector kml data	Eskisehir Transportation Master Plan (ETMP)2035 Report
Satellite images	Raster images with 0.5-1m resolution from different dates	Google Earth Pro software
Street images	Images and field photos from different dates	Google Street View, field observations
Land use map	Raster images with 0.5-1m resolution	atlas.gov.tr
Terrain slope map	Vector map with 5m resolution	Google Earth Pro software and gpsvisualizer.com
Traffic volume data	Number of vehicles	Ministry of Transport and Infrastructure General Directorate of Highways traffic volume map, field surveys

Tab.2 Data used in the study and their sources

2.3 Method

The main goal of the study is to determine the bicycle accessibility of the study area in Odunpazarı and Tepebası districts of Eskisehir by focusing on common indices based on environmental factors related to the infrastructure. In this context, both existing and planned bicycle roads were analyzed with the bicycle stress level (BSL), bicycle suitability score (BSS) and bicycle level of service (BLOS), which are the most commonly used methods for measuring bikeability as discussed in the literature. Each method used to assess bicycle accessibility facilitates a systematic examination of various metrics related to bicycle infrastructure by categorizing road sections as "road segments".

Bicycle stress level

The Bicycle Stress Level (BSL) was developed by Sorton to measure the stress experienced by cyclists when navigating urban roads in proximity to motor vehicle traffic (Sorton & Walsh, 1994; Sorton, 1995).

Cyclists encounter varying levels of stress on the roads due to traffic conditions. A local access road within an urban area, where traffic calming measures are implemented and the speed limit is set at 30 km/h, is considered a very low-stress environment. In contrast, a six-lane arterial road with a speed limit of 82 km/h represents a high-stress environment for cyclists.

BSL divides urban roads into small segments between intersections and calculates stress levels based on three fundamental stress components: "lane widths", "vehicle traffic volumes" and "vehicle speeds". Stress level values range from 1 to 5. According to the scale, a value of 1 indicates the lowest stress level or the best cycling conditions, while a value of 5 represents the highest stress level or the worst cycling conditions.

It is highly probable that as the traffic volume and speed values on a road increase and as lane widths decrease, the stress level on that segment of the road will also rise.

In the BSL, the criteria presented in Table 3 were used to determine the traffic stress levels on urban road segments.

Traffic Volume Index [Vehicles per hour]		**Outer Lane Width Index [meters]**		**Vehicle Speed Index [km/h]**		**Factor Score**
Value Range	**Treshold Value**	**Value Range**	**Treshold Value**	**Value Range**	**Treshold Value**	
0-49	0	4.55	4.55	0-39	0	1
50-149	50	4.25-4.54	4.25	40-49	40	2
150-349	150	3.95-4.24	3.95	50-59	50	3
350-449	350	3.65-3.94	3.65	60-72	60	4
450 ≤	450	0.00-3.64	0.00	73 ≤	73	5

Tab.3 Indicators used to calculate BSL

The index values and threshold values used for the determination of BSL are based on the research of Sorton & Walsh (1994). In this context, the traffic volume index values indicate the total number of vehicles passing in both directions over a designated road segment within one hour, the outer lane width index values indicate the lane width remaining on the far-right side of the road, including parking lanes if available and vehicle speed index values indicate the speed limit values applicable to a road segment.

When calculating the BSL score, a factor score was established for each measured index value for the road segments, and the average of these factor scores was taken (as shown in Tab.5). The calculated BSL scores define five levels of stress. The descriptions of these stress levels, the threshold values, and explanations regarding the appropriate user groups for such bicycle roads are presented in Tab.5.

Calculation Component	Road Segment n
Traffic volume index factor score	F1
Outer lane width index factor score	F2
Vehicle speed index factor score	F3
Bicycle stress level score	**Fort**

Tab.4 BSL calculation matrix

BSL Score Range	Treshold Value	Definition of Stress Level	Suitable Bicycle Users
0.00-1.00	1	Very Low Stress	Cyclists of all ages and abilities
1.10-2.49	2	Low Stress	Some adult cyclists
2.50-3.49	3	Medium Stress	Most adult cyclists
3.50-4.49	4	High Stress	Experienced cyclists
4.50-5.00	5	Very High Stress	Strong and fearless cyclists

Tab.5 Calculation components of BSL

Bicycle suitability score

The Bicycle Suitability Score (BSS) is a methodology designed to assess the appropriateness of a roadway for bicycle travel. Originally introduced by Turner et al. (1997), the BSS framework evaluates current road conditions to determine the most suitable urban routes for cyclists, thereby facilitating the identification of potential enhancements based on these assessments. The BSS determines the suitability of urban road segments by considering various factors, such as outer lane widths, sidewalk dimensions, vehicle traffic volumes, road surface quality, and vehicle speeds. The resulting rankings employ three-point, four-point, and five-point likert scales to convey the level of suitability for bicycle use.

In the BSS analysis, the criteria presented in Table 6 were utilized to determine the suitability levels of urban road segments for bicycle use.

Traffic Volume Index (Vehicles/Day)		Shoulder width index (meters)		Vehicle Speed Index (km/h)		Pavement conditions index*		Factor Score
Value Range	Treshold Value	Value Range	Treshold Value	Value Range	Treshold Value	Value Range	Treshold Value	
0-999	0	1.80 ≤	1.80	0-39	0	1.00-1.90	1	2
1,000-1,999	1,000	1.20-1.79	1.20	40-49	40	2.00-2.90	2	1
2,000-4,999	2,000	0.60-1.19	0.60	50-59	50	3.00-3.90	3	0
5,000-9,999	5,000	0.30-0.59	0.30	60-72	60	4.00-4.90	4	-1
10,000 ≤	10,000	0.00-0.29	0.00	73 ≤	73	5.00	5	-2

* Pavement condition index values are based on the study of Turner, Schafer and Stewart (1997).

Tab.6 Indicators used to calculate BSS

The index values and threshold values used for measuring the BSS are based on the work of Turner et al. (1997). In this context, the traffic volume index values indicate the total number of vehicles passing in both directions over a designated road segment on a daily basis, the shoulder width index values indicate the width of the section between the lane on the far right and the sidewalk, the vehicle speed index values indicate speed limit values and the sidewalk condition index values indicate the physical conditions of the sidewalks, with "1" indicating the worst condition and "5" indicating the best.

When calculating the BSS, the factor scores for the measured index values for each road segment are determined, and the BSS score is established by summing these factor scores (Table 7).

Calculation Component	Road Segment n
Traffic volume index factor score	F1
Shoulder width index factor score	F2
Vehicle speed index factor score	F3
Pavement condition index factor score	F4
Bicycle Suitability Score	**F1 + F2 + F3 + F4**

Tab.7 BSS calculation matrix

The calculated BSS defines four levels of suitability. The descriptions of these suitability levels, their threshold values, and explanations regarding the user groups that are appropriate for such bicycle roads are presented in Table 8.

BSS Score Range	Threshold Value	Definition of Suitability Score
(-6) - (-8)	-8	Unsuitable
(-2) - (-5)	-5	Moderately Suitable
(-1) - (5)	-1	Suitable
(6) - (8)	6	Highly Suitable

Tab.8 Definitions and threshold values of the BSS

Bicycle level of service

Bicycle Level of Service (BLOS) is used to determine the comfort levels of bicycle use on roads as a function of the geometric characteristics of the roads and traffic conditions in urban areas.

The methodology for BLOS has evolved over time, with initial frameworks developed by Landis et al. in the 1990s, which adapted the Level of Service (LOS) concept originally designed for motor vehicles to better suit the needs of cyclists (Liu et al., 2021). BLOS statistically assesses the suitability or compatibility of urban roads for bicycle use by utilizing variables such as road width, bike lane width, vehicle traffic volumes, road surface conditions, vehicle speeds, the proportion of heavy vehicles, and the availability and rates of on-street parking. Service levels are typically expressed on a scale where "A" represents roads with the highest comfort level and "F" indicates roads with the lowest comfort level (if a six-point scale is used). In this study, the calculation variables used for BLOS analysis are based on the work of Lowry et al. (2012). The variables are presented in Tab.9.

Calculation Component	Acronym
Outer lane width (m)	Wol
Bicycle path width (m)	Wbl
Shoulder width (m)	Wos
Traffic Volume (vehicle/hour)	v
On-street parking rate (decimal)	Ppk
Presence of pavement (yes/no) (1/0)	C
Number of lanes (in 1 direction)	Nth
Average vehicle speed	SR
Heavy vehicle rate (decimal)	PHV
Pavement condition (poor-excellent) (1-5)	Pc

Tab.9 Variables Used to Calculate BLOS

While calculating the BLOS, the calculated component values for each road network segment were determined and computed according to Eq.1.

$$\begin{aligned} \mathrm{BLOS} = {} & 0{,}76 + \left[-0{,}005\left((\mathrm{Wol} + \mathrm{Wbl} + \mathrm{Wos}) + (2 - 0{,}005v) + (\mathrm{Wbl} + \mathrm{Wos} + 20\mathrm{Ppk}) - 1{,}5c^2\right)\right] \\ & + 0{,}507\ln\left(\frac{v}{4\mathrm{Nth}}\right) + 0{,}199\left[1{,}119\ln(\mathrm{SR} - 20) + 0{,}8103(1 + 0{,}1038\mathrm{PHV})^2\right] \\ & + 7{,}066\left(\frac{1/}{\mathrm{Pc}^2}\right) \end{aligned} \quad (1)$$

The calculated bicycle service level values define six service levels. The threshold values and designations for these service levels are presented in Tab.10.

BSL Score Range	Treshold Value	Definition of Service Level
≤ 2,00	A	Perfect environment for cycling
2,00 - 2,75	B	Good environment for cycling
2,75 - 3,50	C	Reasonable environment for cycling
3,50 - 4,25	D	Poor environment for cycling
4,25 - 5,00	E	Inadequate environment for cycling
> 5,00	F	Unsafe environment for cycling

Tab.10 Definitions and limit values of the service level for bicycle use

2.4 Bridging qualitative perception and quantitative assessment

This study moves beyond conventional methods that rely solely on physical metrics for evaluating bicycle paths and road networks, by incorporating the perceptual experiences of cyclists into the process. The three quantitative indices used in the study (BSL, BSS, BLOS) are traditionally based on physical infrastructure parameters such as lane width, traffic volume, vehicle speed, and pavement conditions. In addition to this physical data, perception surveys and focus group discussions were conducted with 256 cyclists in the Odunpazarı and Tepebası districts as part of the study. This qualitative data was not used to directly change the threshold values or weighting schemes used in the calculation formulas of the quantitative indices. Instead, this data was used for two critical purposes:

Validating the results

The perception data were used to validate the findings of the BSL analysis. For example, the 88 % alignment of cyclists' perceived stress with the high-stress areas on the BSL map supports the output of the BSL model, which is based on physical data, and reinforces its methodological robustness. Similarly, the fact that 67 % of female cyclists reported harassment stress shows that areas classified as high-stress on the BSL map are challenging not only due to traffic but also due to social and perceptual factors.

Explaining paradoxical findings

The qualitative data played a vital role in explaining the main finding of the article: the paradox of why "physically suitable" infrastructure is still "high-stress". While models based on physical parameters like BSS and BLOS might classify a road as "suitable" or "reasonable," the stress experienced by cyclists is related not only to physical factors (such as traffic volume or road width) but also to factors that cannot be measured directly with quantitative indices, such as perceived safety, concerns about harassment, and a general sense of discomfort. This shows that cyclist perception and behavior, independent of the infrastructure itself, profoundly affect bikeability. This multi-method approach demonstrates that assessing only the physical infrastructure is insufficient in bicycle transportation research, and that the integration of human-centered, perceptual data is critical for scientific rigor and the replicability of the study.

3. Results and discussions

3.1 Results on BSL

Upon assessing the Eskisehir urban road network based on Bicycle Stress Level (BSL), it becomes evident that most roads exhibit high stress levels for cyclists. Conversely, there are only a limited number of roads that demonstrate very low stress levels, which are primarily found in the city's peripheral areas and consist of roads with minimal traffic loads or those that are closed to vehicular traffic.

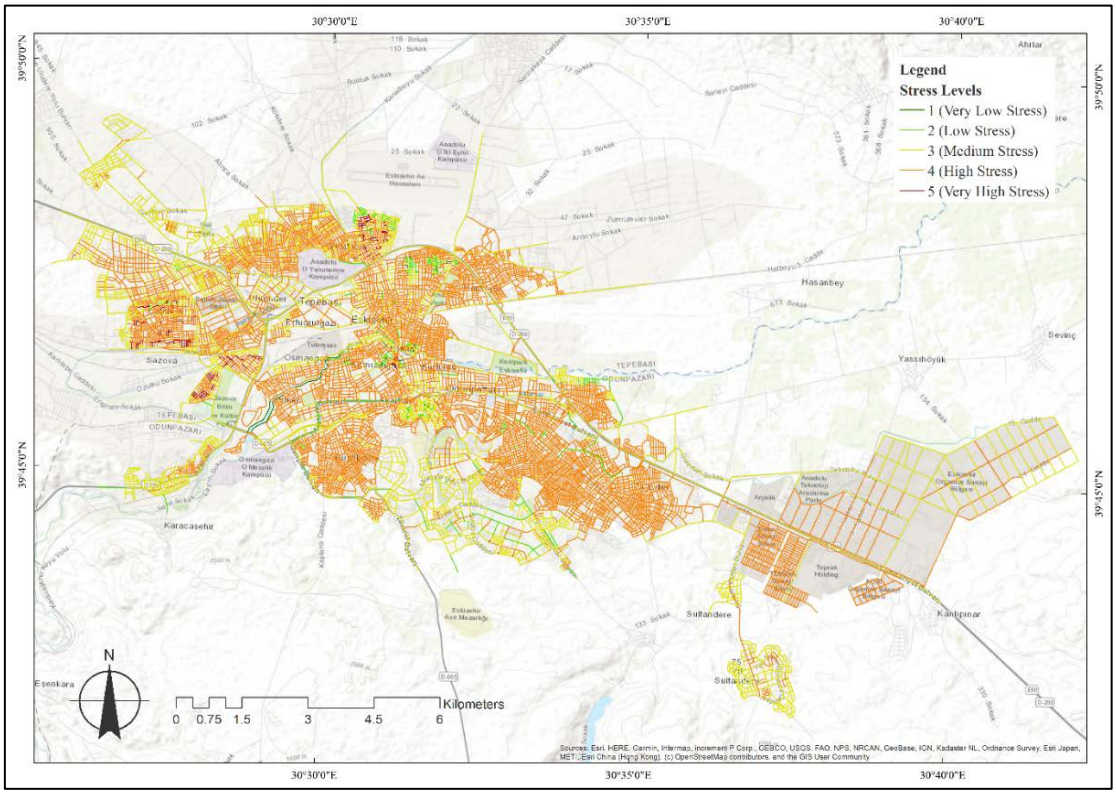

Fig.4 BSL values of the road network in the study area

The results of the BSL analysis including existing and planned bicycle roads, are presented in Tab.11.

		BSL Score				
		Very High Stress	High Stress	Medium Stress	Low Stress	Very Low Stress
Share in the urban road network	km	19.40	1,921.10	725.60	102.80	11.30
	%	0.70	69.10	26.10	3.70	0.40
Share in existing bicycle roads	km	0.00	37.80	17.30	5.40	4.00
	%	0.00	58.60	26.80	8.40	6.20
Share in planned bicycle roads according to ETMP 2035	km	0.00	13.70	14.70	1.90	0.00
	%	0.00	45.20	48.50	6.20	0.00

Tab.11 Results on BSL

According to the results based on BSL, roads with very high stress levels account for 0.7 % of the entire urban road network (19.4 km). There are no roads with this stress level among the existing bicycle roads in the city. It has been observed that roads with high stress levels comprise the largest share, covering 69.1 % of the urban road network (1,921 km). In parallel, 58.6 % (37.8 km) of the existing bicycle roads also exhibit high stress levels. This situation is believed to stem from bicycle roads that do not meet legal standards and the lack of necessary physical safety measures on shared bicycle roads. Roads with a medium stress level, where primarily adult or experienced cyclists can ride with less stress, make up 26.1 % of the urban road network (725.6 km), and 26.8 % (17.3 km) of the existing bicycle roads are located on these roads. Although these bicycle roads are designated as separated paths, they do not comply with the standards specified in the legislation. Low-stress roads, where cyclists aged 5-19 can comfortably ride, constitute 3.7 % of the urban road network (102.8 km). Among the existing bicycle roads, 8.4 % (5.4 km) are situated on these roads, which are separated from vehicle traffic and comply with the standards outlined in the legislation. Roads with very low stress levels, where all cyclists can ride comfortably, represent 0.4 % of the Eskisehir urban road network (11.3 km), and 6.2 % (4 km) of the existing bicycle roads are located on these roads. The primary reason for these roads having the lowest stress levels is that they are free from vehicle traffic.

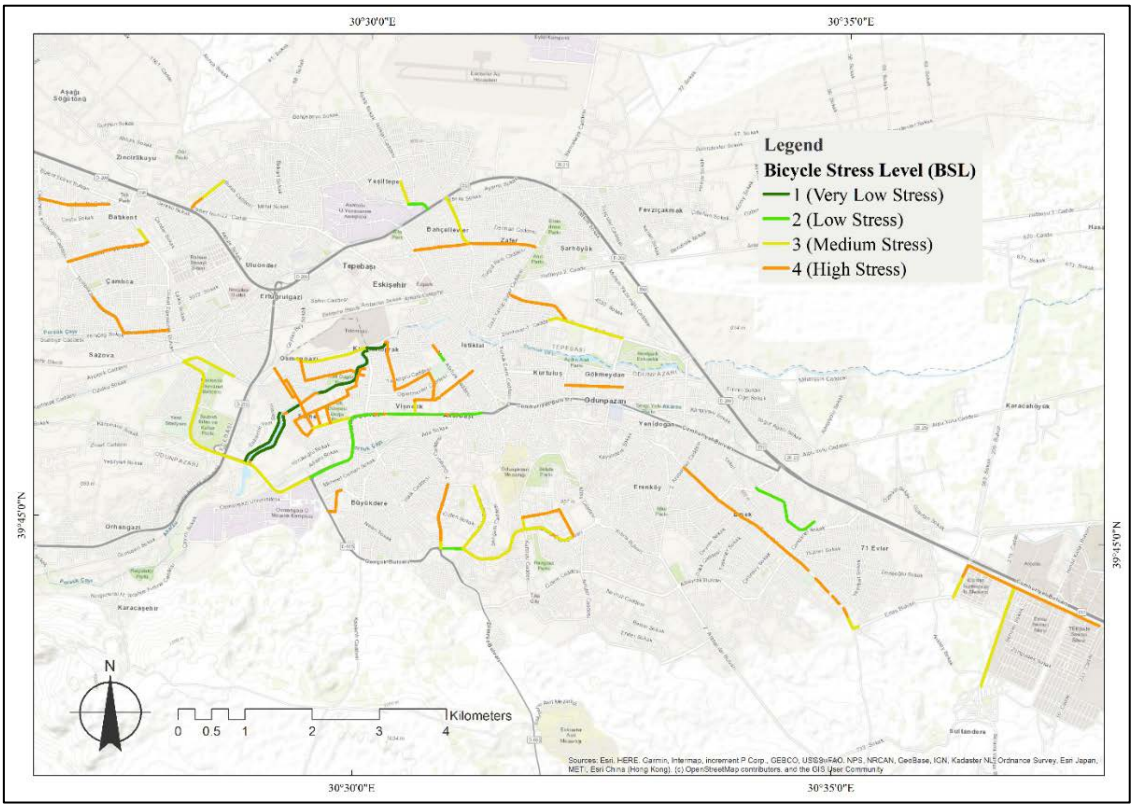

Fig.5 BSL values of existing bicycle roads in the study area

Upon evaluating the planned bicycle route alignments in accordance with ETMP 2035 and the Bicycle Stress Level (BSL), the following conclusions were drawn. Within the planning period from 2015 to 2035, a total of 30,373 meters of bicycle roads are intended to be developed.

The BSL analysis indicates that none of the proposed routes fall into the categories of very high or very low stress levels; instead, only 1.9 kilometers of the paths are classified as low stress, which represents just 6.2 % of the overall planned bicycle infrastructure. Additionally, it was noted that the lengths of bicycle roads categorized as medium and high stress levels are quite similar. Specifically, the medium stress level paths total 14.7 kilometers, making up 48.5 % of the planned bicycle routes, while the high stress level paths total 13.7 kilometers, accounting for 45.2 % of the overall planned bicycle roads.

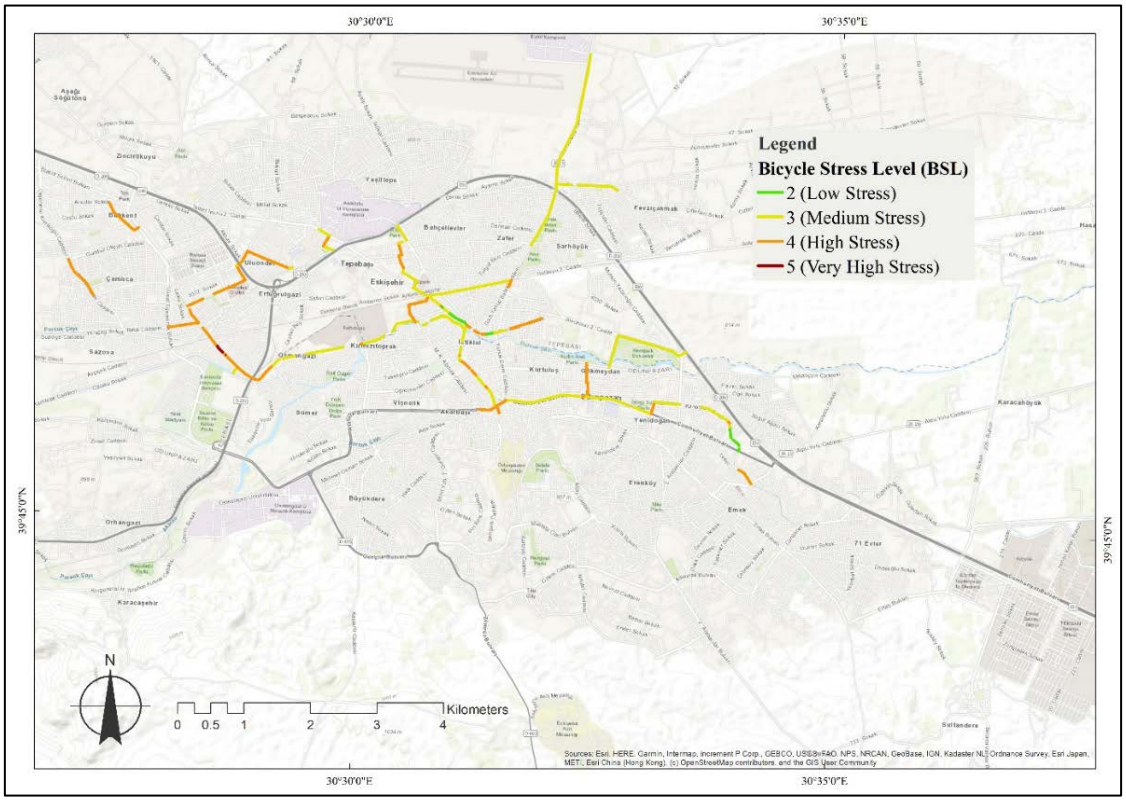

Fig.6 BSL values of bicycle roads planned according to ETMP 2035 in the study area

3.2 Results on BSS

Upon assessing the Eskisehir urban road network using the Bicycle Suitability Score (BSS), it is evident that a considerable majority of the roads (95.5 %) are categorized as "Highly Suitable" or "Suitable" for bicycle use.

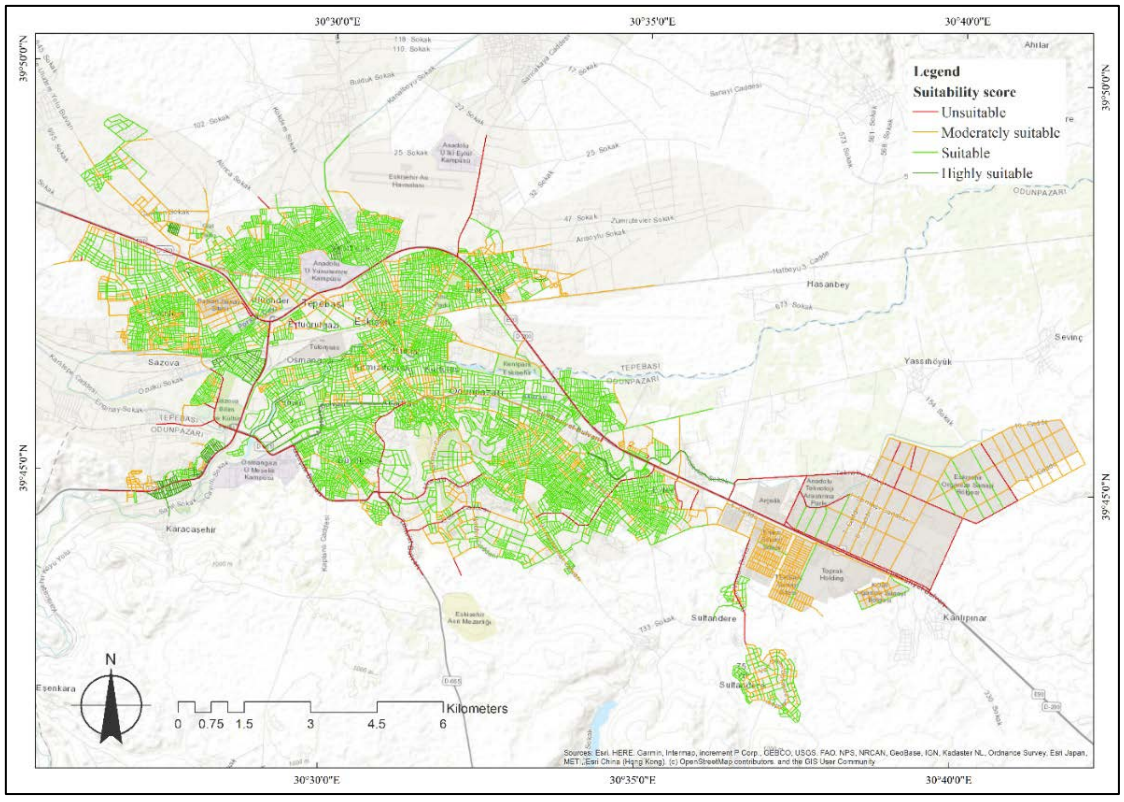

Fig.7 BSS values of the road network in the study area

The results of the BSS analysis including existing and planned bicycle roads, are presented in Tab.12.

		BSS Score			
		Unsuitable	Moderately Suitable	Suitable	Highly Suitable
Share in the urban road network	km	80.20	46.40	2,598.50	55.10
	%	2.90	1.70	93.50	2.00
Share in existing bicycle roads	km	7.80	18.90	29.80	8.00
	%	12.10	29.30	46.20	12.40
Share in planned bicycle roads according to ETMP 2035	km	2.40	10.80	16.60	0.50
	%	7.90	35.60	54.70	1.60

Tab.12 Results on BSS

It was noted that the road segments classified as "Highy Suitable" within the four suitability categories utilized for the BSS assessment account for 2.9 % (80.2 km) of the entire urban road network. Among these, 12.1 % (7.8 km) of the existing bicycle paths in the city are situated on these roads. This situation is believed to arise from the presence of one or more factors in the identified road segments, including bicycle paths that fail to meet legal standards, pavements with physical conditions unsuitable for cyclists, and vehicle speed values exceeding legal limits. Additionally, it was found that roads rated as "Unsuitable" represent 1.7 % (46.4 km) of the total urban road network, with 29.3 % (18.9 km) of the existing bicycle paths located on these segments.

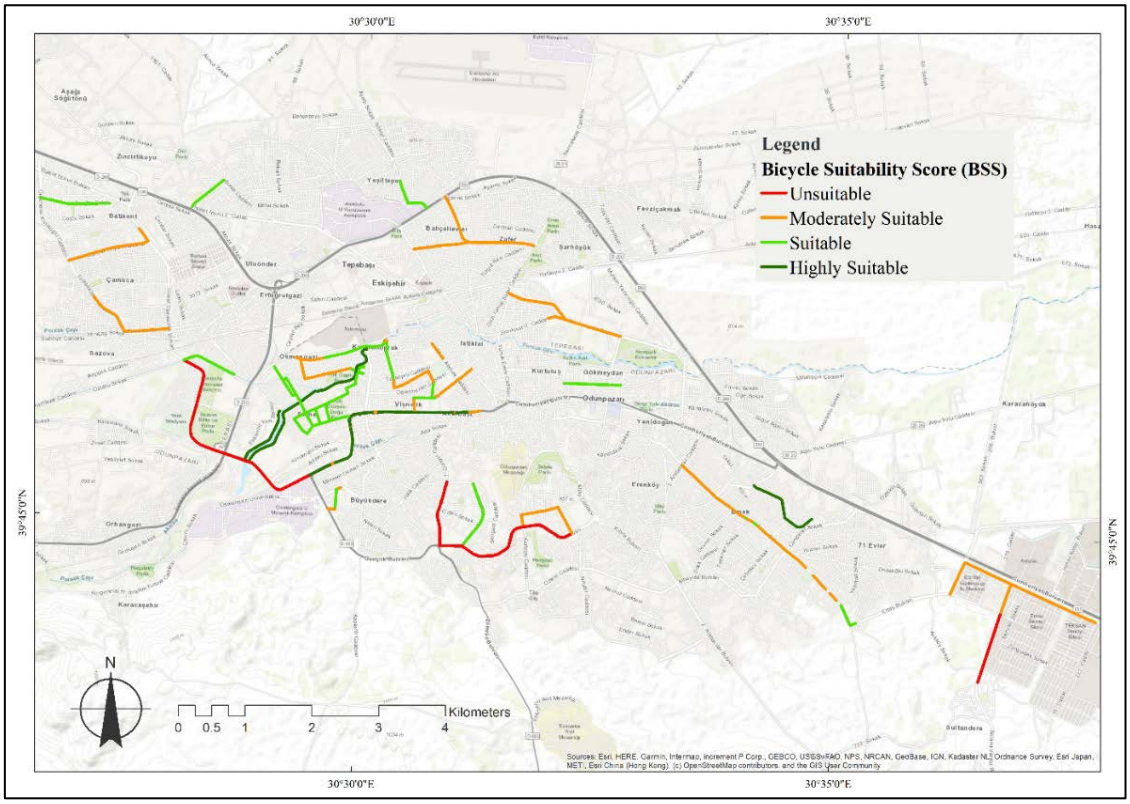

Fig.8 BSS values of existing bicycle roads in the study area

The relatively high traffic volumes and inadequate pavement conditions for cyclists contribute to this classification. Conversely, roads classified as "Highly Suitable," which constitute the largest proportion of the urban road network, cover 93.5 % (2,598.5 km) of the total network. Similarly, 46.2 % (29.8 km) of the existing bicycle paths fall within this category. It is posited that these bicycle paths are deemed "Highly Suitable" because, despite the pavement conditions being insufficient for cyclists, the vehicle speeds and traffic

volumes create adequate conditions for cycling. It was observed that the roads defined as "Highly Suitable", which are the most ideal class for cycling, cover only 2 % (55.1 km) of the urban road network, with 12.4 % (8 km) of the existing bicycle roads situated on these roads. The factors contributing to the suitability of these roads for cyclists include dedicated bicycle paths that comply with legislative standards, roads that prohibit vehicle access, and roads characterized by very low traffic volumes. When the bicycle paths proposed for construction in accordance with ETMP 2035 are analyzed using the Bicycle Suitability Score (BSS), the following results are obtained. It was found that 2.4 km (7.9 %) of the planned bicycle paths, which are set to be built between 2015 and 2035, were classified as "Unsuitable." In total, the roads deemed "Unsuitable" amounted to 10.8 km, representing 35.6 % of the planned bicycle paths. Conversely, the classification of "Suitable" exhibited the highest proportion among the planned roads, with a length of 16.6 km and a share of 54.7 %. In contrast, the roads categorized as "Highly Suitable" had the lowest representation, measuring only 0.5 km and accounting for 1.6 % of the total.

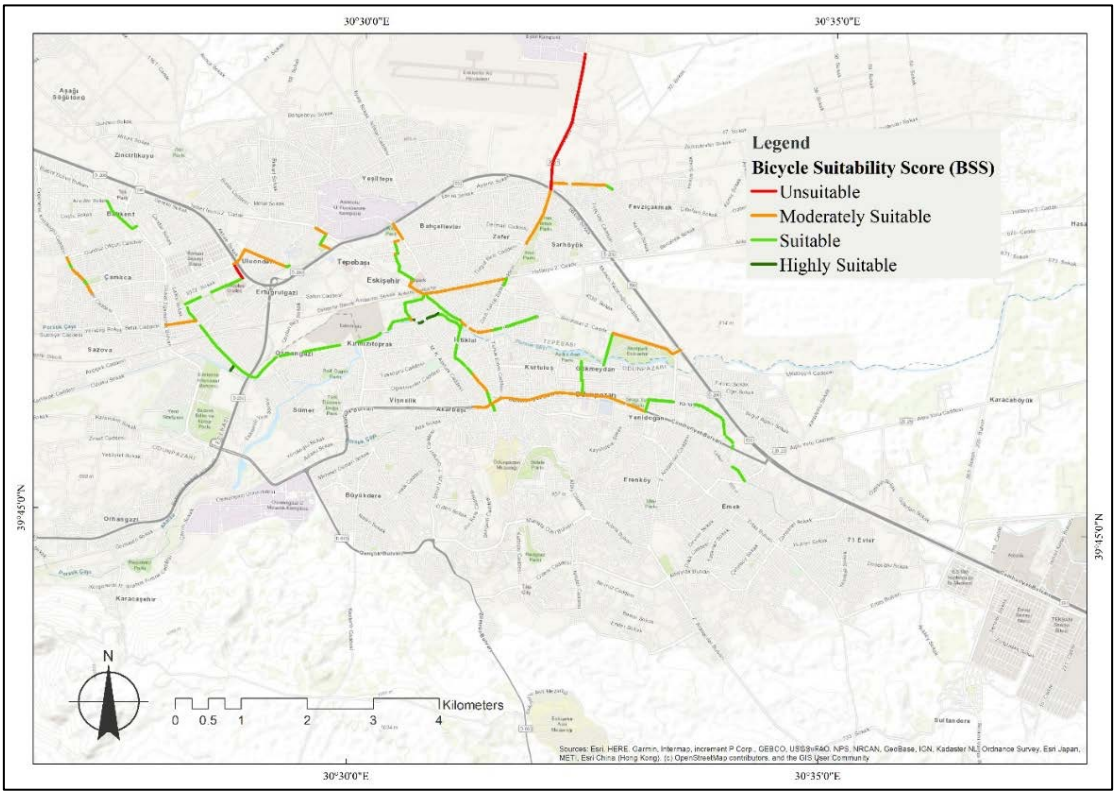

Fig.9 BSS values of bicycle roads planned according to ETMP 2035 in the study area

3.3 Results on BLOS

Upon evaluating the urban road network in terms of the Bicycle Level of Service (BLOS), it can be asserted that a substantial segment of the Eskisehir urban road network (76.3 %) attains a "B" service level. This classification signifies that the cycling experience is deemed acceptable for a diverse range of users, encompassing both "novice" and "experienced" cyclists.

It was observed that road segments classified as Level A, described as providing an excellent environment for cycling, and those classified as Level F, described as unsafe for cycling, were not exist. The lack of Level A roads across the city is thought to stem from several factors: the majority of bicycle paths are not dimensioned in accordance with standards, the proportion of on-street parking is remarkably high, the widths of outer lanes are insufficient for safe cycling, and the poor physical condition of sidewalks.

Road segments classified as Level B, described as providing a good environment for cycling, account for 76.3 % (2,122.6 km) of the total urban road network. Of the existing bicycle paths in the city, 65.7 % (42.4 km) are located on these roads. Key variables influencing the designation of these Level B bicycle paths include

traffic volume and the utilization rates of on-street parking spaces. The Bicycle Level of Service (BLOS) values for roads with restricted vehicular access further support this classification.

The results of the BLOS analysis including existing and planned bicycle roads, are presented in Tab.13

		BLOS Score					
		Level A	Level B	Level C	Level D	Level E	Level F
Share in the urban road network	km	0	2,122.60	349.60	235.80	72.20	0.00
	%	0	76.30	12.60	8.50	2.60	0.00
Share in existing bicycle roads	km	0	42.40	8.10	12.80	1.20	0.00
	%	0	65.70	12.60	19.80	1.90	0.00
Share in planned bicycle roads according to ETMP 2035	km	0	25.50	3.20	1.60	0.00	0.00
	%	0	84.10	10.50	5.20	0.00	0.00

Tab.13 Results on BLOS

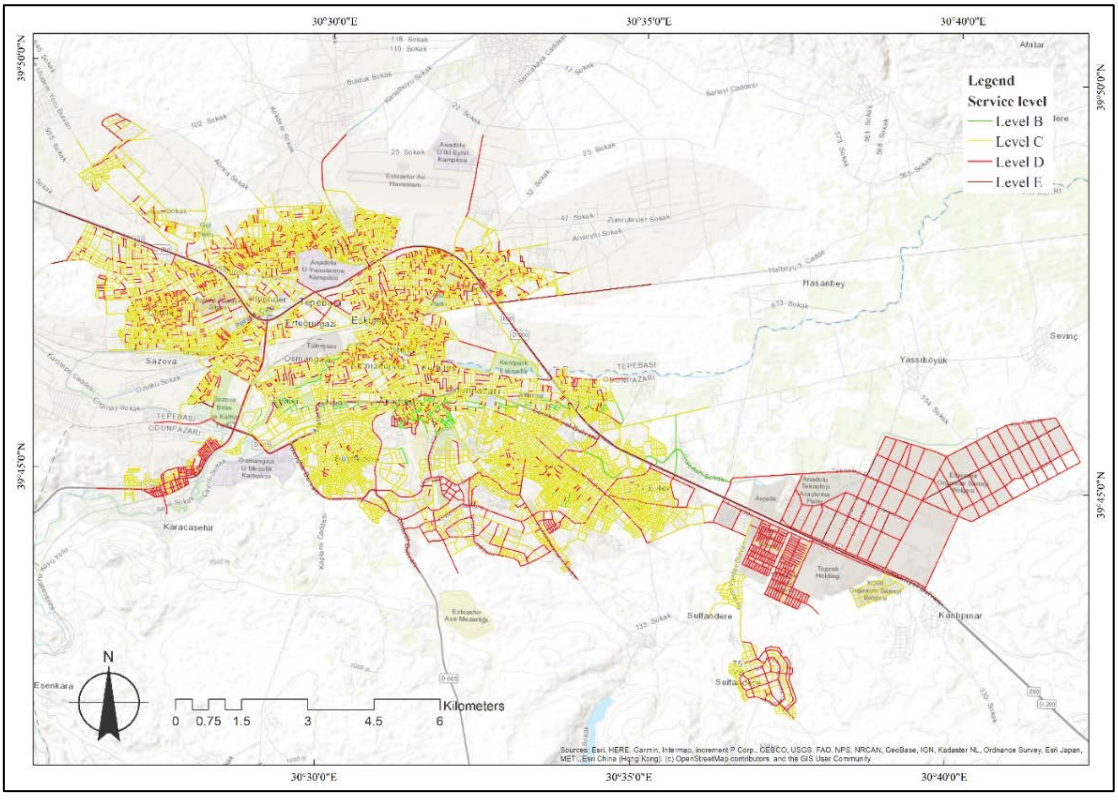

Fig.10 BLOS values of the roads in the study area

Level C road segments, described as providing a reasonable environment for cycling, constitute the largest share of the urban road network, covering 12.6 % (349.6 km). The existing bicycle paths within the city that fall into this category represent 12.6 % (8.1 km) of the total. Variables such as traffic volume, sidewalk conditions, and changes in the on-street parking utilization rates significantly contribute to the emergence of this classification.

Road segments classified as Level D, described as providing a poor environment for cycling, make up 8.5 % (235.8 km) of the total urban road network. Of the existing bicycle paths, 19.8 % (12.8 km) are located on these roads. On roads at this level, where cycling is particularly challenging, bicycle path widths are inadequate, and outer lane widths are insufficient to allow for shared-use arrangements.

Level E Road segments, described as providing an inadequate environment for cycling, account for 2.6 % (72.2 km) of the total urban road network. Only 1.9 % (1.2 km) of the existing bicycle paths are situated on these roads. The external lane widths, bicycle path dimensions, and the physical condition of sidewalks on these road segments fail to meet necessary standards, while the utilization rates of on-street parking spaces remain high.

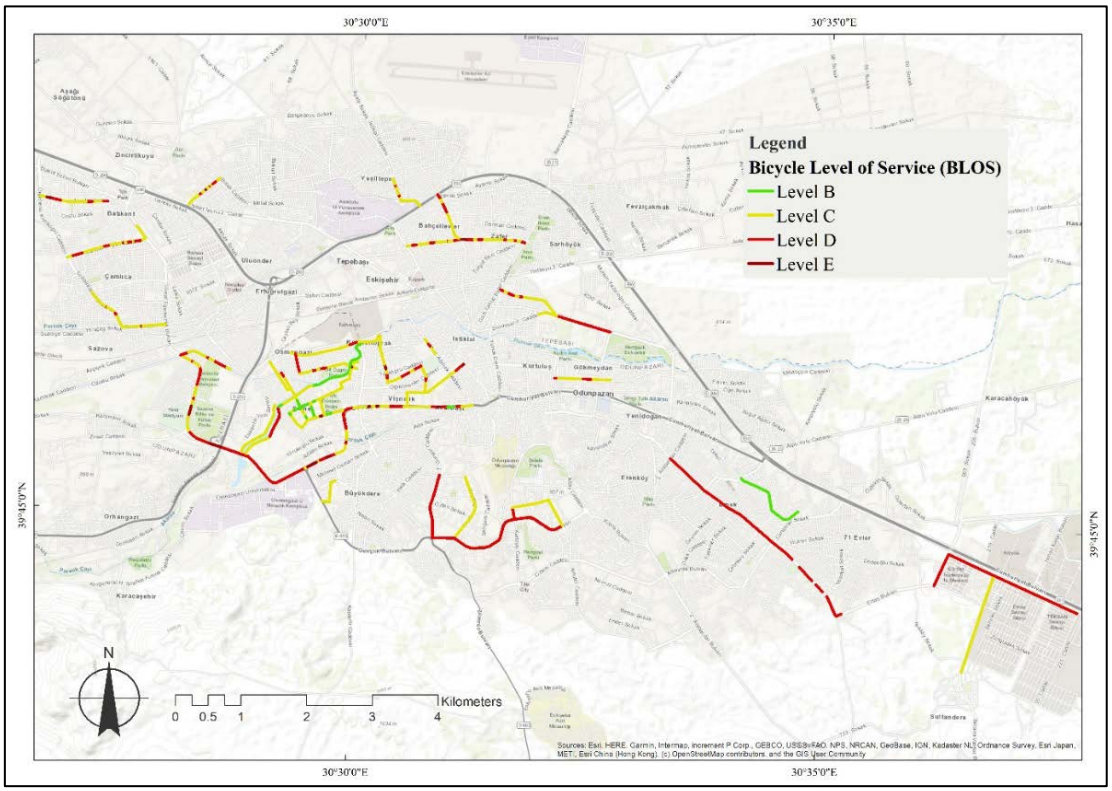

Fig.11 BLOS values of existing bicycle roads in the study area

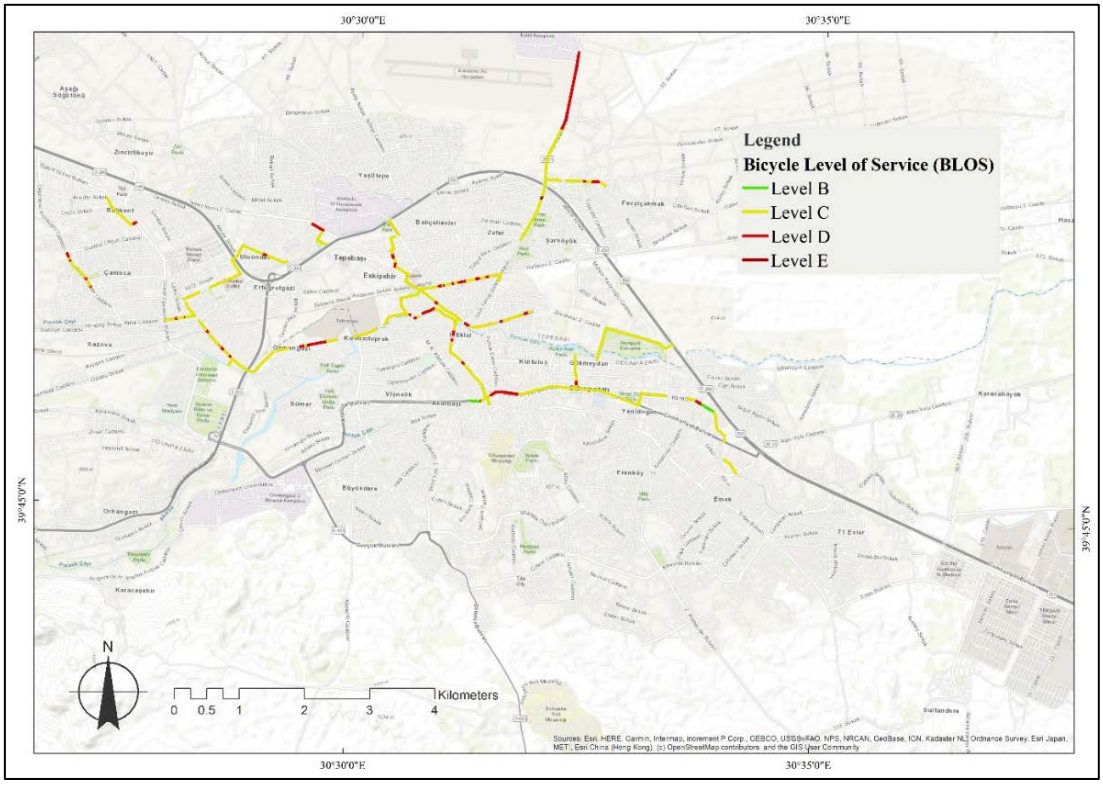

Fig.12 BLOS values of bicycle roads planned according to ETMP 2035 in the study area

When the planned bicycle path routes for 2035, as outlined in the ETMP, are analyzed based on the BKHS approach, it is observed that there are no routes classified at levels A and F among the planned bicycle paths during the plan period. Routes at level B constitute the highest proportion, accounting for 84.1 % (25.5 km) of the total planned paths. Routes at level C have a total length of 3.2 km, representing 10.5 % of the planned bicycle paths, while level D routes have the lowest share, with a total length of 1.6 km, corresponding to 5.2 % of the planned routes.

3.4 The paradox of physical suitability and perceptual stress

The methodology of this study has revealed that the urban road network in the study area has a contradictory structure. While a large portion of the road network (93.5 %) is classified as "Suitable" or "Highly Suitable" according to the BSS, the BSL identifies significant "High Stress" areas (69.1 %). Similarly, although the BLOS analysis shows that most of the network operates at "Level B" (76.3 %), this contradicts the high stress levels indicated by the BSL.

This paradox points to a fundamental problem: even when infrastructure appears to meet physical standards or satisfies basic service level criteria, it can still create significant challenges and stress for cyclists. The primary reason for this is that conventional indices, such as BSS and BLOS, which measure physical parameters, are unable to adequately capture the perceptual and social factors experienced by cyclists. This study fills this perceptual gap with survey data from cyclists, which helps explain the reason for the paradox. The fact that Eskisehir's car ownership rate (23.5 %) is higher than the national average (17 %) creates a negative situation for cyclists in terms of sharing urban infrastructure and increases stress levels. Furthermore, the lack of compliance of existing and planned bicycle roads with national standards (TS 9826, TS 10839) and the absence of fundamental safety measures like intersection layouts, signaling, and marking, cause even physically present infrastructure to create an unsafe and stressful environment for cyclists. This finding proves that there is no direct correlation between a road's physical width or surface quality being rated as "suitable" and a cyclist feeling "safe" on that road. Therefore, a comprehensive assessment requires both quantitative physical data and qualitative data on cyclists' experiences.

3.5 Policy implications and the path to cultural change

The study's findings reveal critical challenges in the implementation of Eskisehir's strategic plans for bicycle transportation. The city has taken determined steps to promote cycling; the Eskisehir Transportation Master Plan (EUAP 2035) aims to expand the bicycle network, and concrete initiatives like the "Bicycle Paths and Parking Stations Project" have been launched. Furthermore, by organizing workshops like "Come on Turkey, Let's Cycle!", the city supports the "cultural change" needed for the widespread adoption of bicycle transportation.

However, the data obtained in our study shows that the implementation of these well-intentioned plans faces a fundamental problem: a significant portion of the existing and planned infrastructure does not comply with national standards, making physically present roads stressful and unsafe for cyclists. For example, BSL results show that 58.6 % of existing bicycle roads are located in high-stress areas. This proves that a quantitative increase in infrastructure investments does not always qualitatively enhance cyclist comfort and safety.

Our GIS-based approach offers a valuable tool for urban planners to identify this critical divergence. By mapping specific road segments that the BSS and BLOS have marked as "suitable" or "reasonable" but the BSL has identified as "high-stress," the GIS analysis clearly shows the areas where investment will genuinely improve the cyclist's experience. This will allow for a more efficient use of resources and will close the gap between policy goals and on-the-ground realities. In conclusion, for Eskisehir to achieve the desired cultural change in bicycle transportation, the planning and implementation processes must be handled with an integrated approach, prioritizing the quality and compliance of existing infrastructure with standards, rather

than simply increasing the length of bicycle paths. This approach will not only increase the number of cyclists but also foster a safer, healthier, and more sustainable life in the city.

4. Conclusions and limitations

4.1 Key findings and contributions

The methodology adopted in this study has shown that the urban road network in the study area has a paradoxical structure. While it is largely classified as "Suitable" according to the Bicycle Suitability Score (BSS), the infrastructure also contains significant "High Stress" areas as identified by the Bicycle Stress Level (BSL). Similarly, although the Bicycle Level of Service (BLOS) shows that most of the network operates at "Level B," this contradicts the high stress levels observed in the BSL. Existing bicycle paths follow a similar trend; although they are classified as "Suitable" in the BSS, a large proportion of them are located in "High Stress" areas in the BSL. This recurring theme indicates that a significant portion of both existing and planned bicycle infrastructure is classified as "Moderate" or "Level B," yet still experiences significant challenges in "High Stress" areas. These findings suggest that while the infrastructure may meet basic suitability and level of service criteria, it still poses challenges for cyclists.

The main contribution of this study is that using three different bikeability assessment indices together provides a comprehensive analytical view that a single assessment cannot. This proves how critical not only physical data but also user perceptions are in urban bicycle transportation planning. The quantitative results obtained clearly show that a single model can be misleading and that a multi-criteria approach is essential to get a complete picture. With its GIS-based approach, this study provides a valuable tool for urban planners to identify areas that require infrastructure improvements and to help create a more bicycle-friendly urban landscape.

4.2 Limitations and quantitative significance

This study has some limitations. The data used, such as traffic volume, is static for some variables and may not fully reflect the dynamic changes that occur at different times of the day or on different days of the week. In addition, adherence to the standard formulas of the quantitative indices used (BSL, BSS, BLOS) has limited the direct integration of perceptual data into the formulas. However, these limitations also highlight the study's most important finding and its quantitative significance.

The quantitative significance of the study lies in the striking differences between the results obtained. For example, the fact that 58.6 % of existing bicycle roads have "High Stress" according to BSL, but 46.2 % are "Suitable" according to BSS, numerically proves how misleading traditional single-index evaluations can be. This contradiction shows that a new paradigm is needed at the core of bicycle transportation planning. Future research could overcome these limitations by combining dynamic data from GPS trackers or by developing a new, hybrid index that directly incorporates perceptual factors into the calculation mechanism. In conclusion, this study underscores the need for a comprehensive approach that goes beyond basic suitability and service level assessments and effectively addresses the factors that create stress for cyclists.

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Risk as a wicked problem in planning: the role of future non-knowledge

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Abstract
Dealing with spatial organization, planning and design has to cope with something that is not (not yet or never will be) there. This is a matter of knowledge and of knowledge management, a matter for times to come: so in knowledge management the facet of non-knowledge appears. The research reflections proposed here are connected with activities carried out in the case study of Biccari, a small village in the north of Puglia (Italy), located on the slopes of the Dauni Mountains, between the Apulian plateau and fragile mountain terrains. It involved the University of Sannio and the Polytechnic University of Bari, to provide scientific support aimed at drawing up the town's master plan (PUG). The territory is affected by an extensive paleolandslide, creating significant hydrogeological risk conditions. Despite this, the local community tends to remove such risk from their perception, showing fatalistic attitudes toward phenomena considered inevitable. The paper explores how to deal with "non-knowledge" in spatial planning, particularly by integrating local risk perceptions and decision-making dynamics into agent-based simulation models developed using NetLogo software. As an exploratory study, it proposes a prototype framework to simulate interactions between institutional decisions, environmental dynamics and community behaviors, with the goal of supporting more adaptive, informed and resilient planning strategies – managing uncertainty as a constitutive element of planning in fragile territories, rather than as a problem to be eliminated.

Keywords
Planning, Future, Non-knowledge, Uncertainty, Risk, Fatalism

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1. Introduction

Planners and decision-makers face the complexity of spatial and environmental decisions all the time. In recent decades there has been a high degree of uncertainty and rapid environmental changes. It required policy-making and planning approaches useful for making effective, robust and resilient or antifragile choices with a final far sighted look at the environment as a system (Taleb, 2012; Buurman & Babovic, 2016). In our discipline field the consciousness of the necessity to deal with the future arose in a few decades with a flourishing of methods and reflections. They dealt with future workshops, building scenarios, back chain mirror strategies (Jungk & Mullert, 1996) that dialogue by constantly investigating the future even though not all the developers of the research in this field has worked in this direction.

As human beings we are immersed in the eternal present that changes moment by moment, and we are also constantly projected towards a tense future (which we can imagine on a continuous line that goes from the infinitely close to the infinitely remote). This is a matter of daily living. Reality is full of hints that appear as unrelated and subtle, they are in a chain of causes instead in space and time that often are not read in a systematic and coherent perspective (Gumbrecht, 2014). This has been sadly and problematically true, e.g., about the climate change issue and the last pandemic. A part of the literature, both scientific and informational, had tried to argue and speculate about such topics, in order to forward the message to the communities and decision makers: it was a reading of a feared future toward the forecasting of a future to be averted.

Dealing with spatial organization, planning, design has to cope with something that is not (not yet or never will be) there. This is a matter of knowledge and of knowledge management, a matter for times to come: so in knowledge management the facet of non-knowledge appears (Stufano Melone & Camarda, 2022).

We have dealt with an interesting case study in a small town in Southern Italy (Apulia region) that could be, in its smallness, a paradigmatic sample. There, a mountain is crumbling but people still want to build there: why?

The case study mentioned above is Biccari, a town of around 3000 inhabitants on the slopes of the Dauni Mountains. The drafting of the new master plan has been engaging the Polytechnic University of Bari group since 2018. A rather long time for such a low-populated centre, only partly due to the problems induced by the recent years of pandemic. A significant problem is the request for expansion of areas to be developed economically, despite widespread and significant hydrogeological problems. The territory is in fact largely affected by phenomena of ancient and slow landslides and hydraulic infiltration which make the soil fragile and prone to extensive cracking. The risk to the safety of people and buildings is significant and the hydrological basin authority has placed strong restrictions on soil transformations. These constraints are enforced until consolidation works are set up - which however are expensive and await appropriate public funding. Yet the Biccari community insists on finding ways to rapidly develop its territory, even in fragile areas, aspiring to immediate socioeconomic improvements. Curiously, a large part of the community tends to consider the indications of the hydrological authorities exaggerated, if not false. They don't believe in the risk, they think that these are slow phenomena that have always been present in Biccari and that cannot be used to block development.

In the above context, the paper aims to explore how to deal with "non-knowledge" in spatial planning, particularly in relation to risk management within contexts marked by uncertainty and environmental fragility. Using the case study of Biccari, the research tries to investigate how local risk perceptions and decision-making dynamics can be integrated into agent-based simulation models, with the goal of supporting more adaptive, informed, and resilient planning strategies over the long term.

It must be said that this work is explicitly positioned as an exploratory and preliminary study, aiming to investigate conceptual tools and modelling frameworks for addressing spatial planning under conditions of epistemic uncertainty and community-based fatalism. This paper builds on our previous research into non-knowledge for planning in this journal (Stufano Melone & Camarda, 2022) by applying and testing those concepts within a concrete case study of environmental risk and community perception. Rather than delivering

a fully validated or predictive model, we propose a prototype framework – grounded in real-world complexity but intentionally simplified – to open a discussion on alternative planning logics in fragile territories.
After the present introduction, in Chapter 2 we suggest slightly wider reflections about non-knowledge and future in planning in the broader research field about uncertainty. Chapter 3 examines the case study of Biccari, the above cited small municipality in northern Apulia, particularly dealing with its geomorphological criticalities between the Apulian plateau and the fragile slopes of the Daunia mountains. Chapter 4 develops a reflection on a methodological approach to integrate fatalistic and precautionary agents' positions toward a risky situation, also using a simple simulation model based on NetLogo software. Finally, chapter five reports brief conclusion remarks and possible follow-ups.

2. Dilemmas in planning: the consciousness of a non-knowing the future

Humans project themselves along a linear path that moves through time - the future appears as an open horizon of possibilities to which humans tend from the possibilities offered by the future itself (Gumbrecht, 2014). It is made up of uncertainties, ambiguities, deep unknowns that fatally affect the results of a strategic plan or, more generally, the effectiveness of environmental and design choices.
Furthermore, the relationship between knowledge, non-knowledge, and digitality is a complex one, not fully explored (Monnin, 2018), in an environment of smart cities, sensors, STS, AI support, urban digital twins and so on, a tumultuous growth of tools and devices to be supported with new consciousness about reality and intentions (the purpose for a desired future) (Bencardino & Greco, 2014).
Our reflections concern non-knowledge, and its possible management perspectives in the face of spatial, urban, regional and environmental planning actions, in a constant arrow that looks at the future, searches in the future, and in some sense tries to build a future. But at the same time in our research we intend to fill a quest, about the future of the planning activities for the city, for the territory and extensively for the environment itself, working on methods and theories more and more inclusive, extensive, iterative, adaptive, robust (Marchau et al., 2019).
Unknowing is often not considered negative but is deemed a constitutive condition of knowledge (Wulf, 2018) and at the same time is a challenging opportunity for new ways of being, of staying, of planning and designing objects, the environment we intend to live in, ourselves and our self-future too.
To go back to our field of reflection and application, planning for cities and territories contains normative elements and seeks to control spatial development with social implications (Schubert, 2019). A paradox of planning and non-planning arises, and the interdependence of chaos and order becomes an integral component of planning and of the debate on the future (Schubert, 2019). Planning procedures often are vague and too generally fulfilled with ambiguities and developed over such a length of time that makes them an answer of the past for a future already present.
How to plan resilient and sustainable cities in the long-run? Or would non-planning and the abandoning of cities to market forces and private developers generate the best solutions? (Schubert, 2019).
We see two possible paths to follow, among others. An imaginative path builds scenarios for either desirable or undesirable aims, integrating the largest possible number of hints and intuitions - even the less 'interesting' ones. Another path follows the 'apparently' do-nothing option, building a scenario for future planning where the decision and 'use' are freed from profit, in a sight of a highest common good. The idea, leaning trough a happy degrowth, is using all the new tools, and devices, and consciousnesses in a reflexive and differently constructive way: observing the natural movements of nature and acting only to prevent pre-sighted risks.
For the study of the future, the construction of scenarios, future workshops, strategies, planning actions, the representation of knowledge (and non-knowledge), the role of metaphor cannot be ignored. It is useful also in the organization of memories to be launched -renewed- toward the future, in a form of anterior future or

memory of the future, also in the construction of the questions that are asked about the future, in a form of a blind built scenario (Brandimonte, 2004).

These dilemmas of planning under uncertainty are acutely visible in the field of risk governance. Contemporary international debates increasingly move beyond technical risk assessments to focus on the social processes of risk perception, communication, and decision-making (e.g., Renn, 2008; Aven & Renn, 2010). This shift emphasizes adaptive and participatory governance models that can accommodate deep uncertainty and conflicting stakeholder values, much like the "wicked problems" paradigm (Rittel & Webber, 1973). The case of Biccari, with its tension between hydrological authorities and a fatalistic community, exemplifies this governance challenge. It highlights the gap between technical risk calculations and local risk acceptance, a central theme in modern risk governance literature.

3. Paths to overcome the dilemma: introducing a case study

Biccari exemplifies a constellation of factors that make it particularly relevant for exploring the dilemmas of planning under conditions of non-knowledge and environmental uncertainty; it serves as a paradigmatic example in relation to the theoretical framework outlined. Biccari is a municipality in northern Puglia with 2.720 inhabitants, located on a hill in the Daunia mountains at 450 meters above sea level. The municipality develops across a large and variegated territory that includes Mount Cornacchia, the highest peak in Puglia, along with the sources of the Vulgano torrent and Lake Pescara.

Biccari represents a widespread typology of marginal, environmentally fragile territories in Mediterranean mountain contexts and embodies the socio-spatial dynamics of depopulation, economic restructuring, and resource rediscovery that characterize many inland areas. The case encapsulates the drama of demographic decline while simultaneously revealing the tension, intelligence, and environmental sensitivity of its inhabitants in their determination to ensure the survival of their territorial system, coupled with a failure to perceive the intrinsic and 'silent' risk of situations such as the paleolandslide. This duality makes the case particularly instructive, as findings are potentially transferable to similar contexts facing analogous challenges.

The coexistence of significant natural resources – such as Lake Pescara and naturalistic areas with tourism potential – alongside major environmental risks creates a condition of radical uncertainty emblematic of the "consciousness of not knowing the future." The extensive paleolandslide affecting both residential and recreational areas represents the most striking dimension of this complexity, yet what emerged most clearly during participatory activities was a systematic "removal" of hydrogeological risk from community visions despite its objective significance. This cognitive-cultural dimension – the gap between expert knowledge and local perception – makes Biccari particularly suitable for exploring how collective belief systems interact with technical assessments in shaping planning futures, a central concern in contemporary debates on risk governance and participatory planning.

The paradigmatic complexity of this small inland center is further enriched by the energy dimension characterizing its subsoil. Beyond the presence of wind turbines already present, investigations have been conducted on underground gas resources as potential sources of renewable energy. This stratification of energy potentials adds another layer to the intricate tapestry of opportunities and constraints that planning processes must navigate.

The institutional context further contributes to this paradigmatic quality. The regulatory rigidity and implementation delays characteristic of Italian planning systems have resulted in environmental constraints producing stasis rather than adaptive management. Legal orders blocking possible transformations, established following the identification of the paleolandslide, left planning activity formally unupdated while awaiting consolidation works significantly behind schedule. The Biccari administration's request to explore dynamic, behavior-based regulations that could adapt normatively to the landslide's behavioral dynamics represents an innovative yet challenging attempt to overcome deterministic planning paradigms.

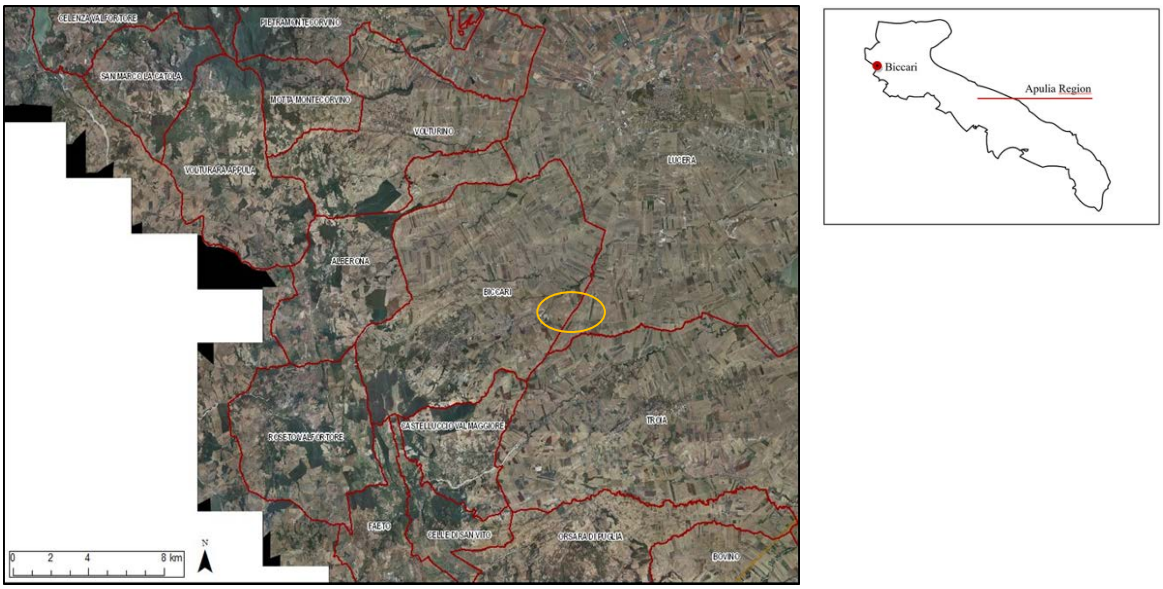

Fig.1 Biccari between Capitanata and Monti Dauni (from S.I.T. Puglia – orthophoto 2016)

The municipality concentrates environmental fragility alongside resource potential, socio-economic marginality alongside community resilience, cultural fatalism regarding the 'invisible' paleolandslide alongside environmental awareness regarding renewable energy possibilities, institutional rigidity alongside administrative innovation, and knowledge multiplicity emerging from participatory processes. The inhabitants' failure to fully grasp all the nuances of inherent territorial risks – particularly the paleolandslide's implications – while simultaneously demonstrating sophisticated understanding of the territory's potential for sustainable tourism and renewable energy development, exemplifies the misalignments between place perception, community aspirations, territorial risks, and regulatory frameworks that characterize contemporary planning dilemmas.

These characteristics converge to outline reflections that are, in a sense, 'prêt-à-porter' – ready to be engaged with and adapted to confront realities that may be either more simplified or more complex, yet sharing fundamental dilemmas of uncertainty and misalignment. The availability of rich qualitative data from participation processes – visions, narratives, local discourses – combined with the technical complexity of modeling landslide dynamics and risk perception creates an ideal testbed for the multi-agent approach proposed in this research. Biccari thus becomes not merely a case study but a microcosm concentrating the theoretical and practical challenges that demand serious reflection within both scientific approaches and the applicative pathways of planning processes.

The vision of the master plan is interpreted in an intrinsically operational sense and is built with a strategic and inclusive approach, structurally based on the collection and exchange of multi-agent knowledge (Borri et al., 2014; Camarda et al., 2020). The regulatory framework of the Puglia Region requires a set of administrative and planning acts aimed at defining an optimal structure of the regional territory, to be prefigured and regulated through regional territorial planning, as well as through guidelines that must be compatible with the plan. Since the 1960s, the small municipality of Biccari has been affected by the phenomenon of depopulation of the mountain anthropic system, in a period in which political pressure and economic attention had focused on the implementation of large industrial systems. It was a period in which in a context like that of the small town there seemed to be no possibilities and resources. Today there is still a generalized economic crisis but there is also a new awareness of the immense naturalistic and geomorphological resources as well as the traditional richness of these places. This is where the community wanted to restart, and this is where scientific support for the PUG got involved.

Within the participation activities for the collection of 'local' knowledge useful for the construction of the new Biccari plan, participants were asked to tell how they imagine their country in the near future, asking for a long-term 'vision' effort term. But few of the descriptions collected can truly be defined as visions, the answers are mostly requests or claims that derive directly from the desire to resolve the perceived and experienced critical issues. The future Biccari is mostly imagined as a town with a tourist and agricultural vocation thanks to the valorisation of the historic center and the naturalistic areas, hypothesizing the possibility of a commercial focus on crafts and typical local food products. The historic center and the rural/landscape/agricultural areas are imagined as dotted with activities that thrive on tourism managed in a sustainable and responsible manner. Together with the hope for what is defined as the 'care of the walls', i.e. the request for physical regeneration, we have noted the focus on the desire for specific attention to social aspects with respect to all age and income groups.

The cooperative knowledge construction phase made it possible to collect a series of data, indications, suggestions, and ideas of remarkable interest to fuel the start of the planning process. The result of the participation activity lends itself to some detailed preliminary readings, as well as to the production of reflections also in operational terms (Stufano Melone & Rabino, 2014). A summary of the possible interpretations that may emerge from this reading exercise is reported below, with the aim of providing a first framework from which it is possible to define further reflections, amendments and additions, as well as definitions more oriented and focused on the purposes of the planning process. Our administrative and legislative system is made up of superordinate administrations, so political decisions have an extremely important impact on individual and collective life and on the individual and collective management and use of the territory.

After the crisis induced by the Covid-19 infection, the previous regulatory forms further revealed the planning crisis and how the intrinsic management intentions were aimed at specific programmatic categories and were often separated from the true needs of urban centers or naturalistic areas, of ecosystems, of resources. This today can be interpreted and indeed expressed thanks to a greater awareness of the complexity of the system in which we are immersed. One can clearly read in the visions the distance between the policies and choices made in the past as a form of dyscrasia in the scalarity from large to small, from the collective to the individual, from the anthropocentric to the non-anthropocentric.

What curiously emerges from the consultation is an insurgent removal, from the set of other critical issues identified, of the hydrogeological risk triggered by the paleolandslide downstream of Lake Pescara. The data from the paleolandslide, which constitute such an impactful aspect yet left out of the population's narrative, have triggered a series of reflections on this 'removal' and the possible approaches to 'reconcile' and 'stitch' visions, current reality and perspectives, so as to be as integrated as possible.

4. Notes for an integrate approach in dealing with risks

In the case of Biccari, in fact, a rather particular and for various reasons complex problem arises. The question concerns the presence of an extensive paleolandslide that originates at the peaks of Monte Cornacchia, in particular near Lake Pescara. This paleolandslide concerns an area mainly affected by nature tourism. At its base, this geologically unstable area affects one of the extreme parts of the town, with mixed area uses - including residential and small-industrial uses.

After the legal orders blocking the possible transformations established by the regional bodies, the planning activity was never formally updated, awaiting the consolidation works that the orders themselves prescribed. However, this implementation process is significantly behind schedule, leaving a very large area without regulatory effectiveness and active use. In the meantime, however, activities with low transformative impact have been developed, mainly of a nature-tourism type.

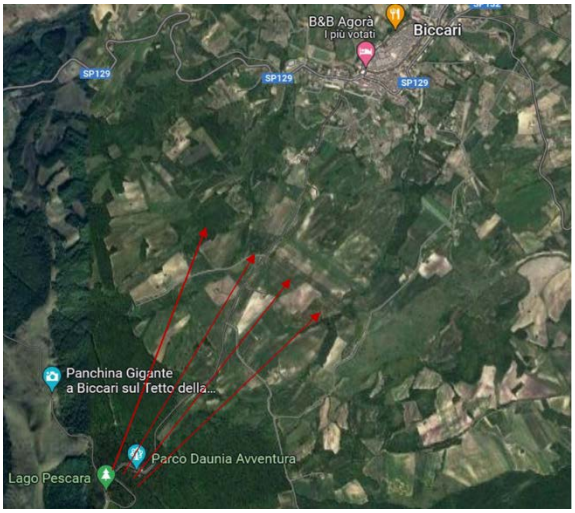

Fig.2 Indication of the paleolandslide near Lake Pescara (on a Google Maps image)

At the same time, a movement against the blocking of the transformability of these external territories has been growing, also triggering illegal construction. The municipal administration is currently exploring the possibility that these critical places can be normatively adapted following the behavior dynamics of the landslide itself. This is clearly a rather pioneering initiative, however linked to the difficulties associated with the fearful rigidity of environmental transformative constraints, typical of many Italian regions - which have always suffered from strong environmental aggression (Koutalakis, 2004). The Biccari administration invited the Polytechnic University of Bari and the University of Sannio, both in southern Italy, to deal with this complex situation (Fistola et al., 2023). They aimed to verify the possibility of setting up formal models capable of defining times, methods, quantities and dynamic rules in connection with the behavior of the landslide - to be subsequently reported in an urban plan. For this purpose, a particular research approach, namely agent-based, is currently being explored (Ferber, 1999).

4.1 Towards an agent-based approach

Methodological justification: Why agent-based modeling for non-knowledge and risk?

The complexity of spatial planning under conditions of uncertainty and community fatalism requires methodological approaches capable of representing heterogeneous behaviors, emergent dynamics, and nonlinear interactions between human and environmental systems. Traditional planning models, often based on equilibrium assumptions and homogeneous stakeholder behavior, are inadequate to address what we call "non-knowledge" – a profound uncertainty regarding future states and outcomes that characterizes fragile territorial contexts.

Agent-Based Modeling (ABM) offers distinct advantages in managing these challenges. First, it allows for the representation of heterogeneous agents with different risk perceptions, decision-making logics, and behavior patterns – an essential capability in communities where fatalistic and precautionary attitudes coexist (Bonabeau, 2002; Crooks et al., 2018). In the case of Biccari, this heterogeneity is empirically observed, with residents displaying very different attitudes toward hydrogeological risk.

Furthermore, ABM allows us to model emergent phenomena resulting from bottom-up interactions rather than top-down prescriptions. Planning processes under uncertainty are characterized precisely by emergent outcomes, which cannot be predicted by the simple sum of individual behaviors (Gilbert & Troitzsch, 2005). This is particularly relevant in contexts like Biccari, where collective outcomes arise from the interaction between individual risk perceptions, institutional constraints, and environmental dynamics.

Also, ABM offers a natural framework for jointly including human and environmental agents in the same model structure (Bousquet & Le Page, 2004). The paleolandslide at Biccari is not a mere passive constraint, but an active system whose behavior both influences and is influenced by human activities. This reciprocal relationship between sociotechnical and environmental systems cannot be adequately represented by traditional tools that consider the environment as an external parameter.

Finally, ABM supports scenario exploration and policy testing, particularly suited to "non-knowledge" contexts. Rather than seeking optimal solutions based on complete information, ABM allows us to explore a range of possible outcomes based on differentiated hypotheses about agent behaviors, institutional arrangements, and environmental conditions (Filatova et al., 2013). This aligns with our conceptual framework, which accepts uncertainty as a constitutive element of planning, not a problem to be eliminated.

The methodological choice of ABM therefore represents more than a technical decision. It reflects a philosophical stance toward planning under uncertainty, which prioritizes mutual and adaptive learning over deterministic prediction, recognizes the legitimacy of diverse forms of knowledge, and aims to understand rather than control complex territorial dynamics.

Building a layout of agents and relations

In a complex context such as an ecosystem or a sociotechnical system, agents are typically multifaceted, operating at different scales and with different roles and sometimes even expressing behaviors that vary with situational dynamics. Risk situations also include unusual, atypical, intriguing but not easily catalogable or manageable behaviors. In the case of Biccari, a community of agents seems to emerge, i.e. interested citizens, who perceive in a diversified way the risk represented by the presence of the paleolandslide - particularly in some areas of greater transformative interest. In general, there are agents who are certainly sensitive to the risks associated with the phenomena in progress. Some, however, seem to express perplexity if not reluctance to accept the presence of a real risk in these areas. Some agents simply do not believe that such a risk actually exists, as they are skeptical of the real knowledge of the experts who established the dangerousness of the areas. Other agents, while recognizing the presence of risk, perceive it in a very limited way in relation to the slow flow of the landslide. Still other agents tend to consider the inevitability of events as an integral part of everyone's life and therefore minimize the risk itself. Generally speaking, quite a few agents seem to show common characters in terms of perception and behavior. On the one hand they seem to express a fatalistic attitude, albeit to varying degrees, towards the risk of a significant landslide event. On the other hand, they seem to consider this risk, here too in a differentiated way, as an intrinsically constitutive element of every action, in particular in territorial transformations. This last vision closely resembles the concept of economic risk (Chatterjee et al., 2003).

With a blend of such characters, specific profiles of agents could be built, consistent with a teleonomic cognitive model of various composition, following for example Ferber (1999, p.16). In the case in question, a more in-depth study can characterize the agents based on their possible activities, with a relationship with the community and the territory affected by the landslide. The same agent-based approach can also hypothesize a coherent configuration of the landslide system itself. Indeed, modeling this 'environmental agent' is actually part of a long-standing, difficult line of research, with multiple attempts to address its intrinsically high degree of complexity. Given the evidently multidimensional character of the concept of environment, modeling experiences have often opted for agent models partialized only to the aspects of specific interest of the study (Bousquet & Le Page, 2004; Weyns et al., 2007; Schreinemachers & Berger, 2011). This approach seems adoptable in the present case, defining a 'paleolandslide agent' through characters of particular interest of the phenomenon studied. It is clear that the behavior of a landslide can be detected through sensor technologies specifically used in these cases (Casagli et al., 2023; Yaprak et al., 2017). The presence of a more accentuated risk induces the need for denser, more elaborate and

sophisticated (and expensive) sensor networks and vice versa. Furthermore, especially in high-risk situations, actual task forces are established made up of experts and analysts from various disciplines. Through also frequent inspections, surveys and field analyses, they report the aspects of the behavior of the phenomenon being studied (Guzzetti et al., 2020). In this case, a hybrid type of behavioral model of the phenomenon can be hypothesized, made up of technological sensors and human analysts, oriented towards updating databases representing situational dynamics. It is evident that this is a partialized environmental agent, located through parameters/variables that approximate its behavior, and that interacts with the other agents generating a model of territorial dynamics oriented towards its transformation/conservation (Occelli & Rabino, 2006; Fusco et al., 2021).

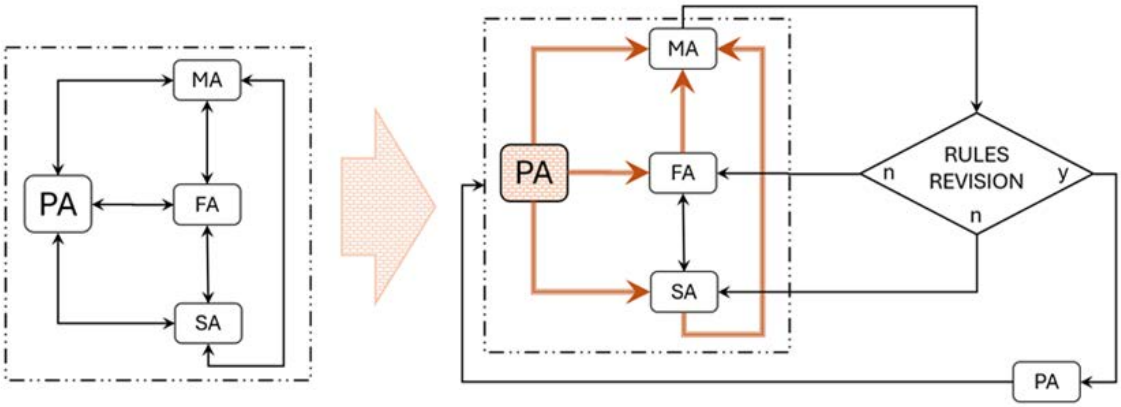

Fig.3 Simplified agent-based layout

Fig.3 schematizes a possible interaction layout between agents active in the problematic situation in question. This is a rather simplified context, both from a situational point of view and from the point of view of the agent profiles involved. Clearly, this is only an example to set the prodromes of a possible real process. From the point of view of the context, there is the paleolandslide with its slow or very slow dynamics, with the agents that in some way have an interest in it. The agents are schematized in an extremely small number, with the simple aim of showing a possible functioning of the model. On the left we see the initial equilibrium situation, characterized by the presence of four agents. The acronym SA indicates the sensitive agent, i.e. the individual who, when faced with even a minimally perceptible dangerous situation, shows acute sensitivity and therefore develops defensive, not very enterprising behavior, with the aim of maintaining a calm status quo as far as possible. The acronym FA indicates the previously mentioned fatalistic agent, i.e. that individual who shows little reactive if not indifferent behavior towards the possible dangerous event. This agent profile is intended here as an illustrative way to represent all those other types of agents that have similar behaviors, as seen before. The agent indicated with MA is intended as the civil/municipal administration, which holds the planning, regulatory prerogative of the rules established on land use. It is clear here that we are dealing with an 'agency', that is, a group of agents who contribute to defining the behavior of this collective agent towards the outside. The other collective agent is the paleolandslide, denoted PA, which we dealt with previously, too. In the left part of the figure, the initial (unstable) equilibrium condition is defined in which agents communicate with each other, mainly in terms of information exchange. Assuming that an element of modification of the equilibrium comes from the outside, we have therefore chosen the possible construction of a series of consolidation structures along the extension of the landslide. Indeed, these have long been prescribed in regional programs but have not been implemented, leaving the Biccari situation in its current precarious state. In agent-based modeling, the creation of these support structures represents a modification in the behavior of the paleolandslide agent, which tends to modify the situation and therefore the equilibrium of the system (Wooldridge, 2012). We thus move on to the right part of the figure in which the initial relationships become essentially unidirectional, from the paleolandslide towards the other agents. In particular, SA and FA agents maintain a

close relationship as they are both interested in the best management of the land they own or manage. The fatalistic agent immediately turns to the administrative agent MA with an impulse to relax the constraint rules. The sensitive agent, although certainly reluctant to carry out transformative operations, could probably also tend to solicit the administrative agent in some way - perhaps due to the interaction normally taking place with the fatalistic agent. Based on these requests the administrative agent, in turn in constant (even institutional) correspondence with the paleolandslide agent regarding the changed environmental behavior in progress, can decide or not to relax the constraints. By deciding not to review the constraints, MA can simply notify the agents involved of the permanence of the previous rules. Otherwise, MA can activate a process of reviewing the rules, in particular of the spatial plan, by involving the PA planning agent. At this point the situation finds a new equilibrium - but still unstable, both because it is intrinsically characterized by instability, and because the behaviors generated by the revision of the environmental rules can affect the behavior of the paleolandslide agent and therefore determine further variations in the equilibrium. In fact, it should be underlined that the revision of the plan itself clearly represents per se an action with a possible impact on the environment and therefore a change in the behavior of the paleolandslide agent.

4.2 An experiment with NetLogo software

With the aim of exploring the potential of an agent-based approach in this complicated territorial story, we decided to use a simulation architecture. Given the very preliminary stage of the research, the simulation was done using a simple and very common software with basic generic data. Starting from the previously illustrated scheme (Fig. 3), some basic parameters were set with NetLogo 6.4.0 and more agents were hypothesized, to allow a minimally structured simulation.

Please note that the simulation described in this paper should be considered a first experimental layout rather than a validated planning tool. At this stage, model parameters are based on heuristic assumptions and literature-inspired scenarios, without calibration on real-time or high-resolution datasets. This choice is consistent with our aim of exploring how agent heterogeneity, perceptions of risk, and institutional reactions might interact in shaping long-term planning decisions under uncertainty.

A new agent list follows, rewritten to show profile behaviours, actions and relations:

- SA = Sensible Agent: (i) exhibits strong concern for unforeseen events; (ii) develops defensive behaviors in response to perceived risk; (iii) aims to maintain a calm status quo; (iv) engages in competitive or cooperative relationships with FA; (v) formulates requests to MA; (vi) activates EEA and/or BA, consistent with its risk-averse behavior; (vii) can own or manage land parcels; (viii) is satisfied when its requests achieve objectives.
- FA = Fatalist Agent: (i) shows low concern for unforeseen events; (ii) exhibits a reactive or indifferent behavior towards potential hazards; (iii) considers risk as inherent in spatial transformations; (iv) engages in competitive or cooperative relationships with SA; (v) formulates requests to MA; (vi) activates EEA and/or BA, consistent with its fatalistic behavior; (vii) can own or manage land parcels; (viii) is satisfied when its requests achieve objectives.
- MA = Municipal Administration: (i) is legally responsible for issuing a long-term local land use plan; (ii) is willing to promote regional socio-economic development through transformations; (iii) makes decisions on land use rules; (iv) makes decisions on planning, programs, and strategies for sustainable development; (v) makes decisions on physical interventions for territorial safety; (vi) decides on the application and removal of land use restrictions and permits; (vii) assigns tasks to agent P; (viii) receives feedback from agent P; (ix) receives requests from FA and SA agents; (x) receives safety feedback from agent PA; (xi) is satisfied when it legally issues an effective and safe long-term local land use plan.

- P = Planning Agent: (i) develops draft land use plans; (ii) drafts programs and rules on land use; (iii) receives requests from MA to design and/or modify plans, programs, and rules on land use; (iv) gathers knowledge and information from agents.
- PA = Paleo-landslide Agent: (i) moves slowly downwards, varying speed depending on uncertain causes and land transformations; (ii) creates territorial risk conditions; (iii) alerts agents; (iv) receives MA's decisions on land use and sustainable development; (v) its movements are sensitive to land transformations.
- BA = Building Agent: (i) carries out substantial land transformations for building development; (ii) is activated by FA or SA.
- EEA = Environmental Entrepreneurial Agent: (i) carries out minimal land transformations for environmental tourism; (ii) is activated by FA or SA.

Using NetLogo 6.4.0, the compiled code for the simulation consists of about 200 commands in 300 command strings, which are omitted here due to obvious space limitations. However, a synthetic architecture of the code can be extracted for a general clarification of the process (Tab.1).

Simulation Phase	Code Step	Key Agents Involved	Primary Actions
Initialization	`setup procedure`	PA, MA, SA, FA	- Landscape grid initialization - Agent placement - Parameter setting
Annual Cycle	`go procedure`	All agents	- Agent interaction calculations - Landslide behavior update - Satisfaction metrics recalculation
Policy Decision	`decide-pug-revision`	MA, P	- Plan revision triggers - Restriction relaxation checks - PUG draft evaluation
Project Implementation	`execute-projects`	BA, EEA	- Development project execution - Eco-tourism infrastructure build - Consolidation works
Satisfaction Update	`update-satisfaction`	SA, FA, MA	- SA: Risk perception algorithm - FA: Development gain calculus - MA: Plan effectiveness evaluation
Monitoring	`update-metrics`	PA, MA	- Velocity measurements - Stability index calculation - Risk level assessment

Tab. 1 NetLogo Simulation Architecture

In general the model develops as follows. It is a territory affected by an ancient landslide classified as PG3 (high geomorphological hazard) in the Hydrogeological Structure Plan, exhibiting diffuse cracks and fragility despite limited previous consolidation efforts. Initial hypothesized simulation conditions included a baseline landslide velocity of 20 mm/year, moderate stability levels, pre-existing urban planning (Biccari PUG) restrictions, and an environmental impact baseline of 30%. The simulations were initialized with parameters designed to reflect a plausible yet simplified condition of the Biccari landslide system. The baseline landslide velocity was set at 20 mm/year, consistent with the lower bound of the "very slow" category in the Cruden and Varnes (1996) classification for landslide movement. The initial stability level of the slope was randomized within a 40–60% range, reflecting partial consolidation measures previously undertaken, without achieving full territorial security. The initial environmental impact was fixed at 30%, qualitatively suggesting moderate anthropogenic pressure and limited development activity at the start of the simulation. The initial

risk level—not directly assigned, but dynamically computed within the model—emerged between 60% and 66% in the first simulation year. This risk index is calculated via the following expression:

$$\text{Risk Level} = \min\left(100,\ 50 + \left(\frac{\text{velocity}}{\text{baseline}}\right) \times 25 - \frac{\text{stability}}{4}\right) \quad (1)$$

This formula is not derived from existing risk assessment literature but serves to generate a normalized (0–100%) risk estimate that qualitatively reflects the interplay between the dynamic behavior of the landslide and the perceived slope stability. The use of this index is not intended as a substitute of formal hazard-vulnerability-exposure models (e.g., R = H × V × E) (Burton et al., 1993). Rather, it just aims to enable a simulative exploration about system evolution and policy decision-making in a multi-agent framework.
Two simulation hypotheses were tested, differing in agent populations: Hypothesis 1 used a minimal configuration (3 SA, 3 FA), while Hypothesis 2 adopted a denser configuration (10 SA, 10 FA), to evaluate system response under different sociopolitical pressures (Tab.2).

Parameter	Hypothesis 1	Hypothesis 2
Number of Sensible Agents (SA)	3	10
Number of Fatalist Agents (FA)	3	10
Simulation Duration	20 years	20 years
Initial Landslide Velocity	20 mm/year	20 mm/year
Initial PUG Status	Initial (baseline)	Initial (baseline)
Initial Environmental Impact	30%	30%
Initial Risk Level	60–66%	60–66%
Initial Stability Level	~50%	~50%
Decision Style	Development-prone (reactive)	Safety-first (preventive)

Tab.2 Simulation Setup: Hypotheses 1 vs 2

In the first approach (development-oriented), the Municipal Administration implemented initial consolidation works while simultaneously relaxing development restrictions. This led to rapid economic development (22 projects) but caused temporary destabilization of the paleolandslide, necessitating reactive measures when landslide velocity increased from 12 mm/year to 31 mm/year and risk levels escalated to 77.5%. The situation required restriction reinstatement followed by additional consolidation works before reaching stability. While ultimately achieving 100% landslide stability and high stakeholder satisfaction, this approach resulted in significant environmental impact (56%) and required 17 years to reach equilibrium.
The second approach (safety-first) prioritized comprehensive consolidation works (5 interventions) before permitting development. This strategy progressively reduced landslide velocity from 19 mm/year to zero while improving stability from 52.5% to 100%. Only after achieving substantial stabilization were restrictions relaxed, leading to minimal development (2 projects) but rapid attainment of equilibrium (by year 12) with minimal environmental impact (32%). All stakeholder groups achieved high satisfaction levels (SA: 73%, FA: 74%, MA: 100%). It should be noted that while hypothesis 2 increases the number of agents, their binary classification (SA/FA) reflects intentional simplification to isolate the impact of community pressure on governance decisions, not to replicate real-world behavioral diversity.
In the end, the simulation highlights some key findings relevant to landslide risk governance. First, the timing of interventions has significantly impacted both risk levels and stakeholder satisfaction, with early consolidation works providing more sustainable outcomes than reactive approaches. Second, development pressures and risk management could be balanced through adaptive governance that responded to monitored environmental conditions. Additionally, stakeholder satisfaction did not necessarily require

extensive development if safety and stability are adequately addressed first - suggesting that risk-sensitive planning can achieve social acceptance. Finally, multi-agent systems could somehow effectively model the complex feedback loops between physical processes (landslide behavior), governance decisions (PUG restrictions and consolidation works), and stakeholder responses.

These simulation outcomes seem to confirm that governance processes in landslide-prone territories should prioritize stability-establishment before development authorization. The simulation suggests that with limited development activity (only 2 projects versus 22), stakeholder satisfaction can reach comparable levels when safety concerns are comprehensively addressed. This challenges conventional assumptions about necessary trade-offs between risk reduction and economic development, exhibiting interesting perspectives of decision and policymaking.

In this initial stage we have limited the reasoning to a list of possible agents active in the context and to an exemplary diagram of a possible process. We will subsequently explore the levels, quantity and quality of mutual relationships and decisions induced by the dynamics that may occur. In this area, a large line of research has long been developed on aggregate approaches to the modeling of collective decisions which can be a useful reference (Scott, 2018; Santoro et al., 2024; Salvati et al., 2013). On the other hand, the markedly qualitative and emotion/belief-based aspect of decision-making problems may suggest a more structured and disaggregated approach, inspired by intelligent agent-based models derived from computer science (Wooldridge, 2002). This could allow the creation of dynamic support architectures for risk governance models, which prefigure scenarios of dynamic management of urban/anthropic spaces - at least in some environments with slow instability and low community perceptions. Our study group has been engaged in these research topics for a significant time, with research on possible hybrid models of support for cognitive interaction and decision-making in collective environments of complex knowledge (Borri et al., 2018; Stufano Melone et al., 2019). When asked about these perspectives, the administrative managers of the regional control body showed interest, while complaining about a general inadequacy of the current administrative and territorial management laws towards organizational innovations of this type.

4.3 Model limitations and methodological considerations

Despite the valuable insights provided by our NetLogo simulation, it is necessary to acknowledge some important limitations, both related to the model and its technical implementation.

First, the model parameters are based on heuristic assumptions and not systematic empirical calibration. Initial landslide velocity, stability levels, and risk formulas are approximations drawn from general literature rather than Biccari-specific data, reflecting the exploratory nature of the study and the difficulty of acquiring high-resolution data in small-municipal contexts.

Furthermore, the binary classification of agents as "sensitive" and "fatalistic" is a useful simplification for isolating key dynamics but certainly not exhaustive. Indeed, it captures the complexity and actual gradation of risk perceptions and behaviors, nor their temporal evolution.

From the perspective of environmental system modeling, there is a further limitation. The paleolandslide agent is represented with simplified algorithms that abstract from complex geomorphological processes. The velocity-stability relationships used here are essentially functional and cannot represent detailed physical simulations of complex slope dynamics.

Finally, there are limitations inherent in the NetLogo platform itself. While often considered well-suited for exploratory models (e.g., Murphy, 2025), the platform imposes constraints on computational complexity and performance. The discrete, grid-based model may not capture the continuous dynamics and fine spatial differentiations present in complex spatial environments.

These limitations suggest areas for improvement in future work, including integration with geological monitoring systems, more sophisticated behavioral algorithms, and hybrid ontology-based approaches that combine agent-based modeling with detailed physical models.

5. Discussion, conclusions and follow up

A sense of fatalism emerges which seems to influence the perception of phenomena and the interpretation of future events. Fatalism is present in many cases worldwide, for example in cities exposed to tsunamis, or high seismicity, or close to volcanic activity.

The notion of fatalism is generally understood as an attitude of resignation toward future events regarded as inevitable (Rice, 2024). In philosophical discourse, however, the term typically denotes the thesis that human agents lack the power to act otherwise than they in fact do. The classical formulation of the fatalist problem can be found in Aristotle's Περὶ ἑρμηνείας (On Interpretation), written between 384 and 322 B.C.E., where he examines whether, for any given proposition, it must be the case that either its affirmation or its negation is true (Rice, 2024). Within the framework of Aristotelian logical fatalism, if every statement concerning the future already possesses a determinate truth value – either true or false – then it follows that the course of events could not occur differently and thus lies beyond our control. Nevertheless, the philosophical validity of fatalism remains an unresolved and debated issue (Rice, 2024).

Our group aims to study the possibility of integrating the sensor networks typically present in these places with complex sensory models built on the perception of the inhabitants, on surveys and the intuition of multidisciplinary experts and more. Furthermore, in the case of Biccari, the possibility of refining the research on the phenomenon of fatalism is explored, with the aim of drawing indications for the construction of support models for predictions and decisions. The essence of places can often be found in the quality of having been to a specific place. Our knowledge of places can come from experiences, from the stories that structure ideas, from feelings about them. There is therefore a 'subjective knowledge' of places, which adds up in a consonance of intentions and experiences in a rich, collective knowledge of the chorus of individuals who form it, which becomes memory and perspective. But often intentionalities, which even start from a knowledge of places generally common to the same group of agents, are crowded with unclear projects, or which do not look at the consonance of collective intentions, or which in any case ignore the consequences of certain more systemic choices. or needs – contemporary to taking a certain action. 'Subjective knowledge' is a sort of representation of places and a representation varies from subject to subject and also in the life of an agent, anthropic or not. And so, from the world of research in the field of territorial planning disciplines, a different way of interpreting and reading the territory is proposed in the real and factual world. The idea is that this can guarantee a management and planning of the territory that is finally advanced compared to what has been used in planning practice in recent decades, for the identification of an invisible but already true future and resilience in the seeds scattered in the present.

Fatalism is not merely a "feeling" or attitude of resignation, as the more popular sense might imply; rather, in its older semantic and conceptual layers, it refers to a logical-metaphysical structure touching upon freedom, the capacity for action, and the truth of future-tense propositions and a long chain of debate in philosophy didn't solve its problem yet. In the field of environmental and territorial planning, a comparable epistemic or symbolic structure may underline certain forms of reasoning and behaviour, extending far beyond a merely passive or indifferent attitude.

If what is to happen is in some sense already true or necessary, then processes such as knowledge gathering, modelling, and participatory action acquire a different dimension: since we do not know what is true in what must occur, an attitude oriented toward protection, preparedness, and the principle of minimal harm becomes the most strategic course of action – at least in view of an awareness of what is feasible, even within a framework of a priori ignorance concerning what may or may not happen.

Another instance of ignorance that may give rise to broadly fatalistic attitudes concerns what we do not know yet already exists in our contemporary world – either as a cause in potentiality or as an effect that has already triggered, or will trigger, a chain of events leading to previously unforeseen but already latent consequences (Gumbrecht, 2014; Stufano Melone & Camarda, 2022).

Accordingly, the collection, management, and representation of knowledge should serve as instruments of action and decision that are as effective as possible in preventing what can be foreseen as likely. The knowledge entering the planning process must also include that which emerges from participatory processes, in order to identify and possibly mitigate any 'fatalistic' attitude. This is essential to avoid deliberately entering situations of poorly perceived hazard and risk, and to ensure adequate self-protection and collective resilience.

This contribution must be understood as a preliminary and exploratory step within a broader research trajectory. The model and simulation presented do not aim to offer definitive results, but rather to outline a conceptual framework for managing risk and non-knowledge in planning contexts affected by environmental fragility and socio-cultural fatalism. This exploratory work highlights how dynamic agent-based modelling, despite its current simplifications, offers a flexible alternative to static planning frameworks that often fail to capture complex interactions between environmental risks and community behaviors. Future implementations could introduce gradient risk perception (e.g., moderately cautious agents) or external institutional actors (e.g., regional agencies) to enhance realism. Also, future developments will focus on the empirical calibration of the simulation, the integration of sensor-based and participatory data, and the validation of the model through comparative and historical case analyses. The goal is to progressively refine this approach into a flexible and adaptive decision-support tool, capable of navigating uncertainty without resorting to deterministic or overly rigid planning paradigms.

As a whole, we think that an ontological approach will be useful to model and structure the knowledge collected, even in real time, by these complex and hybrid sensor networks (Borgo et al., 2021). Due to the ability to structure knowledge through the formalization of conceptual relationships, we think that applied ontologies should be particularly suitable for managing complex and dynamic knowledge – and non-knowledge as well. Therefore, our future work will be just oriented to explore such modelling perspectives.

Author's contribution

Conceptualization, methodology, data collection, data curation and analysis: M.R.S.M. and D.C.. Writing: sect.4.1. 4.2 and 4.3: D.C; all other sections: M.R.S.M.. The authors are grateful to Dino Borri for early modelling ideas, particularly for his intriguing suggestions about fatalism issues in planning. All authors have read and agreed to the published version of the manuscript.

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Urban physical characteristics for sense of security

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Abstract
This research delves into the symbiotic nexus between the morphology of the urban fabric and the phenomenology of security. Situated in Shiraz, Iran, this inquiry interrogates the determinative role of four morphological attributes; green spaces, land use, illumination, and network connectivity, juxtaposed against socio-economic traits. Through a dialectical comparison of two ontologically distinct urban enclaves, we employ structural equation modelling to forge and empirically ground the Physical Attributes Affecting Sense of Security Model (PAASSM). The analysis reveals that the city's corporeal fabric, principally its land use and green commons, are primary architects of the citizen's sense of sanctuary, with socio-economic variables exerting a subordinate yet non-trivial influence. The superior security manifest in the city's modern, planned district stands as a testament to the virtues of deliberate spatial ordering. Ultimately, this study bequeaths a novel epistemological framework, articulating a new mandate for urban praxis: to recognize the deliberate sculpting of the built form as a primary instrument for cultivating a safer, more resilient, and socially cohesive *polis*.

Keywords
Physical characteristics; Built environment; Sense of security; Structural equation modeling; Shiraz

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1. Introduction

Urbanization has rapidly transformed cities into global centers of economic, social, and cultural activity (Zhong et al., 2023). Today, nearly half of the world's population resides in urban areas (Ahmed Majid & faraydoon Ali, 2024). However, this expansion has not always been strategically planned. Uncontrolled and rapid urban growth has resulted in urban sprawl, infrastructural deficits (Soltani, Azizi, et al., 2025), spatial inequality, and the decline of traditional urban cores, creating complex spatial and social challenges (Talkhabi et al., 2022). These dynamics intensify environmental and social vulnerabilities (Soltani, Jaber, et al., 2025) by generating uneven spatial structures, degrading public spaces, and creating pockets of neglect that are susceptible to crime and insecurity. For example, poorly planned peripheral developments often suffer from insufficient public services, increased exposure to natural hazards such as floods, and reduced environmental quality (Khaliji & Jafarpour Ghalehteimouri, 2024). In Tehran, spatial and temporal population shifts have contributed to urban decline and fragmented urban fabrics (Talkhabi et al., 2022), while in Kuala Lumpur, changes in water patterns have heightened flood risks (Khaliji & Jafarpour Ghalehteimouri, 2024). These negative outcomes illustrate how unplanned urbanization can exacerbate both environmental and human security risks.

Urban security is an essential dimension of sustainable development. Ensuring the safety and security of individuals in cities is fundamental to well-being and community stability (Park & Garcia, 2020; Fakhrahmad et al., 2022). Importantly, security in this context refers to protection from intentional harms such as crime and antisocial behavior, whereas safety relates more to protection from unintentional hazards (Soltani, Qadikolaei, et al., 2025), such as traffic incidents or environmental dangers. A strong sense of security supports residents' mobility (D'Amico, 2023), mental health, and social cohesion (Huang & Lin, 2023). When people feel secure, they are more likely to use public spaces and transport, participate in community activities (Carpentieri et al., 2023), and contribute to urban vitality (Bollenbach et al., 2023). Conversely, insecurity can discourage outdoor activity, foster isolation, reduce investment, and undermine trust in public institutions (Burt et al., 2022; Konkel et al., 2019). The perception of insecurity, even when crime rates are objectively low, can have profound social consequences, highlighting the importance of addressing both objective and subjective dimensions of urban safety.

A substantial body of research highlights the influence of urban physical characteristics on perceived security. Land use patterns are strongly associated with the spatial distribution (Bocca, 2024) of crime: commercial areas, transport nodes, and pawnshops are often correlated with increased property crime risks (Mburu & Helbich, 2016; Yusof & Fauzi, 2019). Street lighting has a significant impact on pedestrians' sense of safety, especially in residential areas, with higher illuminance generally associated with greater perceived security (Liu et al., 2022; Rezakhani et al., 2018). Green spaces, when well-designed and maintained, can increase natural surveillance and deter crime (Maruthaveeran, 2016; Sun et al., 2024; Turkseven Dogrusoy & Zengel, 2017). while road network patterns influence surveillance opportunities, accessibility, and the likelihood of isolation (Dinarta et al., 2025; Ye et al., 2018). These findings align with Crime Prevention Through Environmental Design (CPTED) and environmental criminology theories, which argue that the built environment can shape opportunities for crime and perceptions of safety (Cozens & Davern, 2025).

While the causal relationship between socioeconomic factors and urban form is well established, this study adopts the reverse perspective, focusing on how physical characteristics influence perceptions of security. This approach is grounded in theories emphasizing how urban design can directly shape behavioral patterns (Dehghani et al., 2025), crime opportunities, and subjective security, rather than treating physical form as merely an outcome of socioeconomic structures. Although alternative causal directions such as income and education influencing urban form are plausible, our study positions urban physical factors as key independent variables to examine their direct and indirect effects on perceived security, acknowledging that statistical tools like PLS-SEM test model fit but must be supported by theoretical rationale.

Despite extensive literature, significant research gaps remain. First, most studies are geographically limited to Western or East Asian contexts, with limited investigation of Middle Eastern cities such as Shiraz. Second, few models integrate physical and socioeconomic variables into a single analytical framework. Third, comparative analyses of traditional versus modern urban morphologies within the same city are rare, despite their potential to reveal how different planning logics (Garau et al., 2023) affect perceptions of security. Finally, many studies rely on objective crime statistics rather than subjective perceptions, which often diverge from actual crime rates but strongly influence behavior and mental health. There is also limited use of advanced modeling techniques, such as PLS-SEM, to analyze the interrelations among multiple physical factors and perceived security (Behravesh et al., 2020; Lai & Deal, 2025).

Against this backdrop, the objective of this study is to examine how four key urban physical characteristics green space, land use, street lighting, and road networks influence residents' sense of security in Shiraz, Iran. The research focuses on two contrasting urban districts: District 5, within the historic core, characterized by a compact, organic layout and mixed land uses; and District 10, in the modern expansion area, with wider streets, organized zoning, and larger green spaces. By applying PLS-SEM, this study seeks to clarify the causal pathways linking physical form to perceived security, address the identified research gaps, and offer practical insights for urban planners and policymakers. The analysis contributes to the broader discourse on urban resilience and safety, demonstrating how targeted physical design interventions can strengthen urban security in rapidly transforming cities (Dehghani et al., 2023; Moqadam & Nubani, 2022).

2. Material and method

2.1 Study design

This research adopts a comparative case study design, using multiple techniques including field surveys, spatial analysis, and geospatial data (Gaglione, 2023) to analyze selected variables across two districts with contrasting urban morphologies, in Shiraz, Southern Iran.

2.2 Conducting literature review

The study focused on four keys urban physical attributes (streets lighting, road network, green space, and land use), and two dependents' variables as a personality trait (education and income) selected based on the literature review and relevance to Shiraz's urban structure.

	Variables	**Indicators**
Target	Income	Monthly/annual household income, income bracket, income stability
	Education	Highest educational level attained, degree and careers
Explanatory	Green Spaces	Proximity to parks, vegetation density, quality and maintenance
	Streets Lighting	Distribution of street lights, intensity (lux levels), lighting uniformity
	Land-Use	Diversity of functions (residential, commercial, public), land use ratio
	Roads Network Pattern	Road density, connectivity index, intersection frequency

Tab.1 Variable and Indicators

Additionally, sense of security was operationalized through survey items measuring fear of crime, perceived safety in public spaces, and comfort during daily mobility (Fakhrahmad et al., 2023). To avoid conceptual ambiguity, **"**security**"** (freedom from crime/violence) was distinguished from **"**safety**"** (protection against traffic and environmental hazards). Field observations and GIS mapping were used to supplement questionnaire data

and document morphology, green spaces, and land-use patterns in both districts. The present study considers the factors such as education (E), income (I), district 5 green spaces (DFGS), district 5 land use (DFLU), district 5 streets lighting (DFSL), district 5 roads network (DFRN), district 10 green spaces (DTGS), district 10 land use (DTLU), district 10 streets lighting (DTSL), district 10 roads network (DTRN). Field observations were conducted to understand the actual conditions of the study areas.

2.3 Study area and case selection

The study focuses on District 5 and District 10 of Shiraz. District 5 is located in the historic core, characterized by a compact and organic urban fabric with mixed land uses and narrow alleyways (Panahi et al., 2022). District 10 represents modern urban expansion, featuring wider streets, structured zoning, and planned green spaces. These districts were deliberately selected to capture significant variations in urban form, infrastructure quality, and spatial organization, providing an ideal context for analyzing how built environment factors influence perceptions of safety and security (Hassanshahi et al., 2023). Shiraz is the capital of Fars Province and a major cultural, social, and economic center in southern Iran, with a population exceeding 1.5 million (Bagheri & Soltani, 2023; Javadpoor et al., 2023). The city is situated near the Zagros Mountains at an average elevation of 1,500 m and approximately 800 km south of Tehran (Shiraz Manucipality, 2018). The contrasting physical characteristics between District 5 and District 10, combined with the research team's familiarity with both areas, justified their selection for comparative analysis.

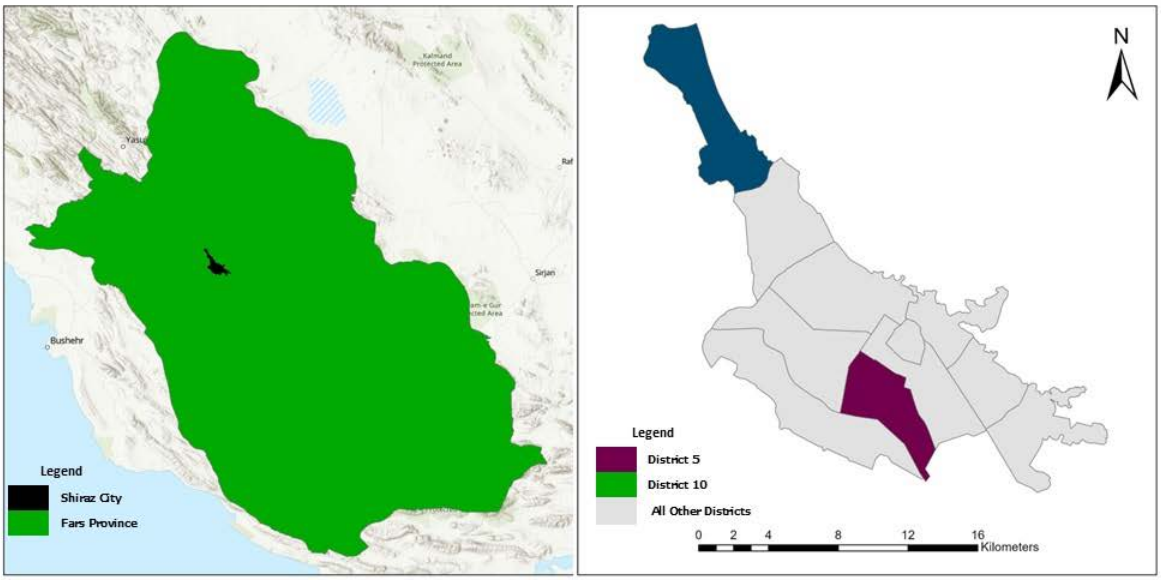

Fig.1 Study areas

2.4 Morphological perspective of study areas that may prone to crime

In (Fig.ss 2 and 3) we can see that the roads network pattern and land use planning had the weakest quality in districts 5 than district10 which causes bicycles riding on the streets especially in district 5 (Roosta et al., 2022). If the roads network settings make all parts relatively similar, more security could be felt on the streets for bike ridings and other functions. The green spaces were not created to make peace and security for residents in both districts especially in district 5. Moreover, district 5 park is an appropriate case study for investigating the sense of security due to its vast area, hidden places, and lack of proper oversight. Besides, lack of inappropriate lighting at the entrance of the parks and lack of attention to urban furniture in the district 5 caused insecure dramatically than district 10.

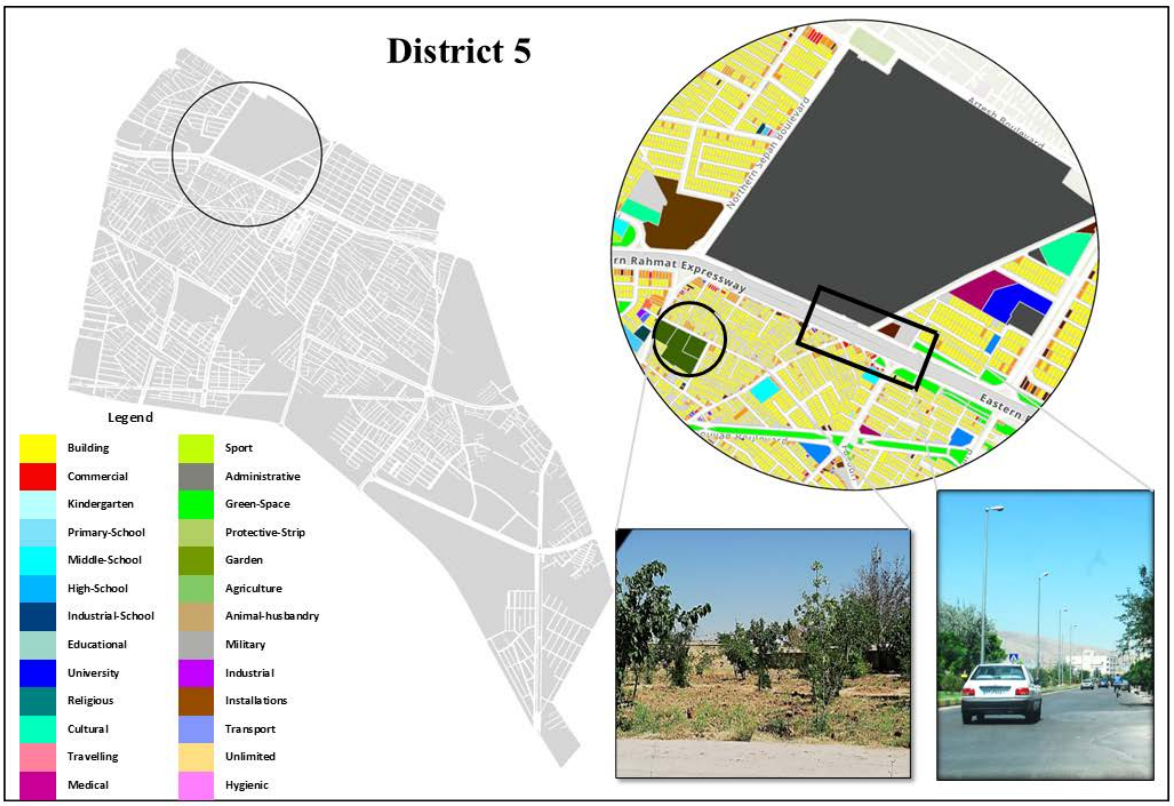

Fig.2 District 5 Land-Use

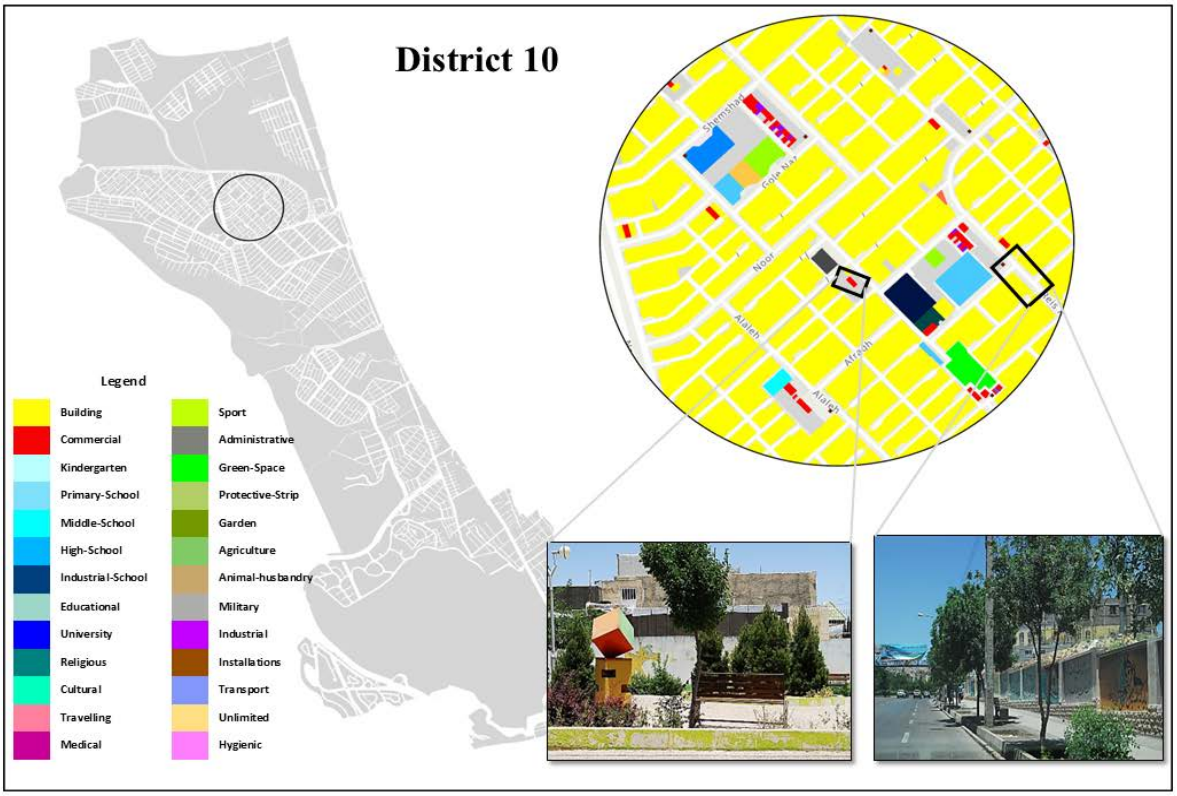

Fig.3 District 10 Land-Use

2.5 Data collection and sampling

Data were collected in 2017 as part of the author's Master's thesis at Shiraz University. A total of 384 valid questionnaires were administered through face-to-face surveys. Based on Cochran's formula, this sample size

was sufficient for the combined population of 281,341 residents in the two districts. Proportionate stratified sampling ensured representation relative to each district's population: 254 questionnaires in District 5 and 130 in District 10. The questionnaire employed a five-point Likert scale (1 = strongly disagree, 5 = strongly agree) and included visual and multiple-choice items. Reliability was assessed using Cronbach's alpha, yielding a coefficient of 0.80, indicating strong internal consistency.

2.6 Analytical strategy and justification for PLS-SEM

The analysis employed Partial Least Squares Structural Equation Modeling (PLS-SEM) using SmartPLS version 4 (Ringle et al., 2015). The selection of PLS-SEM over Covariance-Based SEM (CB-SEM) was theoretically and practically justified as follows:

- Sample size: PLS-SEM is well-suited for moderate samples with complex models;
- Data characteristics: Several indicators exhibited non-normality, for which PLS-SEM's distribution-free estimation is appropriate;
- Model specification: The study involves both formative and reflective constructs, which PLS-SEM handles effectively;
- Research purpose: The exploratory nature of the research aligns with PLS-SEM's strengths in assessing complex relationships rather than testing a well-established theory.

2.7 Model estimation and validation

A two-stage procedure was followed:

- Measurement model evaluation: Indicator loadings (> 0.70), Cronbach's alpha and composite reliability (> 0.70), and AVE (> 0.50) were examined. Discriminant validity was assessed using the Fornell-Larcker criterion and HTMT ratio;
- Structural model evaluation: Path coefficients, R^2 values, and f^2 effect sizes were assessed. The significance of paths was tested using bootstrapping with 5,000 resamples.

3. Results

In this study, two categories of variables were examined: (1) variables that varied based on respondent characteristics, such as physical attributes, and (2) variables related to the sense of security, which were assessed on a scale ranging from low to high. Smart-PLS software tool was employed to explore the relationships between the identified variables. Test statistics were calculated based on the extracted questionnaire data.

3.1 Descriptive analysis

Fig.4 presents the distribution of perceived sense of security among citizens in Districts 5 and 10 of Shiraz. In response to the question, "How would you rate the quality of your sense of security?", the results indicate a notable difference between the two districts. In District 10, approximately 5% of respondents reported a "very low" sense of security, compared to around 40% in District 5. Conversely, 46% of respondents in District 10 rated their sense of security as "high," whereas only about 7% in District 5 reported the same. These findings suggest that District 10 experiences relatively lower levels of crime and that residents there feel significantly more secure than those in District 5.

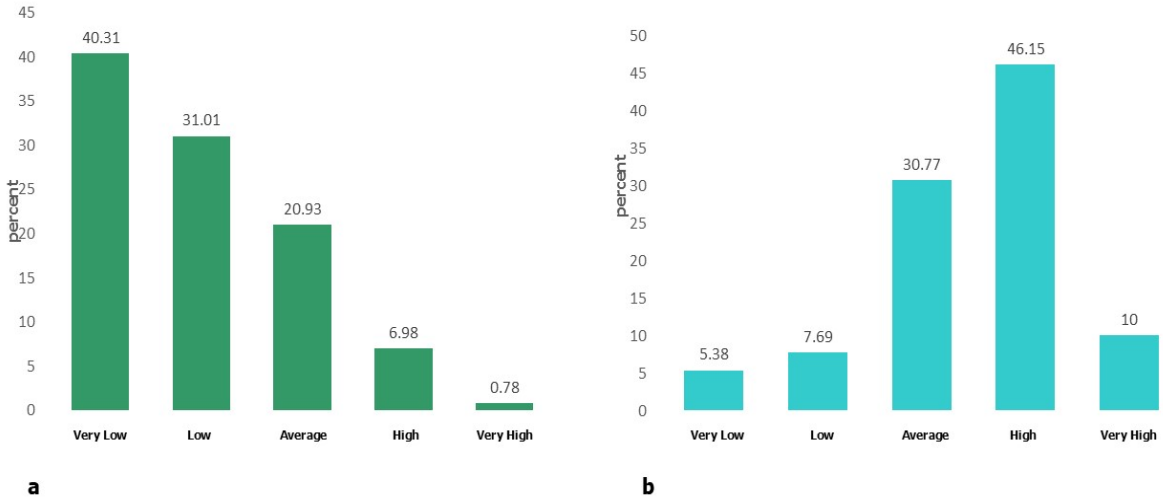

Fig.4 (a) frequency of Sense of security in district 5 and (b) frequency of Sense of security in district 10

3.2 Measurement model evaluation

To evaluate the proposed model, Structural Equation Modeling (SEM) was conducted using Smart-PLS 4.0 software. Two key aspects of the measurement model were assessed: validity and reliability. The structural framework of the model was analyzed in relation to the study variables, and its successful performance across these evaluations confirmed the suitability of the selected constructs and their associated indicators.

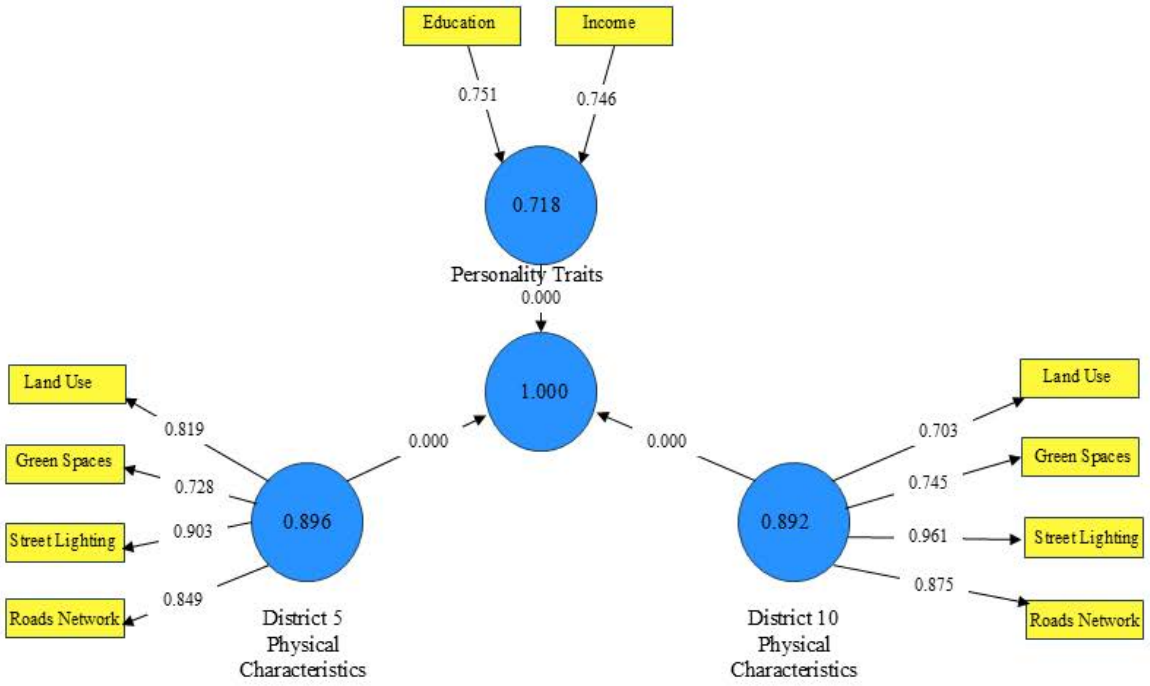

Fig.5 Smart-PLS Algorithm Value of the Measurement Model "PAASSM"

The subsequent sections present the outcomes of convergent validity and discriminant validity tests (Ringle et al., 2015). The structural relationships between the variables are also discussed. From this point onward, the analysis of the adjusted model begins, following the steps outlined (Zhao et al., 2020). The evaluation proceeded in three phases: first, the Empirical Illustration Model was assessed; second, after necessary modifications, convergent validity was re-evaluated; and third, the model's discriminant validity was analyzed. Fig.5 illustrates the Smart-PLS algorithm results for the measurement model. Data were collected via a

structured questionnaire from citizens in Districts 5 and 10 of Shiraz. All constructs were measured using validated scales, and the psychometric properties of these scales were evaluated according to the methodology described (Leroi-Werelds et al., 2014).

The empirical model developed in this study is designed for application in specific urban contexts, offering deeper insight into the perception of security among distinct communities. It can be adapted for use in other settings to examine how physical characteristics influence individuals perceived security (Sedaghatfard et al., 2018). Through iterative refinements, the empirical model enhances and extends general theoretical frameworks. This proposed model, titled the "Physical Attributes Affecting Sense of Security Model" (PAASSM), integrates multidisciplinary knowledge to address the complex factors influencing public perceptions and user acceptance of urban design strategies in future cities.

As regard to verification of latent constructs' convergence validity Cronbach Alpha, AVE (Average Variance Extracted), CR (Construct Reliability), and factor loadings were examined. Moreover, in each latent variable: Cronbach Alpha>0.7, AVE >0.5, CR >0.7; and in the case of each indicator: factor loadings >0.7, thus the existence of all of the latent variables can be justified.

Convergent Validity was examined through factor loadings, Cronbach's alpha, Average Variance Extracted (AVE), and Composite Reliability (CR) (Ringle et al., 2015). Hence, Tab.2, shows the factor loading of the corresponding measures of each construct. These vary from 0.7 to 0.9 The load value of each item on the corresponding construct is well above the recommended value of 0.7 (Fornell & Larcker, 1981) indicating the proper and desirable load factor of each item on its related construct. Measures with the value of < 0.5 can be omitted. The former table shows the result of the three indicators of convergent validity, Cronbach's Alpha was applied to assess the reliability of the variables reflecting the internal consistency of index of variables with 0.718 for Personality Traits, 0.896 for district 5 Physical Attributes, and 0.892 for district 10 Physical Attributes demonstrates that the AVE and CR values are adequate, this result indicated that the internal consistency of model variables is enough and the investigation result has a good reliability so that further data analysis is acceptable, so the findings of the measurement model accounted for the proposed conceptual framework of the research.

Construct	Factor	Load Factor	Cronbach's alpha	AVE	CR
Personality Traits	Education	0.751	0.718	0.560	0.728
	Income	0.746			
District 5 Physical Attributes	Green Spaces	0.728	0.896	0.684	0.898
	Land Use	0.819			
	Streets Lighting	0.903			
	Roads Network	0.849			
District 10 Physical Attributes	Green Spaces	0.745	0.892	0.685	0.895
	Land Use	0.703			
	Streets Lighting	0.961			
	Roads Network	0.875			

Note: average variance extracted (AVE), composite reliability (CR)

Tab.2 Results of the three criteria of Cronbach's alpha, AVE and CR

The highest correlation was observed with its structure compared to other structures. When multiple indicators are used to measure each variable, the researcher should not only reassure the individual scale, but also consider the convergent validity of the constructs. The load-factor was used to check this issue. The hierarchical correlation coefficient was calculated with all other structures of the model, which values should be more than the other structures for the selected construct. The results showed that convergent validity was also confirmed. The high level of the district 10 physical attributes AVE with 0.685 indicates that this variable has a higher relationship with the sense of security as well as these variables (green spaces, land use, streets

lighting, and roads network) next variable which is the most important of the three categories, as the district 5 physical attributes AVE with 0.684. the main respondents include composed of urban spaces users, people, and district's citizens.

Discriminant validity was tested using Fornell-Larcker (FL) criteria and HTMT ratios. To test this, Fornell Larcker (FL) criterion and cross-loadings were used. The first FL criterion (Fornell & Larcker, 1981) assumes that a latent variable (LV) shares more variance with its assigned measures than with any other LVs. The FL criterion was assessed through comparison of the constructs' correlation coefficients. The results are shown in table 3. The constructs values, at the far right of each row, are more than the correlation between them, which are arranged in the lower rows. Therefore, it can be concluded that in the proposed model, the constructs interact more with their own indicators than with other constructs. Since the correlation value between all latent variables was < 0.7. The tests were satisfying because they indicate that all latent variables differ sufficiently from each other (Urbach & Ahlemann, 2010). The significance level of each of the stated components can serve as an appropriate guideline for urban planners and managers in creating security in urban spaces.

3.3 Structural model evaluation

The structural model was then evaluated to test hypothesized relationships between variables. Path coefficients, R^2 values, and f^2 effect sizes were assessed. The significance of paths was tested using bootstrapping with 5,000 resamples at a 5% significance level ($p < 0.05$). All structural paths showed statistically significant relationships with sense of security ($p = 0.000$), confirming the robustness of the model. Although in table 3., we can see that all of variable showed significant relationship with sense of security with (0.000) the values prove that it is acceptable to consistently measure the instruments (Munir, 2018). Among the constructs, Personality Traits exhibited the highest impact (0.867), followed by District 10 Physical Attributes (0.827) and District 5 Physical Attributes (0.749) indicate those stronger relationship with sense of security.

Construct	Personality Traits	District 5 Physical Attributes	District 10 Physical Attributes	P Value
Personality Traits	0.867			0.000
District 5 Physical Attributes	0.732	0.749		0.000
District 10 Physical Attributes	0.991	0.936	0.827	0.000

Tab.3 Discriminant validity based on Heterotrait-Monotrait Ratio variables

Construct	E	I	DFGS	DFLU	DFSL	DFRN	DTGS	DTLN	DTSL	DTRN
E	0.560									
I	0.473	0.438								
DFGS	0.790	0.538	0.597							
DFLU	0.868	0.458	0.643	0.734						
DFSL	0.496	0.610	0.628	0.436	0.598					
DFRN	0.774	0.604	0.502	0.601	0.501	0.571				
DTGS	0.574	0.647	0.435	0.576	0.607	0.454	0.628			
DTLU	0.698	0.572	0.530	0.751	0.760	0.721	0.748	0.675		
DTSL	0.704	0.725	0.780	0.711	0.684	0.810	0.810	0.538	0.446	
DTRN	0.789	0.661	0.535	0.703	0.641	0.540	0.758	0.748	0.634	0.775

Tab.4 Discriminant validity based on Fornell-Larcker criteria

Tab.4 depicts that the value of HTMT of the entire construct is less than 0.90 which indicates minimal discriminant validity for the model. This is performed by looking at the HTMT criterion value to confirm that the items across the construct measure different construct in the model. It is identified by looking at the fact

that the confident interval value of HTMT statistic must not comprise the value of 1 for an entire combination of the construct and by assessing the value Discriminant validity based on Fornell-Larcker criteria which could be below that 0.90 (Munir, 2018) consequently Tab.4. Shows the value of which the entire construct is less than 0.90 which indicates minimal discriminant validity for the model.

4. Discussion

The scholarly inquiry into the human experience of urban security has long been a fragmented mosaic, composed of disparate methodologies from site-plan interpretations to direct phenomenological assessments. Our research enters this discourse not merely to add another piece, but to provide a new hermeneutic lens: the PAASSM model. This framework moves beyond mere observation to articulate the syntax through which the physical city; it's very bones and sinews, inscribes itself upon the human psyche. The empirical validation of a profound correlation between the built environment and the felt sense of security across Shiraz's districts is, therefore, more than a finding; it is a philosophical affirmation. It posits that the city is not a neutral stage upon which life unfolds but an active co-author of our existential condition, compelling urban stewards to recognize that the manipulation of steel, stone, and soil is, in essence, an act of psychological and social stewardship.

This study further dismantles the crude determinism that would reduce insecurity to a simple function of socioeconomic status. In resonance with Ratnayake's (2017) work, we find that an impoverished environmental horizon; a palpable sense of spatial disenfranchisement, emerges as a far more potent harbinger of fear. By expanding the conceptual lexicon beyond the utilitarian calculus of "ease of use," our framework integrates more nuanced dimensions of the human-place relationship: the intrinsic sense of sanctuary, the perception of relative advantage, and the deep-seated need for environmental compatibility and reliability. This enrichment is particularly vital, for it is in the concrete, material world of the city that these abstract needs find their most urgent expression.

The analysis reveals that the elemental forces of urban form; the breathing room of green spaces, the vibrant friction of mixed land use, the guiding hand of nocturnal illumination, and the logic of its circulatory networks, are the primary agents shaping the geography of fear and safety in Shiraz. Where previous research often presented a disjointed or overly generalized cartography, our systematic approach offers a more coherent grammar for guiding urban transformation. Within this grammar, land use emerges not as one variable among many, but as the linchpin, the prime mover. This discovery is a stark admonition: that a failure of spatial imagination, manifest as monolithic or poorly conceived land management, is itself a foundational source of civic anxiety, sowing the seeds of insecurity in the very soil of the city.

Furthermore, we find that green spaces operate as sanctuaries for the civic soul, fostering a topophilic bond; a love of place, through the ritual of recurrent use. This is not a mere functional attachment; it is an emotional and psychological anchoring that transforms public land into a personal refuge, thereby transmuting comfort into a lived sense of security. While the instrumental roles of street lighting and road networks are undeniable, their secondary standing in the hierarchy of influence is philosophically telling. The revelation that the road network wielded the least impact is a powerful counter-narrative to technocratic urbanism, suggesting that mere mechanical efficiency or logistical connectivity is insufficient to quell the anxieties of the urban subject. Infrastructure, it seems, provides the syntax of a city, but it is the social and ecological substance that provides its meaning. These insights present a new mandate for urban praxis. The ascendant importance of land use and green spaces must guide a paradigm shift toward development strategies that are not just functional, but are deeply resonant with the human need for sanctuary. To integrate the physical with the social is to pursue the city's highest calling: to create an urban fabric that is not only resilient and inclusive but is, in its very form, a testament to the safety and flourishing of its inhabitants.

5. Conclusion

This research confirms the symbiotic nexus between urban morphology and the phenomenology of security. We find that tangible urban forms; green spaces, land use diversity, lighting, and street networks, are not passive features but active agents that architect a citizen's sense of sanctuary. The research reveals an uneven geography of fear, proving that security is a spatially contingent experience that refutes universalist planning and demands context-specific interventions.

Consequently, this study mandates that urban governance treat the sculpting of the built environment as a primary tool for social well-being, moving beyond crime prevention to cultivate a more inclusive and cohesive polis. To aid this, we introduce the PAASSM model: a novel, adaptable framework for mapping the physical city onto its psychic landscape of security. While grounded in Shiraz, it offers a universal paradigm for cities seeking to harmonize the material world with the human spirit, advancing the global discourse on urban resilience.

We must, however, acknowledge the epistemological boundaries of this research, constrained as it was by a limited demographic and a select number of urban districts. Our reliance on quantitative modalities, while structurally insightful, cannot fully capture the nuanced poetry of lived experience. These constraints situate our findings not as a final truth but as a foundational one, opening an aperture for future scholarship. The path forward thus calls for a broader canvas and a methodological synthesis; one that weds our quantitative framework with the phenomenological depth of qualitative inquiry to achieve a more holistic understanding of urban sanctuary.

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Image sources

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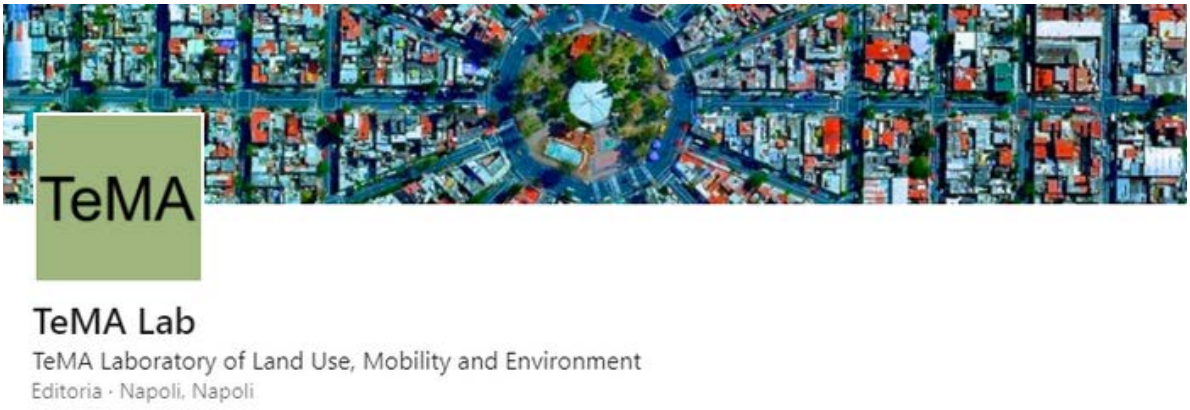

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Developing the charging infrastructure for electric cars. Northwestern Italy facing European targets

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Abstract
This paper analyzes the development of charging infrastructure for electric light-duty vehicles in northwestern Italy in relation to the targets set by EU Regulation 2023/1804. This regulation introduces two types of requirements for Member States: fleet-based targets, related to the number of registered electric and hybrid vehicles, and distance-based targets, which require adequate coverage along the TEN-T road network. Using data from national and European platforms, the study assesses the degree of alignment with these targets at the provincial levels. The results reveal a strong regional variation in infrastructure adequacy: while some provinces exceed the required power output, others - particularly in rural or mountainous areas - remain underpowered. Regarding the distance-based dimension, 71% of the TEN-T core network and 54% of the comprehensive network already meet the 2027 EU targets. The paper applies a Greedy optimization algorithm to propose cost-effective upgrade strategies for existing charging pools, showing that full compliance is achievable with limited interventions. The discussion highlights the critical role of policy incentives and governance, emphasizing the need to empower regional authorities and rebalance funding between vehicle acquisition and infrastructure development. The study concludes by offering policy recommendations to foster equitable and sustainable deployment of electric mobility infrastructure.

Keywords
Charging infrastructure; Electric light-duty vehicles; TEN-T road network

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1. Introduction

As repeatedly stated in the *Review notes* section of this Journal about "International Regulations and Legislation for the Energy Transition" (see, for example, Martinelli, 2024, 2025), electric vehicles (EVs) are increasingly recognized as a key component in the transition toward urban sustainability. By eliminating tailpipe emissions, EVs directly address the pressing need to mitigate climate change and reduce pollution-related health issues in densely populated areas (Aijaz & Ahmad, 2022).

However, their actual sustainability depends on several critical factors (De Vos, 2024; Tilly et al., 2024). For example, the environmental impact of battery production raises concerns about resource extraction and energy-intensive manufacturing processes (Ahmadzadeh et al., 2025). Second, coupling the adoption of EVs with a transition to clean and renewable energy sources is essential to maximize environmental benefits; in regions where electricity is predominantly produced from fossil fuels, the net reduction in emissions achieved by EVs may be less significant (Jansen & Petrova, 2023). In addition, the integration of EVs into existing transport systems needs to be approached with broader, multifaceted urban mobility strategies in mind. Over-reliance on private EVs without complementary investments in public transport and active mobility solutions may not effectively address issues such as traffic congestion and urban sprawl (Hensher, 2021; Orsi, 2021).

Moreover, the adoption of EVs is intricately linked to the availability and accessibility of charging infrastructure. This relationship is often characterized as a "chicken-and-egg" dilemma: is it the development of charging stations that drive EV uptake, or the increase in EV ownership that stimulates the expansion of charging networks? Consumers are reluctant to adopt EV technology without adequate charging infrastructure, and companies are reluctant to invest in such infrastructure without a sufficient numbers of EV in operation. This problem can hinder the diffusion of EVs and prolong the timeframe over which the existing fossil fuel technology system remains locked-in (Brozynski & Leibowicz, 2022).

A robust charging infrastructure alleviates range anxiety (a primary concern for potential EV buyers) by ensuring that drivers have reliable access to charging facilities (Viola, 2021). Empirical studies have demonstrated a positive correlation between the density of charging stations and EV adoption rates. For instance, research conducted in Sweden indicates that municipal expansion of charging infrastructure effectively increases the share of EVs. The study suggests that public charging points in rural municipalities should be strategically placed along high-traffic routes to mitigate range anxiety, while in urban areas, chargers should be placed close to residences to compensate for limited home charging options (Egnér & Trosvik, 2018).

Conversely, the proliferation of EVs can spur the development of charging infrastructure. As the number of EV users increases, so does the demand for accessible charging solutions, prompting the public and private sectors to invest in expanding the charging network.

A study that analyzed data from 95 Chinese cities between 2018 and 2022 found a bidirectional relationship between EV sales and the construction of public charging pools. The research indicates that while the availability of charging stations positively influences EV adoption, the increase in the number of EVs drives the expansion of charging infrastructure, creating a reinforcing cycle that supports the growth of the EV market (Guo et al., 2024).

The article focuses on one side of this two-sided relationship.

It aims to examine the extent to which the targets set by the European Union to its Member States regarding the quantity and spatial distribution of charging stations for duty-light EVs are already met or still far from being met in northwestern Italy. To develop this analysis, the article is structured in the following order.

First, Section 2 presents the policies and the targets set by the European Union. In Section 3, the aim of the article, the selected case study and the methodology adopted for its analysis are described. Sections 4 and 5 are devoted to the overview and discussion of the results.

2. The policy of the European Union for charging infrastructure dedicated to electric light-duty vehicles

In the 2011 White Paper "Roadmap to a Single European Transport Area. Towards a Competitive and Resource Efficient Transport System", the European Commission committed to reducing greenhouse gas emissions from transport by 60% by 2050 (compared to 1990 levels); this target was to be achieved by pursuing a 10% market share target of renewables in transport fuels such as electricity, hydrogen, biofuels, natural gas etc. However, until then the lack of a harmonized Union-wide infrastructure for alternative fuels had hindered the market introduction of vehicles using these alternative fuels. A coordinated policy framework from all Member States proved necessary to provide the long-term security needed for private and public investment to build-up the infrastructure for these vehicles. Therefore, in 2014 the European Union adopted Directive 2014/94/EU specifically to commit each Member State to define a national policy framework for the development of the alternative fuel market in the transport sector and the deployment of related infrastructure. Each State was required to assess the current state and future development of its alternative fuels infrastructure in the transport sector; based on this assessment, the State was supposed to set national targets and objectives for the deployment of the alternative fuels infrastructure, as well as measures to achieve them.

However, Directive 2014/94/EU did not propose a clear common methodology for setting these targets and adopting measures within the national policy frameworks of Member States. This has resulted in large differences in the level of ambition among Member States, and a consequent uneven development of charging and refueling infrastructure across the Union. In addition, meanwhile, the Renewable energy Directive 2023/2413 had raised the market share target for renewable fuels in transport to 29%.

In order to overcome the fragmented level of supply of alternative fuel infrastructure within the Union, and at the same time pursue the higher market share recently set for these fuels, a new Regulation (2023/1804) was adopted in 2023. This Regulation explicitly set mandatory national targets for the implementation of sufficient alternative fuel infrastructure in the Union for road vehicles, trains, ships and stationary aircraft.

In this article, the focus will be on light-duty EVs[1]. In this case, the targets set by the Regulation are twofold: national fleet-based and distance-based. National fleet-based targets should ensure that uptake of light-duty EVs in each Member State is matched by the deployment of sufficient (in terms of total power output[2]) publicly accessible charging infrastructure. Distance-based targets should ensure full coverage of charging pools[3] along the Union's TEN-T (TransEuropean Network - Transport) road network and thus the ability to travel easily and seamless throughout the Union. The goal is to ensure that these pools are deployed proportionally to the uptake of the EVs and that they provide sufficient power output.

Regarding the national fleet-based target, the Regulation requires each Member State to cumulatively provide, through publicly accessible charging pools, at the end of each year starting in 2024, a total power output of

[1] "Light-duty vehicle" means a Category M1 (motor vehicles designed and constructed primarily for the carriage of passengers and their luggage, with not more than eight seating positions in addition to the driver's seating position and without space for standing passengers, regardless of whether the number of seating positions is restricted to the driver's seating position) or a Category N1 (motor vehicles designed and constructed primarily for the carriage of goods, with a maximum mass not exceeding 3,5 tonnes) motor vehicle as described by Regulation (EU) 2018/858. They can be battery electric vehicles or plug-in hybrid vehicles. Battery electric vehicle means an electric vehicle that runs exclusively on the electric motor, with no secondary source of propulsion. Plug-in hybrid vehicle means an electric vehicle with a conventional combustion engine combined with an electric propulsion system which can be recharged from an external electric power source.

[2] "Power output" means the theoretical maximum power, expressed in kW, that a charging point, station or pool can provide to vehicles connected to that charging point, station or pool.

[3] "Charging pool" means one or more charging stations at a specific location. A charging station is a physical installation at a specific location, consisting of one or more charging points. A charging point is defined as a fixed or mobile, on-grid or off-grid interface for the transfer of electricity to an electric vehicle which, although it may have one or more connectors to accommodate different connector types, is capable of charging only one electric vehicle at a time, and which excludes devices with a power output less than or equal to 3,7 kW the primary purpose of which is not the charging of electric vehicles.

at least 1.3 kW for each light-duty battery EV registered in its territory, and a total power output of at least 0.80 kW for each light-duty plug-in hybrid vehicle[4].

Regarding the distance-based target, according to the Regulation Member States must ensure a minimum coverage on the TEN-T road network in their territory through an appropriate spatial distribution of charging pools. The targets are differentiated for the entire TEN-T road network and for its core section[5]. Along the core network (i.e., located on the TEN-T road network or within 3 km driving distance of the nearest exit of a TEN-T road), accessible charging pools must be provided publicly in each direction of travel with a maximum distance of 60 km between them. Each pool has to offer:

- by 31 December 2025, a power output of at least 400 kW, including at least one charging point with an individual power output of at least 150 kW;
- by 31 December 2027, a power output of at least 600 kW, including at least two charging points with an individual power output of at least 150 kW.

Along the TEN-T comprehensive road network, in each direction of travel with a maximum distance of 60 km between them, charging pools have each to provide:

- by 31 December 2027, a power output of at least 300 kW, including at least one charging point with an individual power output of at least 150 kW along at least 50 % of the length of the TEN-T comprehensive road network;
- by 31 December 2030, the same target has to be extended to the whole network;
- by 31 December 2035, a power output of at least 600 kW, including at least two charging points with an individual power output of at least 150 kW.

3. Aim, case study and methodology

3.1 Aim and case study

The article aims to analyze what is the current supply of charging infrastructure for light-duty EVs in the northwestern part of Italy, compared to the targets set by the European Regulation 2023/2413. As mentioned earlier, this Regulation introduced equal targets throughout the European Union, which therefore can be more or less difficult to achieve in the coming years depending on the 2023 starting level.

In this sense, Italy is an interesting case. It is the penultimate State in the European Union in terms of the number of charging points per capita (9.2 per 10,000 inhabitants); only Spain does worse (8.9), while the Netherlands come in at 101, Norway at 55, Belgium, at 64, France at 23, Germany at 18. If the number of charging points is weighted by the fleet of battery EVs, Italy performs better (it is fourth in the EU with 19.25 charging points per 100 battery EVs, after the Netherlands with 33.8, Belgium with 26.3 and Spain with 23.4), but only because it is the last country in terms of the share of battery light-duty EVs in the entire fleet (0.54%) (Motus-E, 2025). In this context, the northwestern regions of Italy (Valle d'Aosta, Piedmont, Liguria and Lombardy) offer a - relatively - rich charging infrastructure. They are home to 35.5% of the total national charging points and 34.2% of the total national light-duty EVs, compared to 25.7% of the total light-duty vehicles registered in Italy and 27% of the total Italian population.

[4] The Regulation specifies that, if the share of light-duty battery electric vehicles compared to the total fleet of light-duty vehicles registered in the territory of a Member State reaches at least 15% and the Member State demonstrates that the implementation of the requirements set out for the total power output can have the adverse effect of discouraging private investments, that Member State may submit to the Commission a reasoned request for authorization to apply lower requirements.

[5] According to the Regulation 1315/2013, the core network consist of those parts of the comprehensive network which are of the highest strategic importance for achieving the objectives for the development of the trans-European transport network. The Regulation identifies both the comprehensive TEN-T and core section.

3.2 Methodology

Fleet-based targets

To verify the fleet-based targets the number of total, battery and hybrid light-duty vehicles in Italy at the national, regional (NUTS-2) and provincial (NUTS-3) levels was first obtained from the database compiled by the Automobil Club d'Italia. The available data were updated to 31/12/2023. Next, data on the total power output of each charging pool were collected from the so-called PUN (Piattaforma Unica Nazionale), the Italian on-line platform (https://www.piattaformaunicanazionale.it) which allows citizens, companies and public administrations to visualize the location, type of access (public, restricted, private) and power output of each pool (even if not all the pools are included[6]). These data were aggregated at the provincial level to calculate the total power output available for electric and hybrid light-duty vehicles in each province in the study area and compare it with the target set by the European Union.

Distance-based targets

Regulation 2023/1804 set distance-based targets to cover the entire TEN-T road network and its core section through appropriate spatial distribution of charging points. Several academic methodologies have been developed to determine the optimal placement of EV charging points along a road network. Micari et al. (2017) adopt a methodology to calculate the necessary number of EV charging points and to determine their location in a road network using demand (the flow of EVs) and supply (the road network where they will be placed). A multi-criteria approach is proposed by Skaloumpakas et al. (2022) to take into account EV range and investment costs, and by Janjić et al. (2023) to also consider walking distances, site safety, parking access, and capacity of the electrical distribution network. Gopalakrishnan et al. (2016) integrate a Canonical Correlation Analysis to predict demand for charging points at candidate sites with a mixed-packing-and-covering optimization framework to model the competing concerns of the service provider and EV users. Lamontagne et al. (2023) use stochastic discrete choice models optimize the placement of charging points based on user attributes and preferences for station characteristics. Torres Franco (2021) proposes a heuristic algorithm for locating charging stations by considering user preferences and constraints. Based on Lam et al. (2014), who compared four solution methods to address the EV charging station placement problem (EVCSPP), we formulated our problem as a minimum upgrade coverage problem on a road network graph with existing nodes (stations) and varying service levels (charging power). To solve it, we adopted a Greedy approximation approach, which provides a near-optimal solution with significantly less computation (Cormen et al., 2014).
First, we checked whether and how far the EU's targets are already met in the case study (as of 31/12/2023), through this sequence of steps:

1. the motorways included in the comprehensive TEN-T road network and its core section were identified from Regulation 1315/2013 maps; their bi-directional routes were geo-referenced from OpenTransportMap and their carriageways were splitted, so to calculate 60 km spacing in each direction;
2. filling petrol stations currently located along (and accessible from) the motorways of the TEN-T were downloaded from OpenStreetMap;
3. the motorway exits of the TEN-T were downloaded from OpenStreetMap, and an isochrone of 3 km driving (network, not Euclidean) distance around each of these exits was drawn using the Plug in HERE route API (Fig.1);
4. public charging pools located at one of the existing filling petrol stations along the TEN-T road network or within one of the isochrones around the network exits were identified from Data Retrieval Platform

[6] https://www.lautomobile.aci.it/attualita/pun-in-arrivo-i-prezzi-e-possibili-agevolazioni-per-la-ricarica-delle-auto-elettriche/

(https://docs.eco-movement.com/guides/data-retrieval-platform/). For each of them, information was collected about the number of public charging points offered and the power output of each charging point; this information provided insight into whether the pool already met the criteria of the Regulation (e.g., as required by December 2025, a power output of at least 400 kW, including at least one charging point with an individual power output of at least 150 kW);

5. segments of the TEN-T road network between two charging pools (located at a filling petrol station along the network or within a 3-km isochrone around a motorway exit) that meet the standards of the Regulation but are more than 60 km apart in each direction of travel were identified, and their total length was measured in order to calculate the percentage of the core and comprehensive network covered by the service.

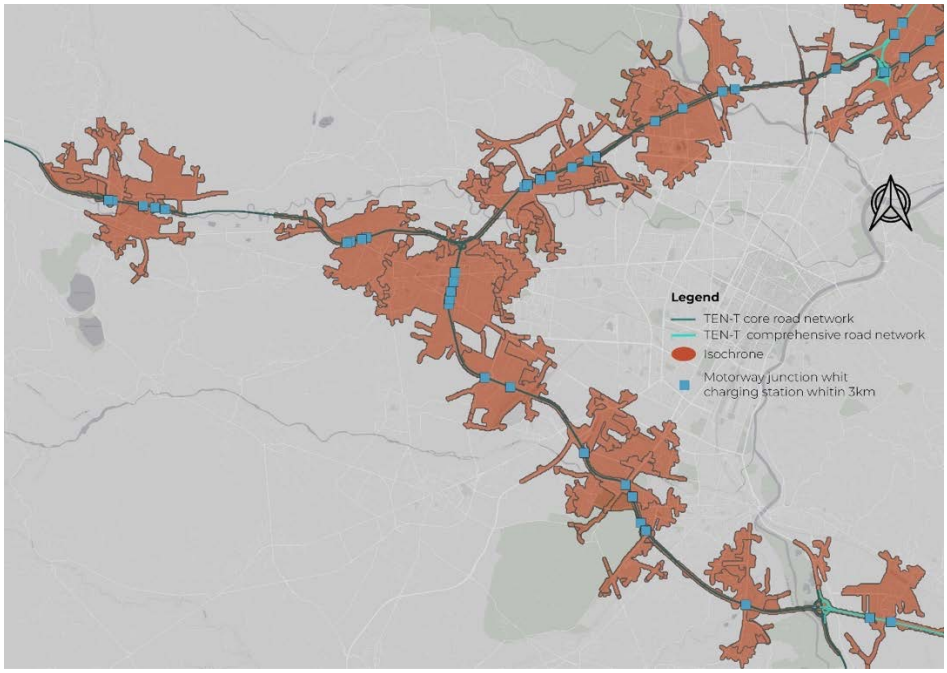

Fig.1 3-km isochrones of the TEN-T motorway exits around the city of Turin

To identify the minimum number of existing charging pools to be upgraded and/or new ones to be placed along the network, the Greedy approximation was applied through this sequence of steps:

1. all unserved segments of the TEN-T road network were identified;
2. for each existing charging pools that does not meet the standards of the Regulation in terms of power output, the number of km of unserved segments it could cover if it were upgraded was calculated;
3. at each filling petrol station and isochrone without a charging pool, the number of km of unserved segments it could cover if it were equipped with a new charging pool was calculated;
4. the existing or new pool covering the greatest number of km of unserved segments was upgraded or installed;
5. this procedure was repeated until all road segments were covered.

In other words, the objective function aims to maximize the additional length of unserved segments covered at each iteration. Formally:

$$\text{choose } p^* = \arg max_{p \in P_{candidates}} \sum_{s \in U} lenghth(s) * 1[p \text{ covers } s] \quad (1)$$

where:

- p = a candidate pool (existing pool to upgrade or new one to install)
- $P_{candidates}$ = set of candidate pools
- U = set of unserved segments

- 1[·] = 1 if true, 0 otherwise
- length(s) = length (km) of segment s

4. Results

4.1 Fleet-based target

At the end of 2023, the light-duty vehicle fleet in Italy consisted of 40,915,229 units. Those battery electric were 219,540, accounting for 0.54% of the total fleet. Those hybrid were 2,211,934, accounting for 5.4% of the fleet. At the regional level, the percentage of electric and hybrid vehicles on the total fleet is much higher: for example, it reaches 23.8% and 18.2% in the Alpine regions of Valle d'Aosta and Trentino Alto Adige; in other regions it is less than 3%, for example in Campania (2.1%) and Molise (2.25%).

Province	Number of electric vehicles	Number of hybrid vehicles	Number of electric and Hybrid vehicles	Total power output delivered (kW)	Total power output required by Reg 2023/1804
Alessandria	1,021	15,411	16,432	30,348	13,656
Aosta	4,343	62,677	67,020	20,062	55,788
Asti	554	6,732	7,286	7,116	6,106
Bergamo	4,840	40,915	45,755	44,946	39,024
Biella	439	7,404	7,843	13,390	6,494
Brescia	6,483	43,061	49,544	50,558	42,877
Como	3,213	31,745	34,958	20,238	29,573
Cremona	1,345	13,382	14,727	10,740	12,454
Cuneo	2,004	22,111	24,115	18,145	20,294
Genova	1,544	29,857	31,401	21,053	25,893
Imperia	377	6,280	6,657	8,207	5,514
La Spezia	555	7,598	8,153	10,273	6,800
Lecco	1,538	14,681	16,219	7,461	13,744
Lodi	742	8,102	8,844	3,763	7,446
Mantova	1,325	12,715	14,040	16,357	11,895
Milano	14,474	164,448	178,922	111,689	150,375
Monza e della Brianza	3,921	42,388	46,309	28,619	39,008
Novara	1,304	15,508	16,812	22,245	14,102
Pavia	1,489	21,475	22,964	14,227	19,116
Savona	536	9,510	10,046	18,570	8,305
Sondrio	675	6,013	6,688	8,412	5,688
Torino	8,332	125,111	133,443	93,340	110,920
Varese	4,260	45,891	50,151	21,321	42,251
Verbano-Cusio-Ossola	431	5,781	6,212	10,780	5,185
Vercelli	497	6,776	7,273	7,007	6,067

Tab.1 Electric and hybrid light-duty vehicle fleet and total power output delivered and required in northwestern Italian provinces

In the regions of northwestern Italy, which are the case study of these paper, the regional percentage is always above 6.5%. If we consider the provinces in these regions, the percentage of electric and hybrid vehicles varies approximately from 5 to 10% (except for Valle d'Aosta, where the regional and provincial boundaries coincide). Relating the total power output delivered in each province to the target set by the

European regulation (1.3 kW per electric vehicle plus 0.8 kW per hybrid vehicle; see Tab.1), the situation is very different, as shown in Fig.2. In the Piedmont provinces of Alessandria and Biella and the Ligurian province of Savona, the current power output is more than double the target. In contrast, in Valle d'Aosta output is a third of the target; in the Lombard provinces of Lodi and Lecco it is close to half.

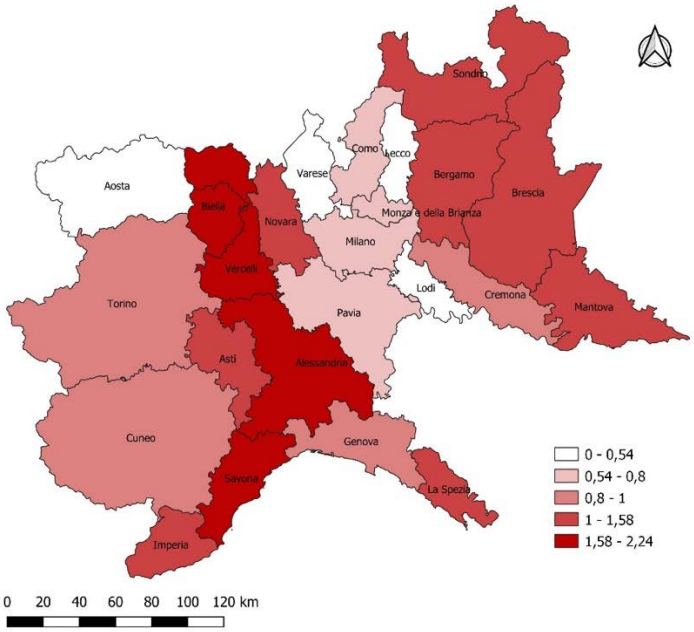

Fig.2 Ratio between total power output currently provided and the target set by the European Regulation

4.2 Distance-based target

The TEN-T road network located within the study area is 2,039 km long in its core section and 1,649 km in the rest of its comprehensive length (Fig.3).

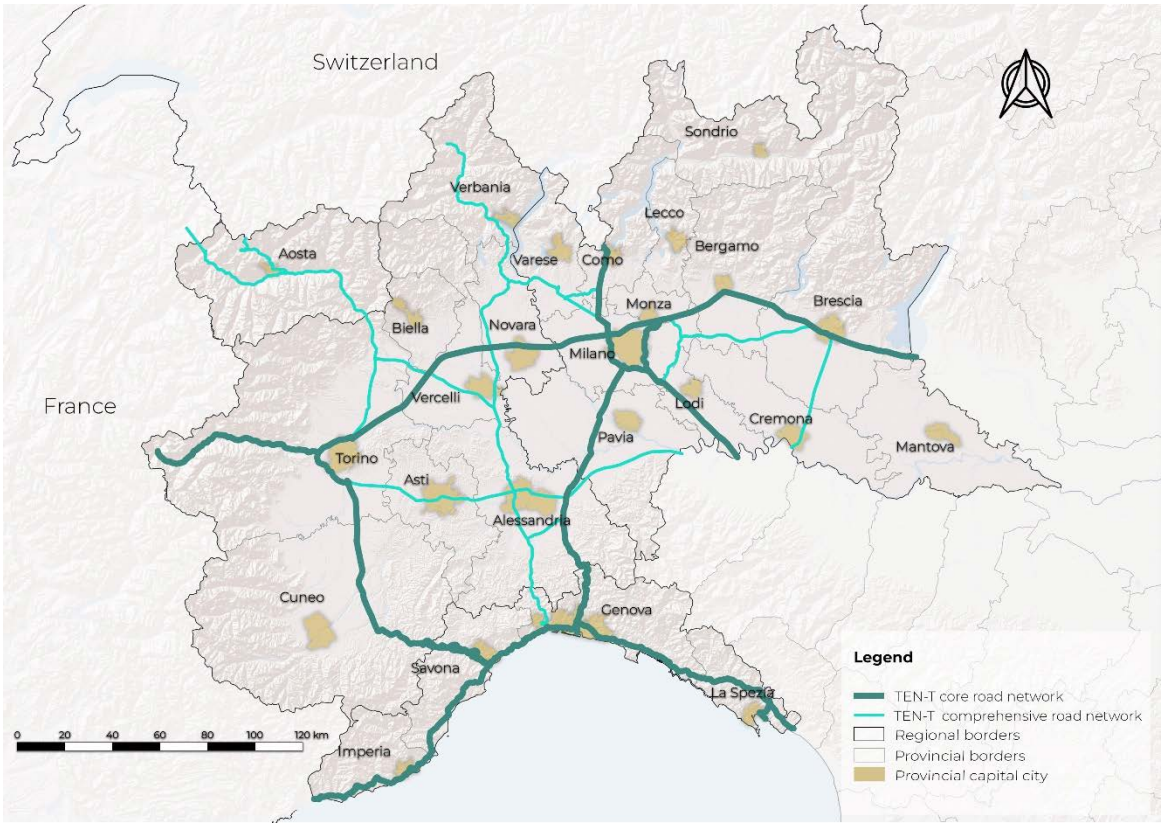

Fig.3 TEN-T core and comprehensive road network. Source: elaboration by the authors

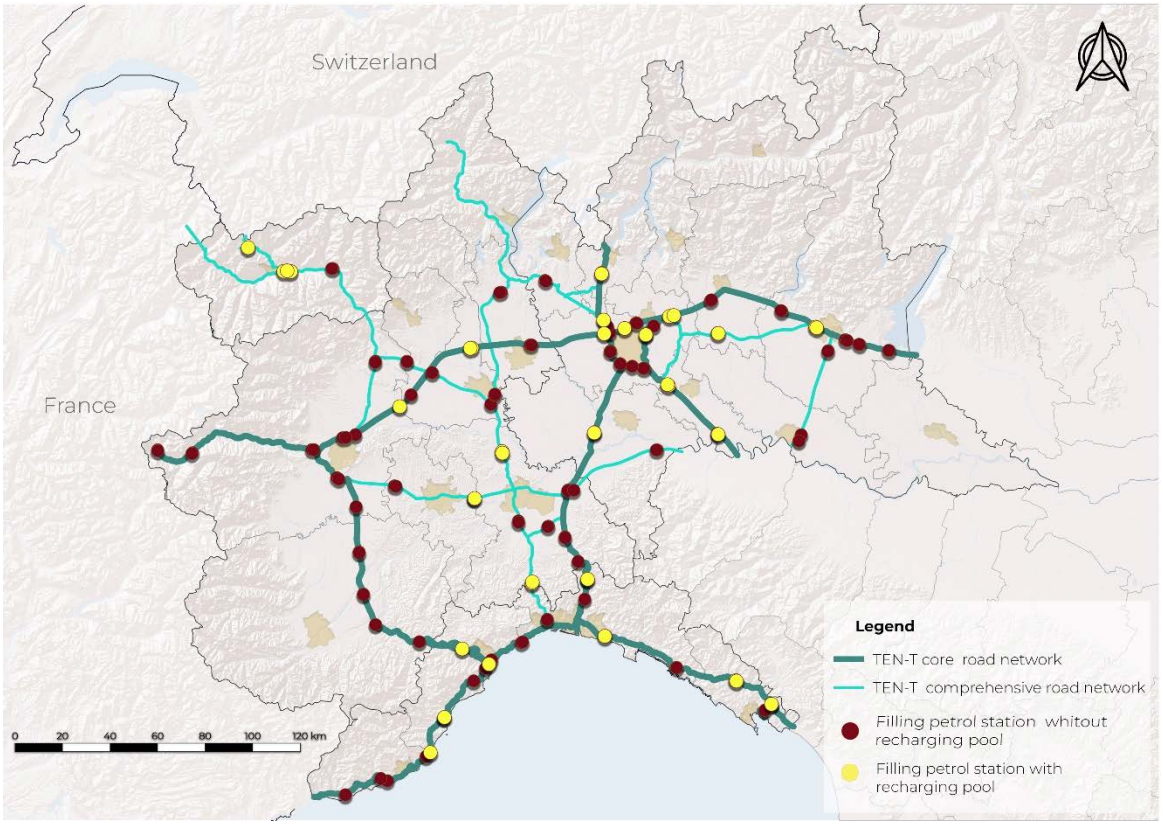

Fig.4 Filling petrol stations along the TEN-T core and comprehensive road network

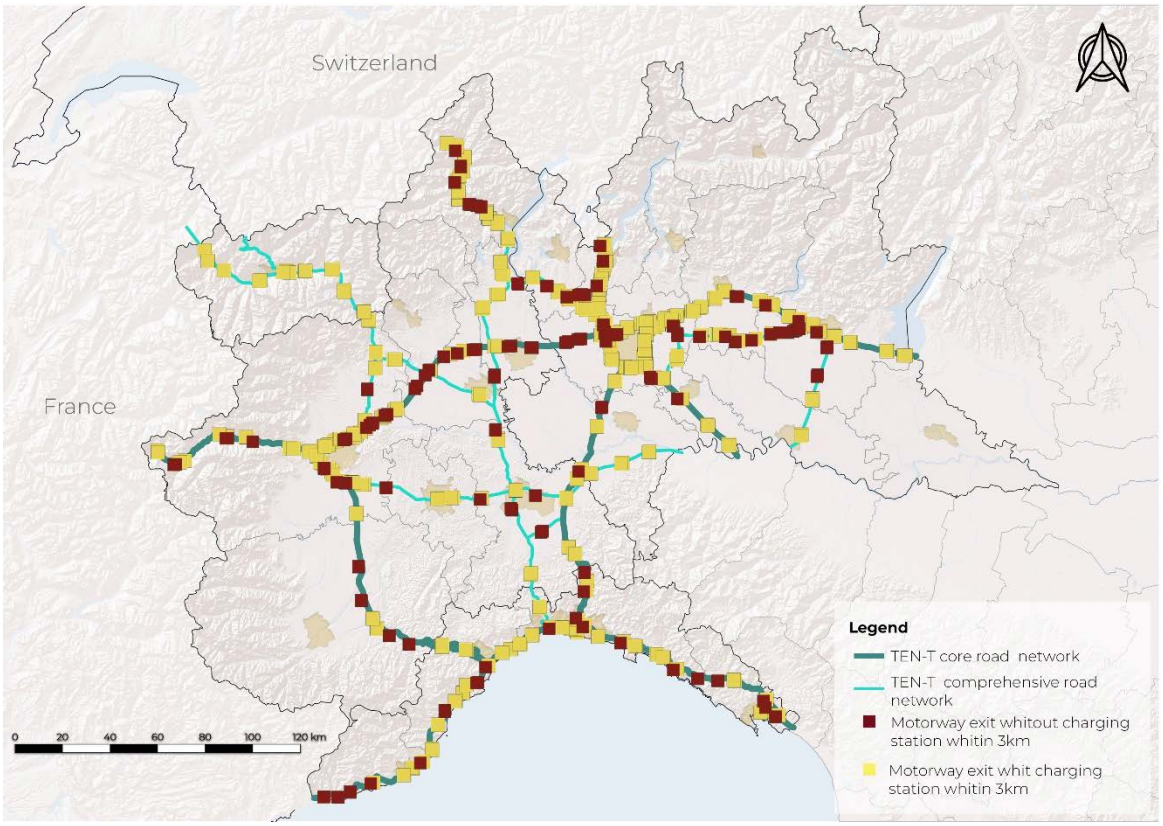

Fig.5 Motorway exits along the TEN-T core and comprehensive road network

Along the TEN-T core road network (Fig.ss 4 and 5) there are 95 filling petrol stations (27 of which offer at least one charging pool) and 344 exits (253 of which offer at least one recharging pool within 3 km of the

exit). Along the rest of the comprehensive network, there are another 42 filling petrol stations (10 of which have at least one charging pool) and 176 exits (121 of which have at least one charging pool within 3 km). In total, along the core TEN-T network drivers can currently reach 712 charging pools, for a total of 2,502 charging points and a power output of 171,995 kW. Of these 712 pools, 20 located at filling petrol stations already meet the standards set by the Regulation for both the end of 2025 (i.e., having a power output of at least 400 kW, including at least one charging point with an individual power output of at least 150 kW) and the end of 2027 (i.e. having a power output of at least 600 kW, including at least two charging points with an individual power output of at least 150 kW). Within 3 km of the exits, another 676 pools already meet the Regulation standards for 2025, and another 49 for 2027. The result is that, by the end of 2023, 71% of the core TEN-T network is already covered by these charging pools, meaning that in this portion of the network drivers can reach a charging pool anywhere (meeting the required standards by 2025) by travelling less than 60 km (Fig.6).

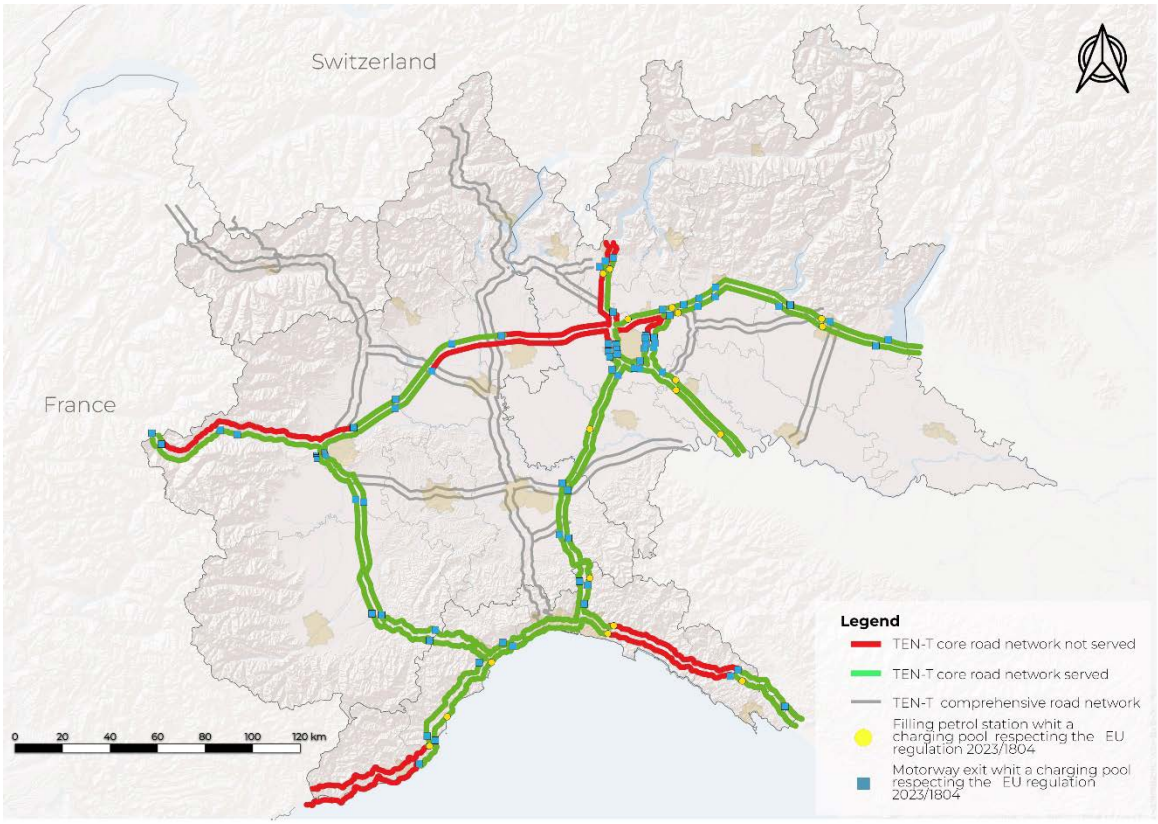

Fig.6 Served and unserved sections of the TEN-T core road network at the end of 2023

TEN-T core road network	n° charging pools	n° charging points	kW
On 31/12/2023	712	2,502	17,1995
target 2025	+0	+14	+2,100
target 2027	+0	+8	+1,200
TEN-T non-core road network			
On 31/12/2023	155	446	26,304
target 2027	+0	+0	+0
target 2030	+0	+17	+2,550
target 2035	+0	+22	+5,500

Tab. 2 Charging points (and relative power output) to be added in order to cover the TEN-T road network in northwestern Italian provinces according to the targets set by the EU Regulation 2023/1804 for the next years

To cover the remaining 29% of the core network (mainly located in Liguria and on the corridor between Milan, Turin and Bardonecchia) according to the target set for the end of 2025, the Greedy algorithm showed that it would be sufficient to upgrade 8 charging pools located at the 8 motorway exit indicated in Fig.6 by adding 14 charging points (for a total added power of 2,100 kW); another 8 charging points proving 1,200 kW are needed for the 2027 target (Tab.2). In other words, to increase by 29% the length of the road network served (585 km), it is not necessary to provide new pools; it is sufficient to increase the number of charging points by 0.88% and their power output by 1.92% (Fig.7).

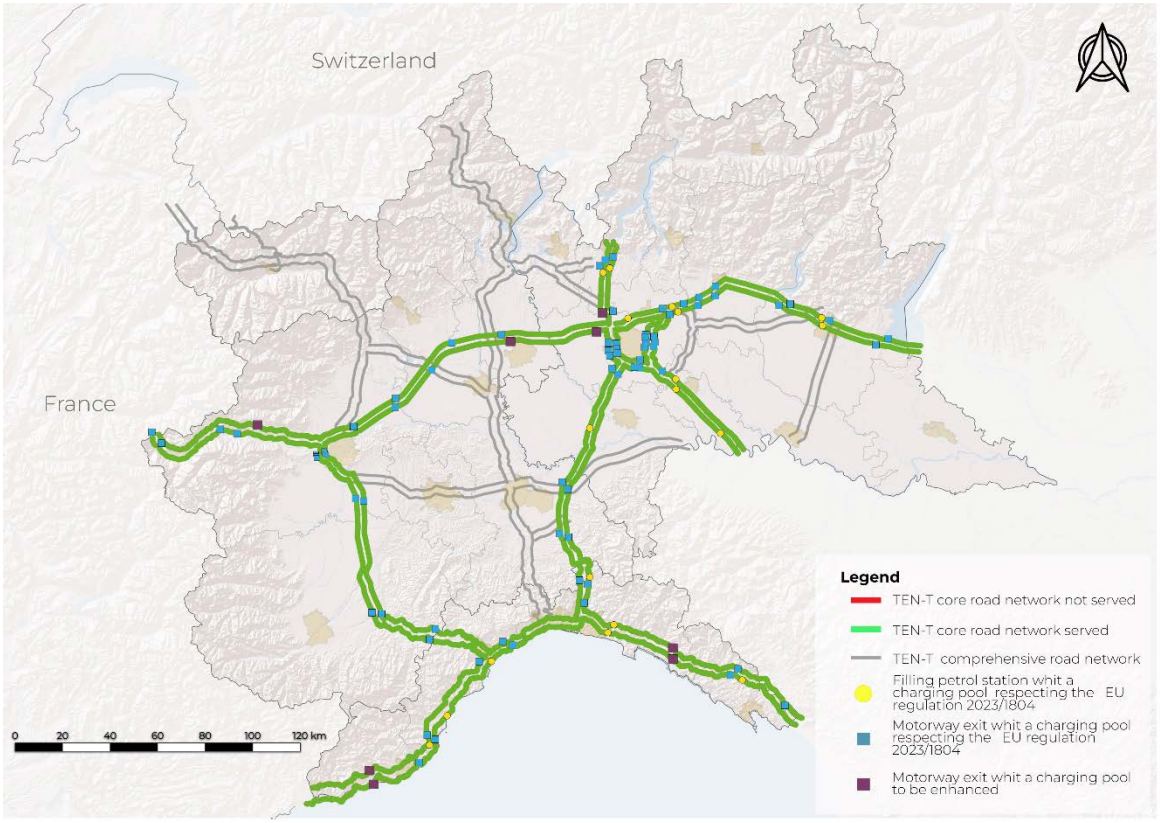

Fig.7 Charging pools to be upgraded at motorway exits to serve the entire TEN-T core road network at the end of 2027

As for the comprehensive network, 155 charging pools can be found along its non-core section, with a total of 446 charging points and a power output of 26,304 kW. Of these 155 pools, 9 located at filling petrol stations already meet the standards set by the Regulation for both the end of 2027 (i.e., having a power output of at least 300 kW, including at least one charging point with an individual power output of at least 150 kW) and the end of 2035 (i.e. having a power output of at least 600 kW, including at least two recharging points with an individual power output of at least 150 kW). Within a 3-km radius of the exits, another 224 pools already meet the Regulation standards for 2025, and another 17 for 2035.

The result is that, at the end of 2023, 33% of the TEN-T non-core network is covered by charging pools that meet the standards required by 2027 (mainly between Turin and Aosta, Milan and Brescia, Milan and Domossola, Ovada and Genoa). Considering the entire comprehensive network (both core and non-core), 54% of its length is already covered by these pools: in other work, the 2027 target (i.e., at least 50% of the whole comprehensive network must be served) is already met (Fig.8). To cover the entire network by 2030, existing pools need to be upgraded at 4 filling petrol stations and 8 motorway exits, by adding respectively 17 charging points (for a total added power of 2,550 kW); by the end of 2035, another 22 charging points are needed, so as to provide an additional 5,500 kW (Tab.2). Also in this case, it is not necessary to provide new pools; it is sufficient to increase the number of charging points by 8.7% and their power output by 30.6% (Fig.9).

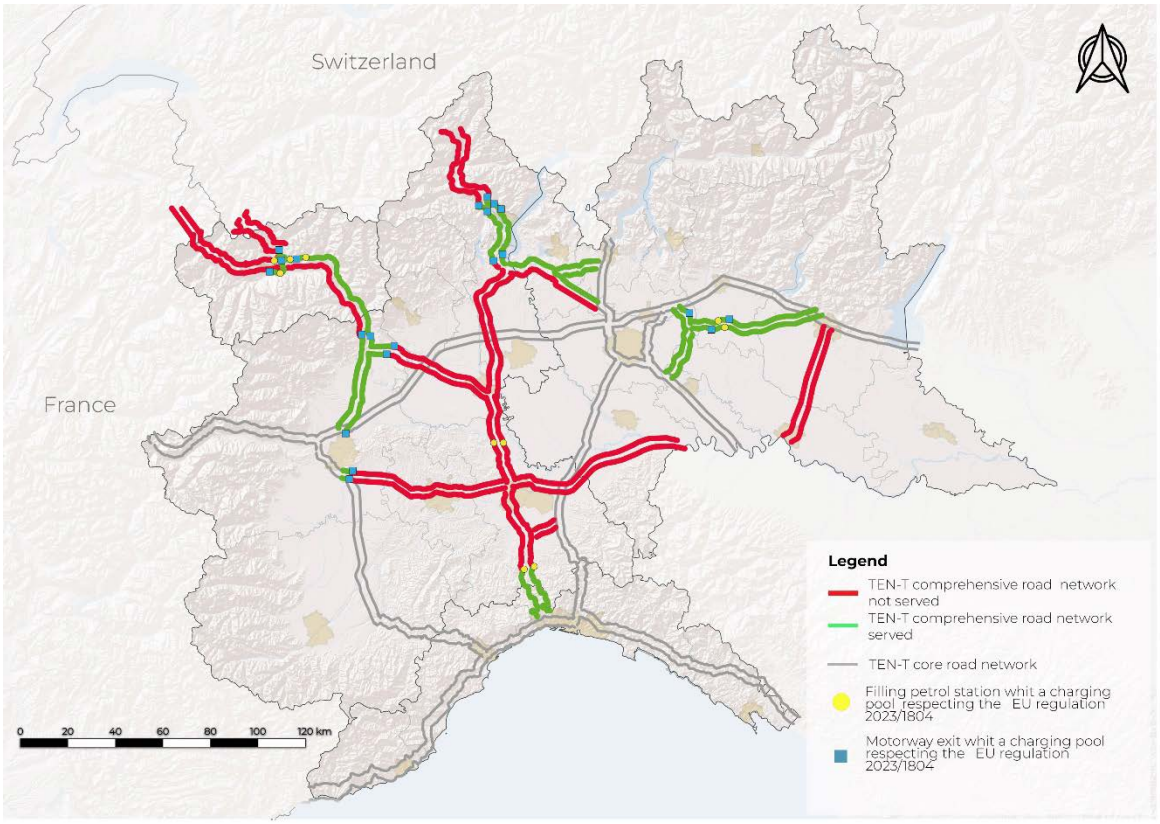

Fig.8 Served and unserved sections of the TEN-T non-core comprehensive road network at the end of 2023

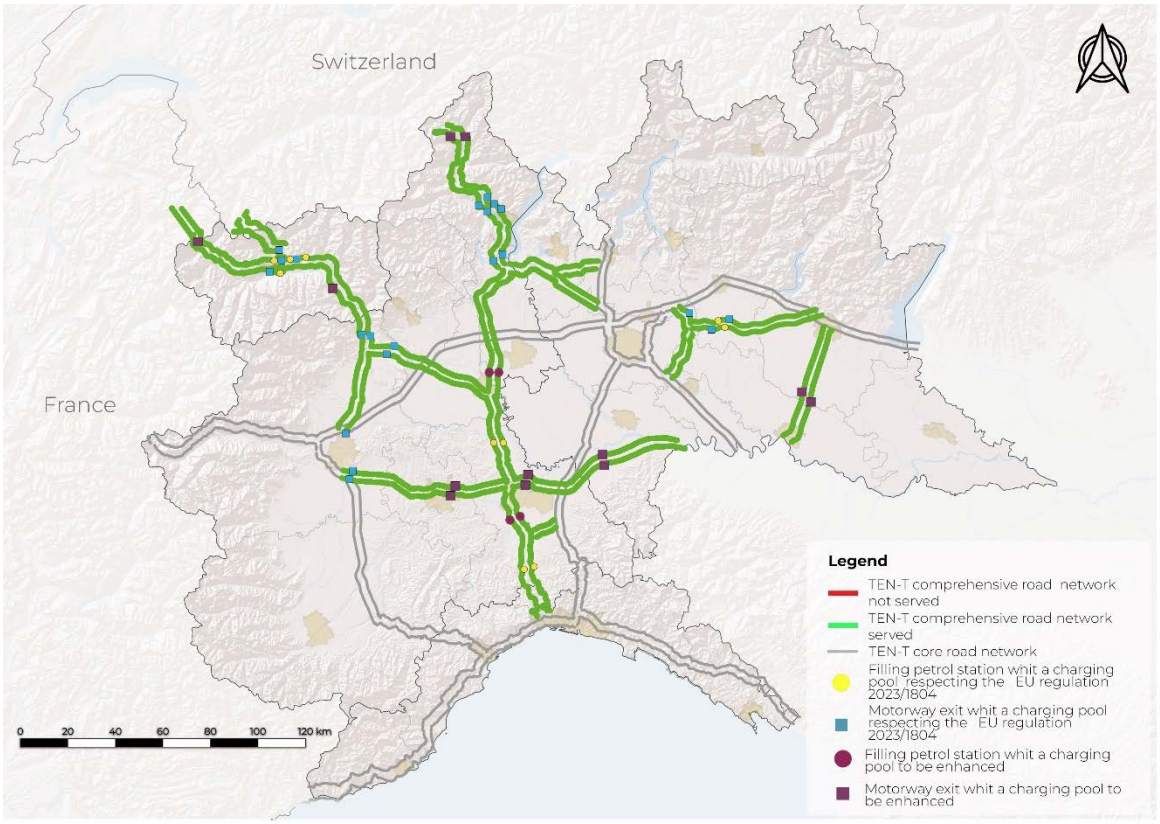

Fig.9 Charging pools to be upgraded to serve the entire TEN-T comprehensive road network at the end of 2035

5. Discussion

The results of the analysis presented in this article highlights a complex and nuanced picture regarding the alignment of northwestern Italy's charging infrastructure with the targets set out by EU Regulation 2023/1804. While the region shows promising signs of development, it also reveals important spatial and systemic gaps that need be addressed to ensure full compliance with EU mandates and enable effective deployment of EV adoption. As illustrated in the Introduction, the relationship between EV adoption and the deployment of charging infrastructure can be mutually reinforcing but is subject to the risk of a lock-in scenario due to underinvestment on both sides. The results seems to confirm this dynamic: while some provinces significantly exceed their fleet-based targets, others fall short of them, indicating a spatial mismatch that may hinder the diffusion of EVs despite broader regional progress. These findings appear to confirm the limitations of Directive 2014/94/EU, which did not propose a common methodology for setting national targets and hence did not prevent unequal development of charging infrastructure. Moreover, the results suggest that, where this infrastructure is abundant, it is likely the result of targeted investments, local incentives, or pilot initiatives rather than a consistent national approach.

These results must be interpreted through the lens of incentives in the Italian market, which have historically focused more on vehicle purchases than infrastructure. Generous subsidies have fostered some uptake in battery EVs, but without commensurate support for charging facilities, especially outside of major metropolitan areas. The Italian incentive structure has thus contributed to regional disparities and slow adaptation in rural and mountainous areas, where private investment is discouraged by lower expected returns and logistical challenges (Delle Site & Tribioli, 2022; Giansoldati et al., 2020).

Moreover, compliance in numerical terms risks obscuring critical system constraints that determine functional service. Regulation 2023/1804 sets clear spacing and power thresholds, yet implementation experience across Europe demonstrates that legal compliance does not guarantee operational readiness when grid connection, substation capacity and per-direction provisioning are not co-planned with charging siting. International assessments stress that corridor continuity often depends on distribution-network reinforcement or local flexibility measures rather than simply adding chargers (IEA, 2023). Two technical implications follow. First, siting and capacity planning must move beyond coverage models to incorporate power-flow and deliverable-power constraints. Location models such as maximum-coverage and p-median heuristics remain useful for identifying candidate sites (Lamontagne et al., 2023; Micari et al., 2017), but their outputs overestimate usable throughput unless they are integrated with distribution-grid simulations and energy-storage sizing. Empirical and modelling work shows that multi-dispenser DC sites operating under a shared connection can experience substantial reductions in per-plug deliverable power during concurrent use, meaning nominal kW figures are not equivalent to guaranteed service levels (Lappalainen et al., 2023; Sun, 2021). Second, operational reliability and user experience matter for network performance. Field audits have repeatedly found that a non-negligible share of public DC fast chargers is non-functional at any given time, and such availability problems disproportionately undermine long-distance travel confidence even where spatial coverage meets the required metrics. Stochastic and queuing analyses indicate that utilization thresholds beyond modest levels produce rapidly increasing waiting times; therefore, monitoring uptime, mean time to repair, and peak-period queuing should be part of compliance metrics (Rempel et al., 2024). Policy and governance implications flow directly from these technical realities. As already said, network or corridor rollout strategies that rely exclusively on national or operator-led investment risk leaving peripheral and mountainous segments underserved because of weak commercial returns and limited substation capacity. To address this, regional planning instruments - notably Sustainable Urban Mobility Plans (SUMPs) and Regional Energy and Climate Plans (RECPs) - should be mandated to include corridor-adjacent prioritization and grid reinforcements, and to coordinate deployment with distribution system operators and local renewable/storage projects. Complementary measures such as targeted infrastructure grants, contracts for difference on reliability, and support for on-site storage or local

generation can reduce the need for upstream reinforcement while improving deliverable power (Lappalainen et al., 2023; Sun, 2021). Finally, demand-side instruments and performance-based monitoring will help reconcile EU targets with user needs. Time-of-use pricing, reservation/queue management and predictive maintenance reduce peak congestion and raise effective throughput; behavioural studies show that perceived reliability and wait times strongly influence charging choices on long trips, often more than spatial density alone (Hoen et al., 2023). In sum, moving from a counting-chargers mindset to a performance-oriented, grid-aware strategy will be essential to translate the promising coverage figures reported here into robust, equitable network service.

6. Conclusion

Northwestern Italy is well-positioned to meet European targets on EV infrastructure. Thanks to a strategically located base of existing infrastructure, 71% of the core TEN-T network and over 50% of the comprehensive network already meet the 2027 requirements. Importantly, simulations using the Greedy approximation algorithm demonstrate that full compliance with both 2027 and 2035 goals could be achieved with limited additional investment. Instead of building new pools, it would be sufficient to upgrade existing ones. This insight underscores the cost-effectiveness of a well-planned spatial redistribution strategy and echoes the findings of previous studies (e.g., Lam et al., 2014; Guo et al., 2024), in which optimization models showed that spatial proximity and power adequacy are more critical than simple quantity. The analysis also highlights several limitations. First, fleet- and distance-based evaluations are accurate from a regulatory compliance standpoint, but they do not capture user behavior, real-time network loads, or the quality and reliability of individual charging pools. Second, the use of publicly accessible datasets, however complete, may not take into account informal or private charging infrastructure that could significantly affect both supply and demand. Lastly, while the Greedy algorithm offers computational efficiency, it also favors quick solutions over potentially more equitable or resilient long-term network designs; sensitivity analysis could be appropriate to verify the robustness of the results. Future research should delve into behavioral dimensions: what motivates private actors to install charging infrastructure, how users perceive charging availability, and how seasonality or tourism (especially relevant in Alpine regions) influence demand. Another promising issue is the integration of renewable energy and smart grid compatibility into charging strategies along motorway network, which would further enhance sustainability outcomes. From a policy perspective, a few key recommendations emerge. First, incentive structures need to shift from a predominantly demand-driven approach to a more balanced model that includes infrastructure subsidies, especially in underserved areas. Second, regional authorities should be granted funding and planning autonomy to tailor interventions to local conditions, as these appear more predictive of success than national averages; in this sense, the role of Sustainable urban mobility plans can be crucial in coordinating the spatial allocation of charging pools to land use transformation (Delponte, 2021). Third, regulatory enforcement should be coupled with continuous monitoring and adaptive planning, using geospatial data and predictive analytics to anticipate future bottlenecks (Valentini et al., 2023). In conclusion, achieving equitable, sustainable, and user-friendly outcomes requires aligning incentives with spatial planning, embracing data-driven policy tools, and investing in both technological and social infrastructure. Only through such integrated strategies can the "chicken-and-egg" dilemma be solved, unlocking the full transformational potential of electric mobility.

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Image Sources

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Landscape enhancement and river preservation. The case of the Aniene River in Rome, Italy

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Abstract
The objective of this study is to integrate the concepts of landscape restoration with the improvement of river areas. Often, there is a coexistence of elements of significant natural value and highly impacting artificial elements, such as large road and railway infrastructures, along watercourses. These elements have altered the landscape value and the usability of the places over time. The 'Landscape Project', as defined by current Italian landscape legislation, facilitates the implementation of measures aimed at enhancing environmental quality. Concurrently, River Contracts, a novel participatory tool, enable the execution of shared governance strategies designed to upgrade river basins and their associated territories. The case study focuses on the Aniene River, situated in a region of Rome adjacent to the Rome Ring Road. A project evaluation methodology is proposed for this study, which could be considered innovative. The methodology is evaluated through the presentation of results quantifying the benefits of the proposed project actions in terms of pollutant recovery and social welfare.

Keywords
Landscape Planning; River; Infrastructures

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1. Introduction

This paper combines two themes: that of the landscape and that of the areas affected by the course of a river. The following methodology is proposed for the purpose of verifying the enhancement of the qualities of the landscape under consideration. This methodology is supported by a case study which features the Aniene river within a mixed-use area, incorporating residential, industrial and agricultural components, situated within the municipality of Rome, Italy.

The overarching theme of rivers and the well-being of the inhabitants living in proximity to them has been addressed in recent literature from various perspectives. The international scientific community recognizes well-being as an indispensable element to guarantee the survival of the contemporary city, increasingly as a territorialized metropolis, which requires a new paradigm for the quality of life.

The landscape is the "space" from which people most benefit and in which health is determined or not. But the contemporary city is a complex organism, which faces increasingly pressing problems. Well-being is itself a multidimensional and complex challenge (Antrop, 2004; Stiglitz et al., 2009).

Starting from this premise and from the complexity of the contemporary city, well-being issues also assume uncertain boundaries and tend to broaden their reference basin, especially in relation to issues of sustainability. It is from these considerations that well-being entered into urban and territorial planning (Hough, 1984; Bentley, 1990; Breheny, 1992; Haughton & Hunter, 1994; Barton & Bruder, 1995; Rogers, 1997; Frey, 1999; Jabareen, 2008; Falk, 2019). Society, in fact, lives in a territory and therefore the challenges it poses are not vague: the population poses questions to planning to obtain responses throughout the space (Indovina, 2003; Marcelloni, 2005; Vicari Haddok, 2013; Lucia et al., 2018). However, not all of the space has homogeneous characteristics, especially the landscape, and there are numerous elements that characterise it.

The elements at stake that have the greatest influence on the health of the urban environment and of the population living there, were then illustrated: the green and blue infrastructures.

Among the elements that most contribute to well-being and therefore to health are green and blue infrastructures, because they provide "ecological, economic and social benefits through solutions in harmony with nature [...] it is a network of natural and semi-natural areas and green spaces that provides ecosystem services, which are the basis of human well-being and quality of life" (European Parliament, 2013). The term "Green Infrastructure" has its origins in the United States (Firehock, 2010), although the basic concept that ecosystems should also be considered as infrastructure has been known since the 1980s (Cardoso da Silva & Wheeler, 2017). This concept arises from the recognition that natural systems are just as important, if not more so, for social and economic well-being than so-called grey infrastructures. The first cases where this term was specifically mentioned in reference to land use planning was in the 1990s in the United States and while many other terms have been used over the years, such as ecological, natural, environmental, green and blue infrastructures, "Green Infrastructure" is the dominant term in the academic literature (John et al., 2019).

The European Union Strategy for Green Infrastructures (European Commission, 2013a) is a key element for achieving the objectives of the EU Biodiversity Strategy for 2020 (European Commission, 2011a; 2011b). The EU's Environment Directorate-General believes that Green Infrastructures have four main "roles": protecting the state of the ecosystem and biodiversity, improving the functionality of ecosystems and promoting ecosystem services, promoting the well-being and health of society and support development of a green economy and sustainable land and water management (European Commission Directorate-General for Environment, 2012). In the Technical Information on Green Infrastructures the European Commission has defined 13 groups of benefits provided by the Green Infrastructure Health and well-being: Improvement of the efficiency of natural resources, Water management, Instruction, Tourism and recreation, Green infrastructure and conservation, Mitigation and adaptation to Climate change, Low carbon transport and energy, Disaster prevention, Land and soil management, Resilience, Investments and employment, Agriculture and forestry (European Commission, 2013b; 2017; 2018). Thus they help to define environmental, social, and

economic actions such as: the conservation of biodiversity or adaptation to climate change, providing water drainage or green spaces, providing jobs and increasing of real estate values (EEA, 2011; Hansen et al., 2015; Olafsson & Pauleit, 2018; Pantaloni et al., 2024). These actions are integrated with climate and ecological benefits including increased carbon capture, improved air quality, mitigation of the effect of urban heat islands, additional wildlife habitat and recreational spaces (MATTM, 2014; Angrilli, 2015; Cialdea, 2015, 2017, 2022). Green and blue infrastructures can be thought of at different scales - local and regional - and include multiple elements -from building (public spaces green roofs, temporary flooding and bio-retention basins) to urban spaces (rain squares, infiltrating systems, gardens, parks, wooded areas, etc.) - that work in connection with each other and with other green and blue infrastructures to create a regenerated city that transforms itself.

The subject of the 'River Landscape' is also increasingly being explored by researchers. Despite the presence of divergent conditions, stemming from disparate contexts, the theoretical theme of the issues of preservation, on the one hand, and development, on the other, is being addressed in practice with highly differentiated solutions. The parameters of concern are the encouragement of landscape value and support for the enjoyment of places with physical difficulties; the combating of climate change; and the role of networking and increasing citizen participation (considering water as a common good). A comprehensive analysis of the available literature reveals a clear picture regarding the study of the planning tools utilised, which are a function of the various legislative bodies in different countries.

As early as the beginning of the 2000s, the research landscape on the topic made it clear that the study of the landscape must be approached by different professions (Butula, 2008; Eiter, 2010; Gobster & Xiang, 2012). It is evident that the overarching objective of sustainability can only be accomplished by integrating the imperatives of protection and development. The planning tool is identified as the primary means to facilitate this integration (Roe, 2013; Tomić Reljić et al., 2023).

There is an emerging consensus that effective sustainable spatial planning necessitates the establishment of models grounded in social and physical systems. However, it should be noted that theories are becoming increasingly diverse. On the one hand, there is a tendency to focus primarily on preserving natural resources as the basis for sustainable development. In this case, the focus is on plans that primarily consider natural values and consequently create development actions. Conversely, spatial policies are implemented with the objective of counteracting built development (Sarlöv Herlin, 2004; Biot & Colard, 2000; Kruse & Pütz, 2014).

In recent years, there has been an increased focus on public participation in the decision-making process. It is imperative to acknowledge the pivotal role of stakeholders in the planning process. Primarily, this encompasses the resident population; however, it is also imperative to recognise the contributions of experienced professionals specialising in developmental issues, including representatives from academic institutions such as universities. Spatial scenarios become the elective site of the results of their desiderata. The philosophy of choice will henceforth be based on an approach endowed with flexibility and adaptability and will replace the traditional, institutional and sectoral approach (Camagni, 2017; van der Voorn et al., 2023; Olesen, 2023; Juschten et al., 2025).

In the specific case of territories that include a watercourse, issues of 'river conservation' and 'river design' are also intertwined.

The principles of conservation are predicated on the concept that rivers represent a "common good" inextricably linked to the essential resource of water. Rivers have long played a pivotal role in sustaining life, providing vital water resources for various applications, including human consumption, agricultural irrigation, and energy production. However, for an extended period, they have been subjected to considerable threat. Two aspects must be considered: firstly, the state of health and the necessity of defence against pollution; secondly, the physical condition and the need for defence against hydrogeological disruption (Sweeney & Blaine, 2016).

It is imperative to acknowledge that the river constitutes more than merely the river shaft; rather, it is an integral component of the broader "river system," a concept that encompasses the "upstream-valley" complex

and exerts a significant influence on the urban environment. This influence can be traced back to the historical expansion of the original urban centre, a process that has been further facilitated by the river's presence, thereby enlarging the area under consideration.

In this regard, the significance of effective local planning is paramount. It is imperative that landscape design for river environments is informed by a comprehensive understanding of existing plans at both the general level and, most crucially, the municipal level (RESTORE, 2013; Ingaramo & Voghera, 2016; Ingaramo & Negrello, 2024).

Consequently, the river can be regarded not only as a natural system, but also as a linear system, and moreover as a complex landscape system involving both natural and anthropic environments. The methodology that will be described later aims at the theme of 'stitching together' all the elements present along the river through the construction of a landscape project that meets the physical needs of the places and the needs of the population living along it.

This paper is divided into five sections: the introduction (Section 1) describes the main issues of the paper, including the literature review. Section 2 deepens the relationship between river and landscape in the Italian corpus of planning legislation. Section 3 defines the methodology, firstly in general terms and later it contains the application to the chosen case-study. Section 4 explains the results and the related discussion and Section 5 regards conclusions and remarks.

2. Raising planning awareness: river and Landscape in Italy

In Italy, the field of spatial and environmental planning has historically been a primary concern for legislators. Indeed, as early as the 1940s, the legislator formally endorsed certain principles that are still in force today. The national town planning law, L. 1150 (Repubblica Italiana, 1942) has remained the cornerstone of reference, albeit with its additions, while the outline has changed and with it the planning criteria.

Since the conclusion of the 1970s, the Regions have been granted powers with regard to the organisation and management of the territory. It is imperative to accentuate the fact that during the 1970s and 1980s, the overarching objective of agriculture - a sector that places significant emphasis, through its diverse organisational structures, on the national territory - was the maximisation of yield quantities. The prevailing perspective was to maximise the exploitation of agricultural land through the utilisation of planning instruments, to the extent of imposing the natural vocations of specific regions.

However, over the past fifteen years, the environment has become increasingly significant, and the necessity to protect it from various threats has become a primary concern. Concurrently, the agricultural sector is undergoing a transformation in its objectives, shifting towards enhancing quality with the aim of promoting environmental rehabilitation and enhancing mountainous regions, which have historically been marginalised by the pursuit of extensive production. In recent years, there has been a notable advancement in the methodology of incorporating environmental assessments into planning documents and tools. This development is characterised by an increased emphasis on environmental considerations, which is a fundamental aspect of the concept of assessments.

However, it was also in the 1940s that the principles of landscape protection as a common good to be safeguarded were established. In the history of landscape protection, there has been a shift from an initial focus on the landscape as an asset to be enjoyed to the environment as the need to curb large-scale development and disregard for the well-being of all. The landscape is now viewed as a structural system with multiple components. In Italy, the planning instrument for landscape protection is the landscape plan, which was first mentioned in 1939. In that year, two laws were issued, L. 1089 and L. 1497, which firstly introduced the concept of constraints to be placed on assets to be protected (Repubblica Italiana, 1939a, b): the first for things of artistic or historical interest and the second on the protection of natural and scenic beauty, providing for the institution of landscape constraints.

It was not until the mid-1980s that Law 431/85 (Repubblica Italiana, 1985) introduced new concepts for the protection of areas of special environmental interest. Indeed, for the first time, the regions are obligated to carry out an organic and systematic protection of their territory. They are required to identify the areas to be protected and are obliged to draw up Territorial Environmental Landscape Plans for Large Areas. However, a significant distinction exists between the notion of constraint as outlined in Law 1497/39 and that delineated in Law 431/85. In the former context, the landscape constraint is defined as the legislative instrument that ensures the preservation of the aesthetic and visual characteristics of the landscape. Conversely, the concept is expanded to encompass the environment in its entirety, incorporating all facets of environmental protection. In the early months of 2004, the recently formulated Cultural Heritage and Landscape Code (Repubblica Italiana, 2004) was promulgated. This legislative instrument adopted the concept of landscape asset in lieu of environmental asset, with the objective of accentuating the manifold components of the landscape, encompassing the morphology of places, architecture, history, and the environmental component. Indeed, the definition provided asserts that 'landscape signifies a homogeneous portion of territory whose characteristics are derived from either nature, human history, or reciprocal interrelations. The preservation and enhancement of the landscape are vital for safeguarding the values it embodies as tangible expressions of identity'. In summary, the landscape is now subject to not only protection constraints but also enhancement obligations, in accordance with the principles of Title V of the Italian Constitution, which with the reform of 2001 now distinguishes between protection and enhancement activities. The cultural asset is to be protected and preserved for the purpose of being made available for collective knowledge and enjoyment.

Another significant legislative intervention in the country occurred at the end of the 1980s. This was Law 183/89 (Repubblica Italiana, 1989), which was designated the Soil Defence Law. This was deemed necessary in the aftermath of the calamitous events that transpired during the 1960s and 1970s, exemplified by the renowned Vajont disaster of 1963 and the Florence flood of 1966. The legal provision stipulated in Law 183/89 thus introduces the concept of a geographical unit, namely the hydrographic basin. This term is defined as a specific territorial area (Cialdea, 2007, 2019, 2022). Indeed, as stated in Article 1, paragraph 3, a river basin is defined as the territory from which rainwater or meltwater from snow and glaciers, flowing on the surface, is collected in a given watercourse, either directly or by means of tributaries. Furthermore, it encompasses the territory that may be flooded by the waters of the same watercourse, including its terminal branches with their mouths in the sea and the facing maritime coastline. Significant changes are also likely to ensue under the recently passed Nature Restoration Law (European Parliament and the Council of the European Union, 2024). The restoration of degraded areas is of particular importance, particularly within the context of the urban environment, where the specific soil type and degradation conditions are a key consideration. This theme, endorsed at the European level, is expected to have significant ramifications, particularly in Italy, where over 90% of municipalities are exposed to varying degrees of hydrogeological risk. It is imperative that significant reflections are undertaken in the domain of urban planning, with the objective of mitigating the loss of green areas within the urban context. This is essential to ensure the preservation of the entire green and blue infrastructure system. In this context, River Contracts - as a voluntary instrument of bottom-up participation, fostered by the involvement of a wide range of subjects (such as public bodies, private subjects and associations, universities) - can be the flywheel for improving the state of rivers and increasing landscape quality (Bastiani, 2022, 2025; Cialdea & Pompei, 2021a; Voghera et al., 2025).

3. Methodology

3.1 Preliminary considerations

The methodology - useful for integrating the concepts of landscape restoration with the improvement of river areas - has been defined in order to create a strong relationship between natural and landscape valuable

elements with the reduction of the impact of the artificial elements, as infrastructures are, quantifying the benefits of the proposed project actions in terms of pollutant recovery and social welfare. A number of preliminary considerations must be given due consideration.

Different methodological approaches from quantity to quality landscape improvement

Within the extensive domain of scientific literature, numerous articles have been analysed that examine aspects of quantitative assessments of the effects of projects. In addition, articles have been examined that highlight the enhancement of the landscape quality of watercourses, including through novel applications. This is achieved within a richly contextualised framework, drawing upon the historical elements of the Italian national territory.

In relation to the initial group, the i-Tree tool is frequently utilised. This tool, by analysing land cover data, identifies the presence of urban forests and determines the priorities for actions to enhance local well-being. This American software is designed to evaluate the economic, environmental and hydrological benefits of a green area on both a small and large scale. The tools most frequently employed for objectives analogous to those pertinent to the case study are Canopy, Eco and Landscape. Nevertheless, these tools are required to surmount the constraints of the American context in which they were developed (i-Tree, n.d.; Vigliocco, 2019). In this study, starting from data structured according to the basic i-Tree method, we proceeded to integrate it with i-Tree Canopy (Ghorbankhani et al., 2023) and the Natural Capital Planning Tool (Hölzinger et al., 2019; O'Keeffe et al., 2022). A combined approach to ex-ante and ex-post assessment of ecosystem services was developed. This approach was based on a combination of statistical remote sensing tools (i-Tree Canopy) and Natural Capital Planning Models (NCPT). The aim of this approach was to measure changes in natural capital and environmental impacts resulting from landscape transformation interventions. The i-Tree Canopy was used to quantify land cover and estimate the ecosystem benefits associated with trees (carbon, air quality, hydrology). The NCPT was used for a broader analysis of ecosystem services (10 categories, including cultural and regulatory services) and for the ex-ante/ex-post assessment of landscape transformation impacts.

A further application needs to be explored for river systems: using the i-Tree method as an adaptive management tool, with constant monitoring of the river ecosystem and adaptation of management strategies based on the model's results. The integration of these approaches has led to significant enhancements in the i-Tree method for riverine environments, resulting in more precise assessments of ecosystem services and the facilitation of more effective river management and restoration interventions (Hirabayashi et al., 2011; Guarini et al., 2018). The methods developed with the aim of improving the qualitative aspects of the landscape experiment with new design approaches in order to define scenarios for the transformation of the territory and landscape. The scales of analysis employed in this study range from large-scale areas - encompassing historical and cultural heritage, rural regions, symbols and traditions of identity, marginalised areas and inhabited centres (Guarini et al., 2017; Vigliocco, 2023) - to local urban scales - with a focus on urban fringes that encroach upon rural and recreational natural areas (Abastante et al*.,* 2022; Cialdea, 2022; Cialdea & Pompei, 2021a,b). Moreover, at the project scale, various complementary systems of action are identified with the objective of establishing a satisfactory river-context system (Morano et al., 2021a, 2021b; Ingaramo & Voghera, 2016). In this framework, the river functions as both a geographical identifier of locations and a connector with the surrounding territory. The objective of the present study was to investigate the applicability of i-Tree in Italy through the integration of qualitative parameters derived from the objectives of current planning tools. This dual comparison formed the basis of the project proposal for the case study.

The main features and elements involved in the case-study area

The study area is characterised by a high degree of complexity, stemming from the presence of multiple conflicting elements. The approach adopted in the present study was to identify the elements of value and

the detractor elements that undermine them. The objective of the present study was to evaluate the potential positive impacts of the proposed project. In order to achieve this objective, a reading methodology that has been proven to be effective was adopted (Cialdea, 2020a,b; Cialdea & Privitera, 2021). This methodology involved the identification of landscape values, as well as the necessity of emphasising the manner in which these values are utilised by the territory and, consequently, the population residing within that territory. Consequently, the "values" were invariably examined in relation to the presence of "detractors" within the territory that actually modify the value itself. These elements, which may be infrastructural, industrial or energy in nature, have been introduced into the territory over time in connection with the uncontrolled development of the territory itself. Methods of interpretation and combination with the values, which are by their nature linked to environmental characteristics, have been identified. With regard to Values, these are: Nature Value (VN), Landscape Value (VL) and Agriculture Value (VA). With regard to Detractors related to anthropisation, these have been identified as follows: DA1 (related to the Urban Residential Fabric), DA2 (related to the Industrial Fabric) and DA3 (related to Road and Rail Infrastructures).

- The Aniene River (VN), which originates in the Simbruini Mountains, is a left tributary of the Tiber and is the second longest river in Lazio, after the Tiber itself. Since Roman times, this waterway has been fundamental to Rome's water supply, feeding the Anio Vetus aqueduct and, later, other aqueducts, including the Acqua Marcia, which is the third aqueduct (after the Appio and Anio) of ancient Rome. The water from the upper Aniene basin was collected directly from one of its sources, rather than from the river itself. This ensured a water supply of the highest quality, which was considered to be the best that reached Rome. Pliny the Elder referred to it as "clarissima acquarum omnium" (the clearest of all waters). Along its urban course in Rome lies the Valle dell'Aniene Nature Reserve, a protected area covering 650 hectares, which does not currently extend to the area of our case study. The Aniene River was utilised for the transportation of blocks of tuff (the lionata stone, which was employed during Roman times, most likely originated from the regions of Settecamini and Salone, where it was referred to as "Aniene tuff"). These materials were conveyed to the city by means of this waterway. The Salone lakes, which were formed in these ancient tuff quarries, merit inclusion in the nearby Aniene Valley Nature Reserve due to their historical, archaeological, landscape and naturalistic significance (Comune di Roma, 1985; La Vigna et al., 2016; Rizzo, 2017; Sembroni et al., 2025).
  This element will be at the centre of the analysis and landscape design proposed here, due to its value (naturalistic, but also linked to history) and its fragility (related to the quality of its waters, but also to its susceptibility to flooding).
- The Latomie di Salone (VL) represent a significant outcrop of quarries of the aforementioned "tufo lionato". It is the only visible example of a tufo lionato quarry environment in the Roman area, especially in terms of its size and morphological structure (Funiciello & Giordano, 2008; Comune di Roma, 2016a; Fabbri & Lanzini, 2020). "The outcrop covers an area of approximately 380,000 m2 between Via delle Case Rosse, Via di Salone and the junction with the A24 Motorway. The area is characterised by morphologies linked to underground and open-air quarrying of tuff stone, which developed from Roman times (when the nearby Aniene River was used to transport the blocks of rock) until the 20th century. There are subvertical quarry faces and depressed areas linked to more recent extraction; the open-air cultivation areas are flooded by the water table, creating characteristic small lakes. In the 19th century, during the Romantic period, the area, known as the Tor Cervara Quarries, was famous among artists (especially German and French) who organised trips and parties there (Fabbri et al., 2014). The area is currently abandoned, although it is privately owned and fenced off. Given the high mechanical resistance of Lionato tuff, the only signs of deterioration are sporadic falls of blocks and wedges of rock. It is the very heart of the study area and the initial motivation behind the project concept.
- In this part of the territory, agricultural activity (VA) remains prevalent, despite the encroachment of residential and industrial development, which will be examined subsequently. This is recognised by the

current urban planning tool, which describes this part of the left bank of the Aniene as generally agricultural, with the exception of the area surrounding the quarries, which is identified as "public green areas", alongside which there is a small portion of "private green areas" corresponding to the existing sports lakes. The Landscape Plan identifies it as a generic "continuous agricultural landscape". It is noteworthy, however, that the Tenuta del Cavaliere, one of the two farms managed by Roma Capitale, is located in the vicinity of the study area. With its 388 hectares, the Tenuta del Cavaliere borders the bends of the Aniene River. This estate derives from the union of three separate estates that merged between the 15th and 16th centuries into the property of Anastasia Cavalieri. In 1640, following a donation, the property passed to the Hospitaller Order of St John of God of the Fatebenefratelli and then subsequently to Rome Capital. Currently, there is a modern cattle farm and fodder cultivation. The area is characterised by the presence of many species of wild animals and diurnal and nocturnal birds of prey (Pavolini et al., 2003; Cardillo & Cimino, 2024; Marino et al., 2024).

- Moreover, to the north of the case study area, there is a substantial residential area known as "Case Rosse" (DA1). Case Rosse was originally a spontaneous settlement that sprang up as a result of the migration of numerous families from Abruzzo to the capital. It is located on the eastern edge of the Municipality of Rome (IV Municipio), along Via Tiburtina, outside the Great Ring Road. The settlement underwent an expansion from the 1970s onwards, reaching its current form, which exhibits the characteristic features of former illegal subdivisions in isolated locations within the Roman countryside. Recent urban expansion has resulted in the town of Case Rosse becoming an integral component of a continuous urban area, extending from the Great Ring Road to the municipal boundaries along the infrastructure axis of the Tiburtina, the A24 Motorway and the railway to Abruzzo. The Case Rosse area, which covers an area of almost 50 hectares, is separate from the rest of the town. This has allowed a strip of land on the edge of the town to be kept free from development and still used for farming. Within the village, there is also a significant presence of plots cultivated with olive groves, which constitute an element of landscape and environmental quality to be enhanced in the implementation of building projects. Furthermore, the open areas under the power lines (now largely abandoned) offer an opportunity to identify a system of environmental connections to the heart of the settlement. The Capitoline Assembly has adopted the urban planning amendment to the current PRG (General Urban Plan) for this area, pursuant to Article 10 of Urban Planning Law No. 1150/1942. This urban planning amendment relates to the areas of Detailed Plans for Zone "O" No. 57 'Case Rosse' and "Case Rosse B", from Areas with Defined Detailed Planning of the City of Transformation (Article 62) to the components Fabrics (Article 52, paragraph 5) and Areas for Integrated Programmes (Article 53, paragraph 11) belonging to the City to be Restructured, as published on 31 March 2021 (Comune di Roma, 2021a, b).
- Since the 1940s, the Tiburtina area (DA2) has been characterised by the presence of industrial plants, which increased further between the 1960s and 1970s. In the 1980s, the area, known as Tiburtina Valley, converted to high-tech products, particularly for the aerospace and electronics sectors.
- In 2003, the Region established the Tecnopolo Tiburtino in the area, a coordination hub for existing companies and an incubator for future ones. According to the Rome Chamber of Commerce, 12% of Italian ICT companies were based here, and Lazio was home to one-fifth of Italy's 150,000 researchers. It covers an area of 265,000 square metres on a total surface area of 70 hectares. The Tecnopolo, which borders the project study area, was created with the primary objective of attracting high-tech business initiatives, enhancing the industrial development of the Rome area and offering new employment opportunities. It has strengthened the link between the worlds of research, academia and business, becoming part of the broader "Roman Technopole System" project, implemented with European Union structural funds under Objective 2 (Camera di Commercio, 2003). Two decades after its establishment, there are complaints about the severe lack of transport infrastructure, which hinders accessibility and

sees the nearby Great Ring Road with its congested traffic as one of the main problems to be solved (RomaToday, 2023).

- The case study area is bordered, and in some cases crossed, by major road and rail infrastructure (DA3). It is located close to Rome's Great Ring Road (GRA). As is well known, the GRA was built in the immediate post-war period. By decree of Minister Giuseppe Romita, on 27 June 1946, the ANAS (Azienda Nazionale Autonoma delle Strade Statali, now ANAS S.p.A.) was established with the task of implementing a transport development plan to boost economic recovery. One of the most important projects was the construction of the GRA, a new ring road around the city of Rome that would connect all the consular roads of the capital with a fast-flowing route, as equidistant as possible from the city centre (based on the ring road methodology introduced in Rome by Edmondo Sanjust di Teulada's 1909 Master Plan). This almost perfectly circular route was thus created. It became a fundamental structure not only for road transport but also for future plans to expand the city, playing a leading role in subsequent urban development plans from that moment onwards. At the same time, however, it left many problems unresolved in the areas close to it, such as the case study.

Furthermore, the area under study is completely crossed by the motorway, which has a significant physical and visual impact. The A24 Motorway starts from Rome's Tangenziale Est ring road, near Tiburtina station, crosses the north-eastern quadrant of the capital and ends at the intersection with the GRA. its construction began in 1960. It was not until 1990 that the section connecting the Tangenziale Est and the Barriera di Lunghezza, which involves the study area, was built.

Finally, the Rome-Tivoli railway line runs south of the area in question, as part of the Rome-Sulmona-Pescara railway, construction of which began at the end of the 19th century. The Rome-Tivoli section was inaugurated in 1887. It is a little-used artery that could be useful for reaching the area in question (Corriere, 2013; MIMS, 2022; Comune di Roma, 2022; Città Metropolitana di Roma Capitale, 2022).

The study area is shown in Fig.1 below.

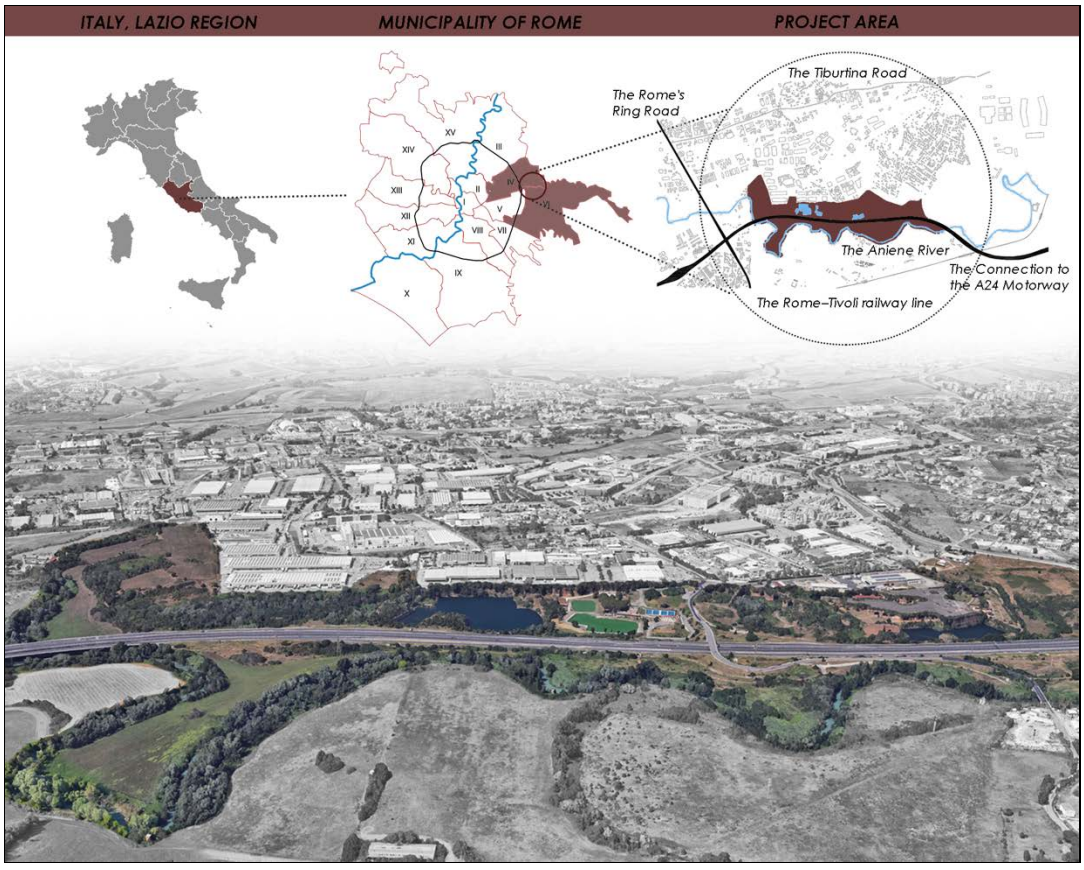


Fig.1 The case-study localization

3.2 The proposed methodological framework

Based on the investigations carried out using the planning documents, the work continued with the verification of conditions in the field. Therefore, a survey of the area was carried out. It consisted of two phases:

- the first involved a drone flight plan, in order to capture the distinctive features of the area and to verify the values and detractors described above. Fig.2 shows the reconstruction of the images taken with the drone;
- the second involved the reconstruction of the Latomie area, carrying out a topographical and architectural survey and, through data processing, creating a 3D model; the information was then implemented and potential interference verified, as shown in Fig.3 below.

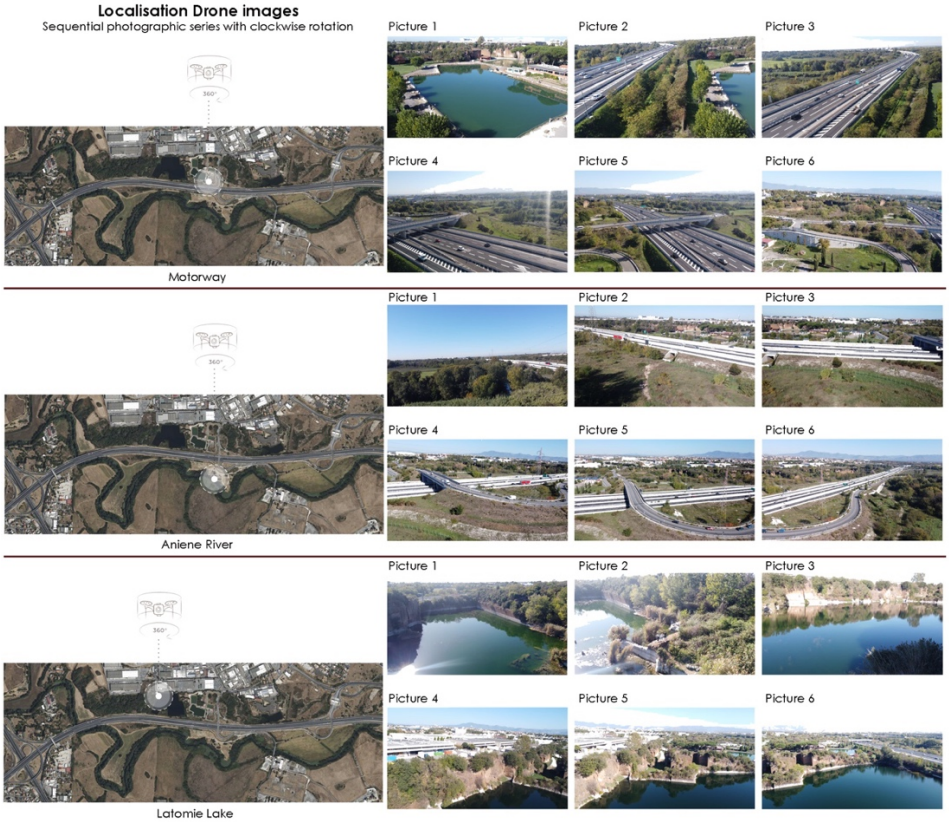


Fig.2 The Landscape Survey by drone

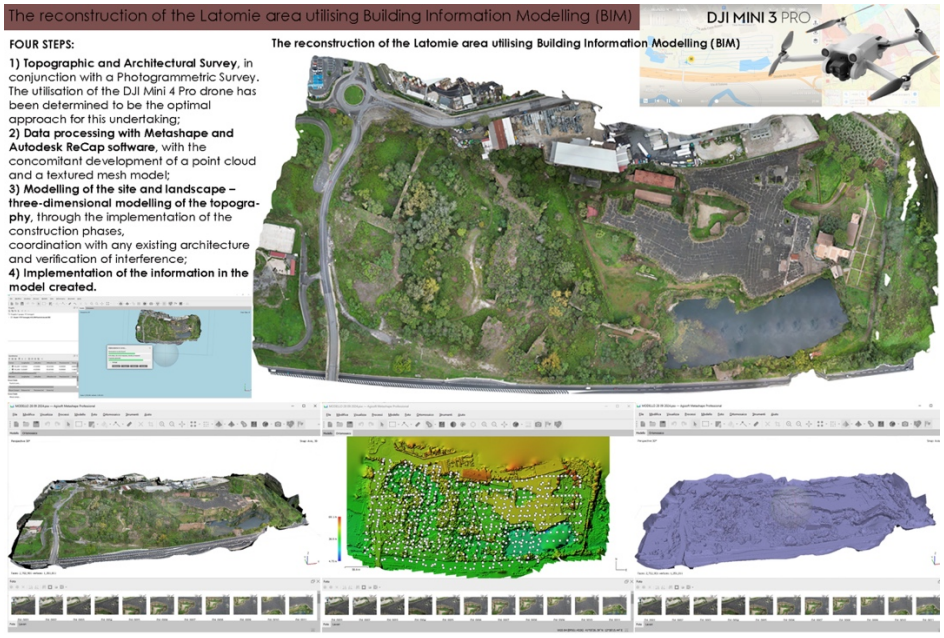


Fig.3 The reconstruction of the Latomie area utilising Building Information Modelling (BIM)

The methodology described below was therefore developed (see Fig.4). As represented in the flow chart, is structured as follows.

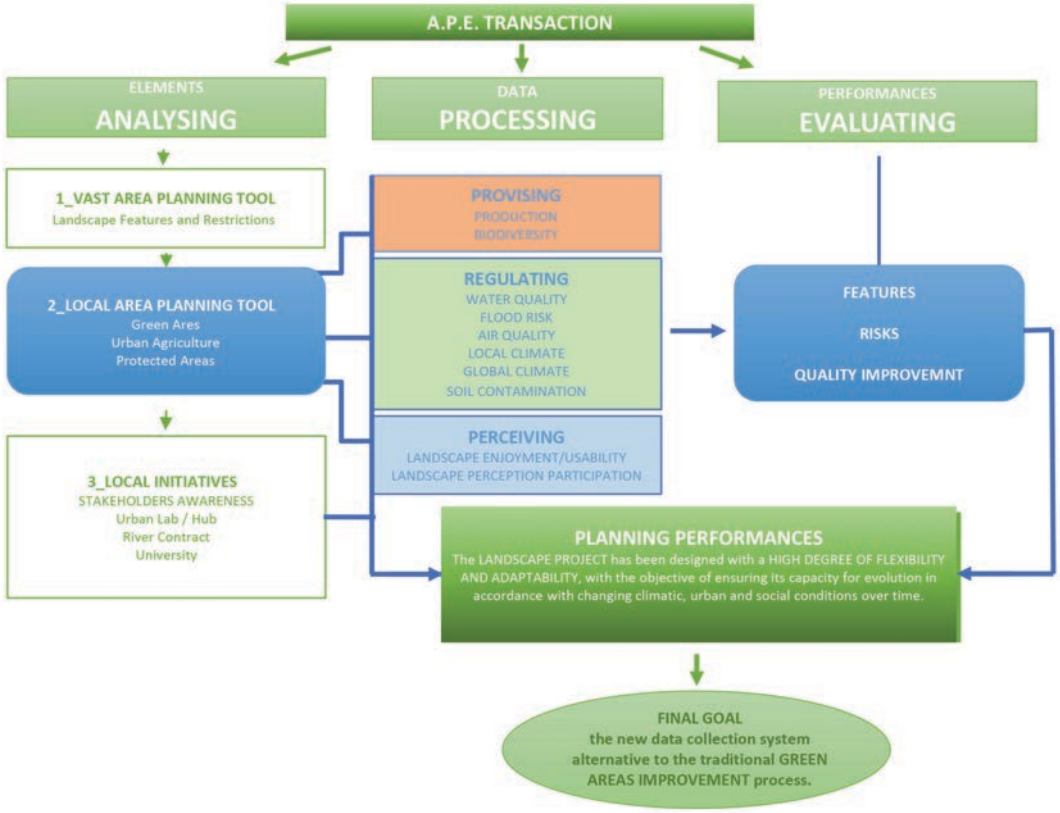


Fig.4 The Methodology's Flow-chart

We started by looking at the current planning rules. This is the first phase of the methodology, which we have named APE Transaction (i.e. ANALYSING - PROCESSING - EVALUATING), or ANALYSING. This forms the basis of the project's intentions: the intentions and forecasts for the area under consideration were extrapolated from the current planning tools.

The second phase, DATA PROCESSING, involved the analysis of survey data using the i-Tree method, which was then divided into three categories: PROVISIONING (relating to impacts on naturalness and therefore to ensuring the conservation of biodiversity and agricultural production), PERCEIVING (relating to the maintenance of aesthetic value and enjoyment) and REGULATING (with regard to water elements, and therefore the river, soil and air).

The synergy between these two phases is instrumental in identifying the site's fundamental requirements, which subsequently serve as the foundation for the landscape design.

The third phase, EVALUATING, will be initiated upon the conclusion of the design phase, with the objective of preserving characteristics and mitigating risks. This phase will also entail the delineation of avenues for enhancing the quality of the sites.

Data analysing and processing

In summary, with regard to the initial phase of ANALYSING, the starting point was an evaluation of the prevailing planning regulations for the area under study.

- Firstly, an analysis was conducted of the Regional Landscape Plan, which is the planning tool for the wider area. As previously outlined in paragraph 2, the landscape plan pertains to those geographical areas within the territory that possess distinctive characteristics derived from natural environment, human history, or the complex interrelationships between these elements. The primary objective of

landscape protection and enhancement is to preserve the values it embodies as tangible expressions of identity, as articulated in Article 131 of the aforementioned Code of Cultural Heritage and Landscape. In particular, the Lazio Region Plan, which was finally approved in 2021 (Regione Lazio, 2021), regulates landscape management methods, indicating the relevant actions aimed at conserving, enhancing, restoring or creating landscapes. The Plan acknowledges the landscape as a vital component of the community's living environment and promotes its enjoyment.

In the case study area, among the Landscape Assets identified in the Map B "Landscape Goods, Art. 134, para. I, letters a), b) and c) of Legislative Decree 42/2004, scale 1:25,000", the following are highlighted for the purpose of "protecting areas of archaeological interest": the Salone quarries and Latomie (mp058_1962 and mp058_2029), the remains of an ancient bridge (mp058_2084), a rock tomb (mp058_2030), several areas of pottery fragments (mp058_2028, mp058_2031, mp058_2033) and an ancient quarry (mp058_2032) as individual elements; for the latter, a precise area (ma058_0124) is also indicated, for which a proposal for restriction is currently being studied.

In the Map C "Natural and Cultural Heritage Assets, Articles 21, 22, 23 of Regional Law 24/98, scale 1:25,000", the quarries are recognised as an important Complex of the Latomie di Salone (pv_138; pv_142) among the Natural and Cultural Heritage Assets, and among the Historical Monumental Heritage Assets, a roadman's house on the Via di Salone (spm_0437) and a fountain (spm_0435).

With regard to the entire area surrounding the river, which constitutes the heart of the study area, in the Map A "Landscape systems and contexts Articles 135, 143 and 156 of Legislative Decree 42/2004 Scale 1:25,000" designates it as a Natural Landscape of Continuity for the Landscape Plan. No value is ascribed to it from an agricultural perspective.

- Subsequently, an analysis was conducted at the local level. The present Master Plan of the Municipality of Rome, which was approved in 2008, was then subjected to scrutiny. However, in 2016, a "final redesign" was formulated, particularly with regard to the "prescriptive documents" examined in this study (Comune di Roma, 2016b). The documentation under consideration is entitled "Systems and Rules". The tables, which are presented at a scale of 1:10,000, stipulate the methodologies and regulations for the transformation of the municipal territory in its entirety, meticulously categorised according to city and system. This classification encompasses the following categories: "Historic city", "Consolidated city", "City to be renovated", and "City undergoing transformation". These categories pertain to settlement, environment, services, and infrastructure systems, respectively. With regard to the Settlement System, the area falls within the "city to be redeveloped" classification. Areas have been identified within it whose intended use is linked not to residential purposes but to commercial activities. With respect to the Environmental System, the area surrounding the river is predominantly designated as agricultural land, with the exception of the portion of territory encompassing the Salone quarries, for which there are plans to intervene with a project linked to the utilisation of public and private green spaces.
- Finally, the aspirations articulated during the River Contract process were duly considered. The Aniene River Contract was initiated in 2018 following the endorsement of a Statement of purpose, while the preliminary phase, involving the organisation of forums, public meetings and consultation tables, commenced in 2002. The conclusion of the final signing in 2022 signifies the culmination of an extensive and intricate participatory process, which has contributed to the dissemination of a perception of the river and its environs as a distinctive entity encompassing nature, culture and daily life. Concurrently, this process has facilitated the cultivation of an identity that is intrinsically linked to the river.

The Aniene River Contract is predicated on the attainment of four overarching objectives: namely, mitigation and adaptation to hydrogeological risks, environmental improvement, sustainable utilisation of environmental resources, and the promotion of tourism and recreation in the area. In particular, the initiatives concerning the study area, which have been planned but not yet implemented, include measures to extend the Aniene Protected Area from the Great Ring Road to Tivoli (BV.02), riparian and urban reforestation along the ecological

corridor of the Aniene Reserve (BV.03.c), systematisation, completion and participatory management of the recreational networks along the ecological corridor of the Aniene Reserve (BV.04.a), and creation of a cycle and pedestrian path along the left bank of the Aniene River from Cervelletta to Lunghezza (BV.04.n and BV.04.p) (Contratto di Fiume per l'Aniene, 2022).
Consequently, Tab.1 was devised, encompassing the elements pertinent to delineate the salient features of the case-study area. The following essay will provide a comprehensive overview of the relevant literature on the subject.

	CATEGORY	ELEMENT	DESCRIPTION
VALUE	**VN** **NATURE** ELEMENT	**The Aniene River**	The 120 km course of the Aniene River, from the Simbruini Mountains to the Tiber, is then followed by a substantial stretch that is included in the 'Valle dell'Aniene' Regional Nature Reserve, continuing on towards Tivoli.
	VL **LANDSCAPE** ELEMENT	**Roman Tuff Quarries "Latomie di Salone"**	Of considerable value (the discovery of the quarries from the description of the itineraries to the sharing of the routes in scenic landscapes, including the lakes). Classified as Geosite No. 66 of the Lazio Region: "Roman quarries of Tufo Lionato in Via di Salone".
	VA **AGRICULTURAL** ELEMENT	**Agricultural areas near the "Tenuta del Cavaliere"**	The geographical area under consideration is predominantly agricultural, albeit with ambiguous identification. The property is situated in close proximity to one of the two farms overseen by Roma Capitale, in conjunction with Castel di Guido.
DETRACTOR	**DA1** DETRACTOR RELATED TO **ANTHROPISATION**	**The Urban Residential Fabric**	The residential area known as 'Case Rosse' (Red Houses) is a prominent feature. The settlement, which began as a spontaneous development, was later established.
	DA2 DETRACTOR RELATED TO **ANTHROPISATION**	**The Industrial Fabric**	The Tiburtina area has historically been distinguished by the presence of industrial facilities, a phenomenon that can be partly attributed to its strategic location in proximity to the Aniene River, which has played a pivotal role in the transportation of goods.
	DA3 DETRACTOR RELATED TO **ANTHROPISATION**	**Road and Rail Infrastructures**	High-impact infrastructure: The railway in question is the Rome-Tivoli section of the Rome-Sulmona-Pescara railway, which was constructed in 1887. The Grande Raccordo Anulare (Great Ring Road), constructed in 1946, is a notable example of infrastructural development. The construction of the A24 Motorway commenced in 1990, encompassing the Tangenziale Est - Barriera di Lunghezza section.

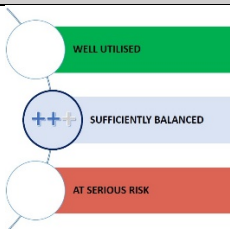
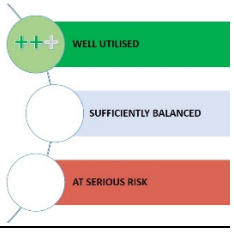
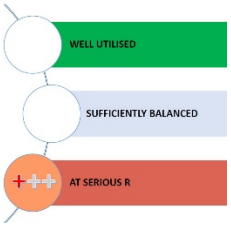
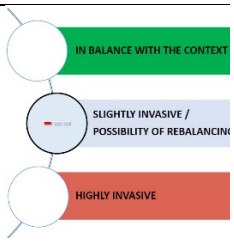
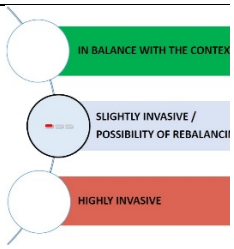
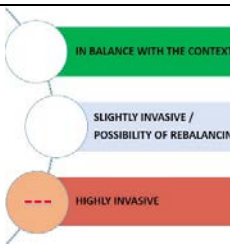
Tab.1 Elements involved to define main features (derived from Planning Tools and River Contract Proposals)

Furthermore, the NCPT model was employed to analyse the following elements, which are then reported in Tab.2:

CATEGORY	N	INDICATOR	DESCRIPTION
PROVISING	1	Harvested products	Impact on the production of food and timber
	2	Biodiversity	Impact on Biodiversity Action Plan (BAP) priority habitats and habitat connectivity
PERCEIVING	3	Aesthetic values	Impact on the visual amenity of a site or landscape
	4	Recreation	Impact on the availability and accessibility of public greenspace
REGULATING	5	Water quality regulation	Impact on water quality improving vegetation
	6	Flood risk regulation	Impact of vegetation on water storage capacities and water run-off
	7	Air quality regulation	Impact on vegetation contributing to air quality
	8	Local Climate regulation	Impact on cooling vegetation reducing the Urban Heat Island Effect (UHIE) - climate change adaptation
	9	Global climate regulation	Effect on carbon stored in soil & vegetation - climate change mitigation
	10	Soil contamination	Impact on risks to human health due to soil contamination

Tab.2 NCPT Elements involved to define main features (derived from Land Cover) 10 INDICATORS

These elements were subsequently documented in the VL_{CS} and VA_{CS} entries and the conclusions and assessments of this phase are shown in Tab.3.

	CATEGORY	ELEMENT	SCORE
VALUE	**VN$_{CS}$** **NATURE ELEMENT**	**The Aniene River** In the ***Regional Landscape Plan***, the buffer zone of the landscape restriction, which covers the river and its banks for 150 metres on both sides, is identified, but the coexistence of intrusive factors within it is ignored. In the ***Master Plan of the Municipality of Rome***, the river is merely indicated on the map. The initiatives of the ***Aniene River Contract*** are important, although they have not yet been funded.	
	VL$_{CS}$ **LANDSCAPE** ELEMENT	**Roman Tuff quarries "Latomie di Salone"** The ***Regional Landscape Plan*** places particular emphasis on the quarries and the numerous elements of archaeological interest that are located in the vicinity of the river. The ***Master Plan of the Municipality of Rome*** encompasses a range of activities for the utilisation of the sports lakes, with the private section being a notable component.	
	VA$_{CS}$ **AGRICULTURE** ELEMENT	**Agricultural areas near the "Tenuta del Cavaliere"** The ***Master Plan of the Municipality of Rome*** delineates the entire area surrounding the river as agricultural land. Conversely, the ***Regional Landscape Plan*** designates it as a natural landscape characterised by continuity.	
DETRACTOR	**DA1$_{CS}$** DETRACTOR RELATED TO **ANTHROPISATION**	**The Urban Residential Fabric "Case Rosse"** The ***Master Plan of the Municipality of Rome*** fails to address the impact of the large residential complex on the natural area.	
	DA2$_{CS}$ DETRACTOR RELATED TO **ANTHROPISATION**	**The Industrial Fabric "Tecnopolo Tiburtino"** The ***Master Plan of the Municipality of Rome*** identifies the entire area within the "Cities to be renovated" system, whose intended use is linked not to residential but to commercial activities.	
	DA3$_{CS}$ DETRACTOR RELATED TO **ANTHROPISATION**	**Road infrastructure: Connection to the A24 Motorway** In the ***Master Plan of the Municipality of Rome***, the presence of major motorway infrastructure is merely indicated on the map, with its associated influences being overlooked.	

Tab.3 Elements involved for the case-study area (CS = CASE-STUDY)

In the subsequent phase of DATA PROCESSING, the survey data were analysed using the NCPT method. As outlined in the methodology description, the data were divided by purpose, categorised as follows: PROVISIONING (indicators 1 and 2), PERCEIVING (indicators 3 and 4), and REGULATING (indicators 5 to 10). The results of this will be described after the contents of the project proposal have been presented. For this purpose, a comparison will be made between the initial state of the sites (before) and the final state once the project has been completed (after), in order to measure the change achieved.

The project proposal for the case-study area

The project is thus the result of a concept aimed at the enhancement of a fragmented area that is rich in potential. The objective of this initiative is to facilitate the integration of the fragments of Via Salone and Case Rosse through an approach that is not prescriptive, but rather encourages discovery, reflection, and the exchange of ideas.

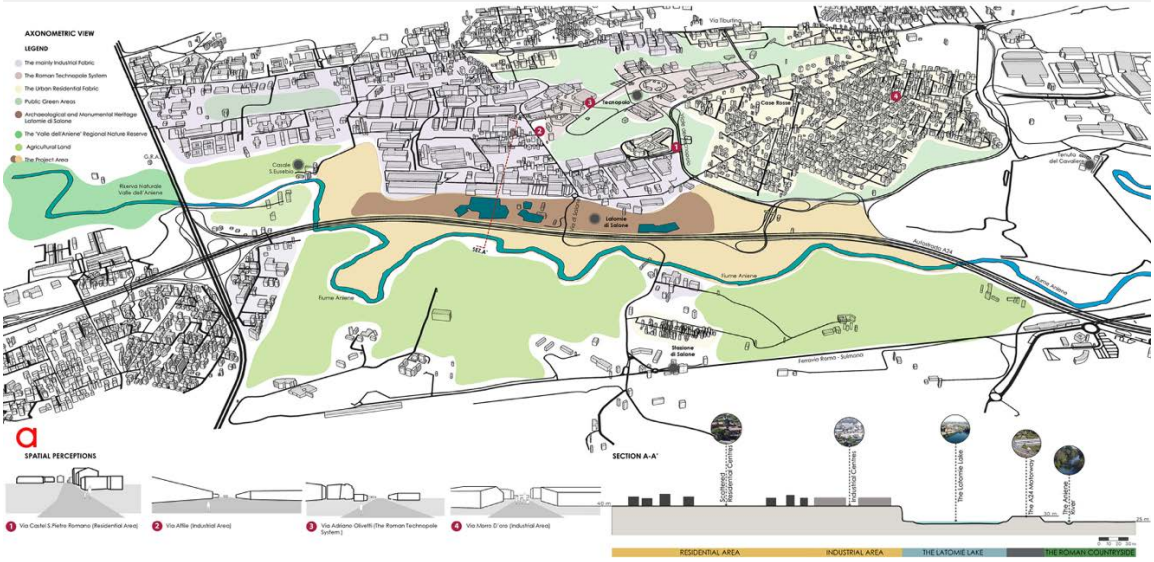


Fig.5a Current relations with the surrounding context

Fig.5b The project master plan

The project has been designated. The concept of "non-authoritarian encouragement to discover the Latomie" is a theoretical framework that aims to promote independent learning and personal growth in a non-coercive manner. The objective of the project is to promote the non-authoritarian exploration of the area, with a particular focus on the Latomie di Salone and the banks of the Aniene River, extending from Casale Sant'Eusebio to Tenuta del Cavaliere. This exploration is facilitated through the implementation of daily actions deemed essential for social functioning. The objective of the present study is, therefore, to assess the recovery and enhancement of a territory that has been fragmented over time by large infrastructure projects and uncontrolled building. This constitutes the core of the project, which is driven by the objective of unveiling the latent value of a region that, at present, appears to be significantly underutilising its full potential.

The analysis, as delineated in the methodology, is conducted on two levels: the broad level, which leads to an exploration of the wider context, and the local level, which allows for a detailed examination of the specific characteristics of the area, thereby addressing the challenge of integrating the various urban fabrics and the landscape.

A thorough analysis of the urban planning tools employed within the broader region has revealed that, over the course of approximately a century, the territory has undergone significant fragmentation as a consequence of urban planning and infrastructure decisions. Comprehension of this process is imperative for the understanding of the present and the capacity to imagine the future.

Local-level analyses yielded an in-depth understanding of the relationships between the Salone area and its environs, encompassing spatial perceptions, resources, and critical issues. The site visits facilitated a comprehensive understanding of the area's potential and the challenges it faces.

This location, which has been instrumental in preserving an age-old tradition, is further elaborated through the experience of the River Contract, a pivotal instrument in the revitalisation of the Aniene River's banks. An opportunity for recovery, but also for cultural rebirth.

Finally, the i-Tree method made it possible to assess the impacts in terms of ex-post ecosystem services, in order to estimate the extent to which the project proposal promotes the development of the context of the intervention.

Based on the above analyses, the project had two priority objectives: to increase greenery design, thereby improving ecological function, and to increase the perception and enjoyment of the sites.

Both following figures show the current state (see Fig.5a) and the planned state (see Fig.5b), respectively.

The following paragraph of the Results section therefore describes the EVALUATING phase.

4. Results and discussion

The current state of the area reflects the consequences of anthropisation processes. Some parts appear degraded and marginalised, characterised by abandonment, the accumulation of industrial waste and illegal dumping. The physical isolation of certain areas and their proximity to informal settlements have accentuated the perception of insecurity, transforming the territory into a vulnerable place from an environmental and social point of view. The agricultural system has also undergone a progressive weakening: the fields between the Great Ring Road, the Case Rosse industrial area, the motorway toll booth and the banks of the Aniene river are fragmented, partly abandoned and difficult to use. Incorrect agricultural practices and settlement pressure have triggered degradation processes that compromise soil functionality, often irreversibly.

Another critical issue is accessibility. Physical barriers, fences and closed underpasses limit internal connections, while the prevalence of private property hinders access to sites of high historical and archaeological value, such as the Latomie di Salone, the Casale di Sant'Eusebio and the Tenuta del Cavaliere. The result is an area marked by physical and social barriers, where cultural and natural potential remains hidden and difficult to exploit.

Conversely, the project constitutes a component of a comprehensive strategy for mitigating climate change. The increase in CO_2 and pollutants, which has been caused by anthropogenic emissions, has had consequences for public health and the urban climate. In this context, urban greenery plays a pivotal role in reducing temperatures, sequestering carbon and enhancing air quality. Trees are known as 'green lungs' due to their ability to retain fine particulate matter, absorb pollutants and accumulate carbon dioxide throughout their life cycle. Furthermore, through processes such as shading and evapotranspiration, they contribute to the mitigation of the so-called "heat island" effect, thereby enhancing the liveability of urban spaces. The presence of vegetation is therefore also crucial for soil protection, as it reduces erosion and increases the infiltration capacity of rainwater.

Finally, it should be emphasised that, from a design perspective, significant results have been achieved in terms of improving quality of life. The interventions are summarised in Fig.6a below: the first milestone

achieved is undoubtedly the increase in greenery. The main action (the Urban Forest) was aimed at designing the greenery of the large area with afforestation and the creation of a new mosaic of vegetation.
The second key element of the project was the creation of paths, in which nature also highlights the connection with the existing reserve (on the left), the archaeological site to emphasise the presence of the Latomie, and a network of cycle and pedestrian paths to increase the connection with the residential area of Case Rosse and the station providing access from the centre of Rome.

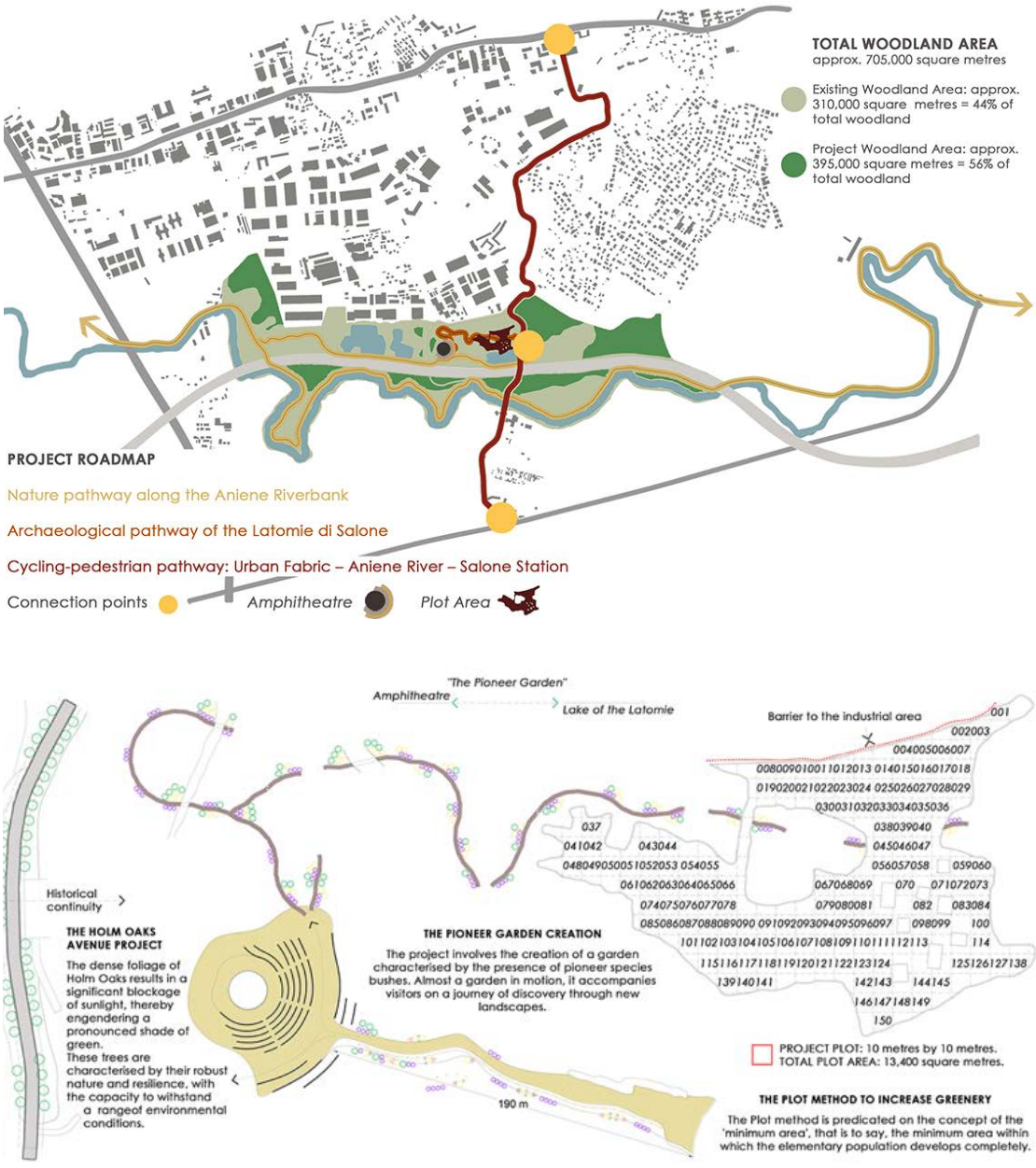
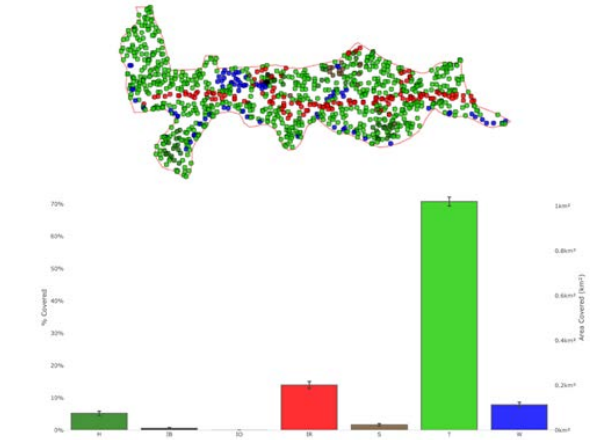


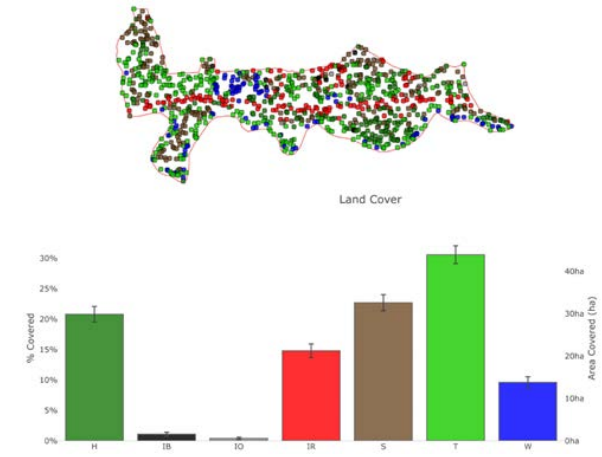
Fig.6 Areas with greater benefits. 6a. Overall view of the new connections, on the left with the existing reserve area, in the centre the area intended for recreation, which reconnects to the naturalistic system to the south and the settlement system to the north; 6b. The Amphitheatre - The Pioneer Garden - The Latomie Lake Network

These are nature pathways on compacted earth, which follow historic agricultural tracks and will connect the Aniene Valley Reserve to the Tenuta del Cavaliere estate. Inside the Latomie, the creation of an archaeological trail using modular and removable platforms will allow visitors to enjoy the site while protecting its heritage. An additional cycle and footpath will connect residential areas, the industrial area, the river and the Salone railway station, promoting sustainable mobility and slow enjoyment of the landscape.
The central part of the project involves creating the amphitheatre and the Pioneer Garden. This will be achieved by restoring the soil covering the Latomie through depaving — the demolition of the asphalt paving in the area

adjacent to the industrial buildings — and subsequently planting pioneer species. As regards the recreation area, the design methodology adopted is that of plots, based on the concept of minimum area. This approach allows the intervention to be divided into monitoring units, simplifying the operational phases and allowing precise control of ecological processes. In an initial artificial phase, the asphalt will be removed and replaced with topsoil, where cuttings and seeds will be placed. Subsequently, the natural process will guide the progressive spontaneous colonisation, stimulating biodiversity dynamics and initiating a cycle of ecological succession that will turn the area into a living laboratory of environmental regeneration (see Fig.6b).
The results of the study are presented in Tab.4.



		ANTE		
Abbr	**Cover Class**	**Points**	**Cover %**	**Area [km²]**
H	Grass/Herbaceous	208	20.80	0.29
H	Impervious Buildings	11	1.10	0.01
IO	Impervious Other	4	0.40	0.00
IR	Impervious Road	148	14.80	0.21
S	Soil/Bare Ground	227	22.70	0.32
T	Tree/Shrub	306	30.60	0.43
W	Water	96	9.60	0.13
Total		1,000	100	1.436



		POST		
Abbr	**Cover Class**	**Points**	**Cover %**	**Area [km²]**
H	Grass/Herbaceous	53	5.19	0.07
H	Impervious Buildings	6	0.59	0.01
IO	Impervious Other	0	0,00	0.00
IR	Impervious Road	143	13.99	0.20
S	Soil/Bare Ground	17	1.66	0.02
T	Tree/Shrub	723	70.74	1.02
W	Water	80	7.83	0.11
Total		1,022	100	1.44

Tab.4 Ante-Post Comparison (Integrated Ecosystem Services Assessment, i-Tree & NCPT-based)

All of the above actions were verified in terms of the benefits they would bring to the area in question. A comparison was made between the state of the sites and the project forecast, with the resulting data being generated using i-Tree Canopy. The findings indicate that the project will result in a reduction of more than 50% in air pollutants (PM10 and PM2.5), whilst also enhancing quality of life and promoting the implementation of plant and animal biodiversity, as shown in Tab.5a, 5b and 5c. These tables present a before-and-after comparison of the effects/benefits of the project.

	ANTE		POST	
Description	**Carbon (t)**	**CO_2 Equiv. (t)**	**Carbon (t)**	**CO_2 Equiv. (t)**
Sequestered annually in trees	105.46	386.70	243.82	894.00
Stored in trees (Note: this benefit is not an annual rate)	3,376.94	12,382.10	7,807.08	28,625.97

Tab.5a Tree Benefit Estimates: Carbon (Metric units)

		ANTE	POST
Abbreviation	**Description**	**Amount (kg)**	**Amount (kg)**
CO	Carbon Monoxide removed annually	38.38	88.72
NO2	Nitrogen Dioxide removed annually	171.58	396.67
O3	Ozone removed annually	1,922.17	4,443.83
SO2	Sulfur Dioxide removed annually	78.29	181.00
PM2.5	Particulate Matter less than 2.5 microns removed annually	97.03	224.33
PM10*	Particulate Matter greater than 2.5 microns and less than 10 microns removed annually	483.14	1,116.97
Total		2,790.59	6,451.51

Tab.5b Tree Benefit Estimates: Air Pollution (Metric units)

		ANTE	POST
Abbreviation	**Benefit**	**Amount (kl)**	**Amount (kl)**
AVRO	Avoided Runoff	8.64	19.97
E	Evaporation	572.43	1,323.38
I	Interception	574.13	1,327.32
T	Transpiration	619.53	1,432.29
PE	Potential Evaporation	3,522.79	8,144.28
PET	Potential Evapotranspiration	2,507.06	5,796.02

Tab.5c Tree Benefit Estimates: Hydrological (Metric units)

Finally, Tab.6 correlates changes in land cover (from i-Tree Canopy) with the 10 ecosystem services analysed using the Natural Capital Planning Tool (NCPT) and highlights the changes that the project has produced.

NCPT CATEGORY	RELATIONSHIP WITH LAND USE (ante/post)	CHANGE	
1. Harvested Products	Not directly affected by the intervention.	≈	situation unchanged
2. Biodiversity	Greater habitat diversity thanks to increased vegetation.	↑	expected change
3. Aesthetic Values	A greener, more structured landscape improving visual perception.	↑↑	positive increase
4. Recreation	New green spaces increasing usability and quality of life.	↑↑	positive increase
5. Water Quality Regulation	Trees doubling the capacity to remove atmospheric pollutants.	↑↑↑	positive increase
6. Flood Risk Regulation	Tree covering helps locally, even if not compensating for hydraulic risk.	≈	situation unchanged
7. Air Quality Regulation	Trees doubling the capacity to remove atmospheric pollutants.	↑↑↑	positive increase
8. Local Climate Regulation	Reduction of bare soil and increase in trees improve permeability.	↑↑	positive increase
9. Global Climate Regulation	Increased shading and evapotranspiration, heat island mitigation.	↑↑	positive increase
10. Soil Contamination	Not directly affected by the intervention.	≈	situation unchanged

Tab.6 Relationship between Land Use and Ecosystem Services

A comparison of the radar charts indicates that the most significant impacts are in the categories of aesthetic values and recreation. This suggests that the project was strongly oriented towards improving the landscape perception of the area and increasing its usability by the community. Although to a lesser extent, there are positive effects on biodiversity and crop production, indicating a certain focus on enhancing the natural component. Key categories such as local and global climate regulation, air quality, water quality, flood risk regulation and soil contamination still show relatively low values, but an improvement can be seen compared

to the initial situation. Although these ecosystem benefits have not reached high levels, there is a positive trend indicating a first step towards strengthening the environmental functions of the area. (see also Fig.7).

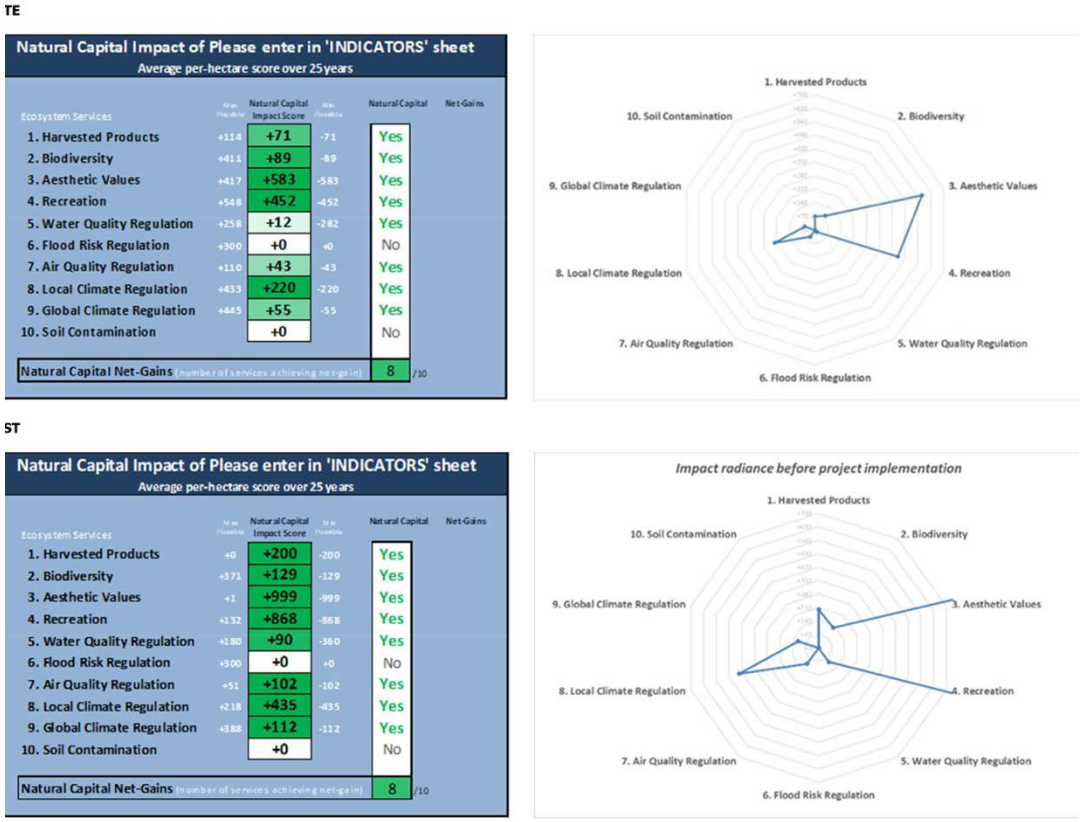


Fig.7 Report NCPT for the case-study area

The ex-post analysis highlights a clear improvement in natural capital following the intervention. Tree cover has more than doubled, significantly reducing bare soil and herbaceous surfaces. This has led to substantial gains in carbon capture and storage, air pollutant removal, and microclimatic and hydrological regulation. Cultural ecosystem services (aesthetic and recreational values) have also been enhanced, with expected benefits for quality of life and the social use of spaces. Only flood risk regulation shows no significant change. Overall, the intervention has generated a net and measurable gain in ecosystem services, contributing to environmental resilience and community well-being. These results highlight how nature-based interventions can effectively strengthen environmental resilience and generate tangible benefits for human well-being.
The following section seeks to provide a rationale for the outcomes observed by way of an examination of the individual interventions incorporated within the scope of the project (cfr. Tab.7).

5. Conclusion and remarks

The methodology described in this study was tested on a section of the Aniene River in the Municipality of Rome. The study was conducted with the aim of integrating the concepts of landscape restoration with the improvement of river areas.
The analysis of the area under study, based on site inspections and urban planning documentation, highlights a condition of profound fragmentation that has become stratified over time. This phenomenon can be attributed to the historical and functional evolution of the area, which has undergone a transformation from a natural landscape into a rural landscape, akin to the Agro Romano. Over time, the area has gradually become home to industrial and residential settlements, and more recently, a business centre.

ACTIONS	IMPACTS ON NATURAL CAPITAL CHANGES *		
	PROVISING INDICATORS (1-2)	PERCEIVING INDICATORS (3-4)	REGULATING INDICATORS (5-10)
AFFORESTATION 	**=/+**	**+/+**	**++++++**
Action_ Increase in green areas. Renaturalisation and enhancement of vegetation in sensitive areas (rivers, lakes) and ecological restoration of abandoned areas. This action has also led to an increase in **VN** value. **Action_** Recovery of agricultural areas no longer in use through the planting of trees and shrubs and soil regeneration. This action has also led to an increase in **VA** value**.**			
ARCHAEOLOGICAL PATHWAY 	**=/+**	**+/+**	**+=+++**
Action_ Archaeological pathway for visiting and accessing the tuff quarries, aimed at understanding the historic quarries, with a focus on accessibility and cultural enhancement. This action has simultaneously reduced the impact of Detractor DA2 and produced an increase in **VL** value**.**			
AMPHITHEATRE 	**=/=**	**+/+**	**=====**
Action_ Creation of the Amphitheatre within the sequence: Amphitheatre-Pioneer Garden -Latomie Lake. From here, connections branch off towards both the Aniene River and the Case Rosse settlement. This action has simultaneously reduced the impact of Detractor DA1 and produced an increase in **VL** value**.**			
NATURE PATHWAY 	**=/+**	**+/+**	**+=+++**
Action_ Creation of a nature pathway along the river, continuing on from the existing trail in the Valle dell'Aniene Regional Reserve. This action has also led to an increase in **VN** value**.**			
CYCLING-PEDESTRIAN PATHWAY 	**=/-**	**=/+**	**-=+--**
Action_ Cycle and footpath connecting the residential area of Case Rosse with the natural area (river, lakes and tuff quarries). Gentle connection (on foot/by bike) between residences and natural areas, promoting sustainable mobility and ecological use of the territory. This action has also reduced the impact of Detractor **DA1**.			
DEPAVEMENT 	**=/+**	**+/+**	**++++++**
Action_ Connection systems to overcome infrastructure, green mitigation for panoramic viewpoints and recovery of anthropised soil near the industrial area through depaving and planting of pioneer species cuttings capable of enriching the soil with organic substances over time. This action has also reduced the impact of Detractor **DA3.**			

* (+ Positive, = Neutral, - Negative)

Tab.7 Comparison between Actions and Effects

This succession of transformations has produced a significant landscape discontinuity, which has had an adverse effect on the legibility of the context and generated an uneven territory that is difficult to trace back to a unified system.

The causes of this fragmentation can be traced back to several levels. Geologically, this area is distinguished by the presence of formations of lionate tuff, accompanied by notable variations in elevation that disrupt the integrity of its topographical continuity. Human intervention has had a further impact on this balance. For centuries, the area was exploited as a quarry for building materials, leaving visible and persistent traces. In contemporary times, the construction of large-scale infrastructure projects has further segmented the space. During the 20th century, in response to the demands of mobility and economic development, the construction of the Rome-Tivoli railway, the Great Ring Road and the motorway took place, thereby establishing interconnected infrastructure that facilitated the operational efficiency of the urban system. However, this development resulted in a marked disruption to the cohesion of the territorial landscape.

The project aims to address these critical issues with the goal of recomposing the fragmented territory and restoring a new landscape coherence to the area. Consequently, it is hypothesised that the aforementioned actions have catalysed the regeneration of the area from both an environmental perspective, resulting in widespread renaturalisation, and from an urban and landscape standpoint, where there has been a diminution in the impact of expansive industrial zones and obtrusive large-scale artificial infrastructures.

Moreover, it is hypothesised that the methodology employed can be regarded as validating the project proposal outlined above. This methodology - which, as previously stated, has already been successfully implemented in situations where elements of significant landscape value coexist with intrusive and imposing detractors - can be re-proposed in situations presenting the same conflicts.

The i-Tree method, a software system designed to assess the benefits of planned interventions, has undoubtedly proved a valuable support. However, it is essential to note that integration of this method is necessary, given that a significant proportion of the intervention involves actions to increase the presence of green areas.

The Natural Capital Planning Tool (NCPT) is a decision support model designed to integrate the assessment of ecosystem services into land-use and urban planning processes. Unlike i-Tree Canopy, which focuses primarily on trees and biophysical effects, NCPT takes a broader approach, including ten categories of ecosystem services: provisioning, climate and hydrological regulation, biodiversity, risk reduction, recreational and cultural values, and landscape quality.

Its strength lies in its ability to conduct ex-ante and ex-post analyses, allowing the potential benefits or impacts of a landscape transformation to be estimated and compared with the actual effects subsequently observed. In this way, NCPT is not only an assessment tool but also a guide for the design of sustainability-oriented interventions.

In the case study considered, the application of NCPT confirmed the clear improvement in natural capital following the renaturalisation intervention. In addition to the environmental benefits, the analysis highlighted a strengthening of cultural services, such as recreational use, the aesthetic quality of the landscape and the improvement in the well-being perceived by the community. The only category that did not show significant changes was hydraulic risk regulation, an aspect strongly influenced by geomorphological and infrastructural factors.

The integration of i-Tree Canopy and NCPT therefore constitutes an innovative methodological model for the assessment of ecosystem services. The former provides accurate and quantitative data on the environmental functions associated with trees, while the latter broadens the perspective to include the social, cultural and regulatory dimensions of natural capital.

This synergy makes it possible to:

1. Rigorously quantify the environmental benefits deriving from landscape transformations;
2. Assess the overall impact of land use choices on ecological resilience and human well-being;

3. Orient urban and territorial planning towards nature-based solutions capable of generating multiple and lasting benefits.

The case study demonstrates how interventions to increase tree cover can produce a net gain in natural capital, translating into environmental, social and economic benefits. The integrated use of i-Tree Canopy and NCPT not only allows these changes to be monitored, but also to be leveraged within sustainable planning strategies. In an era characterised by climate crisis and increasing anthropogenic pressure, these tools are essential for promoting territorial policies geared towards resilience and collective well-being.

The necessary additions to the method in this work were identified in the introduction of parameters derived from the interpretation of current urban planning instruments, with particular emphasis on the landscape protection and enhancement plan, an instrument that characterises Italian legislation. However, it also contains interesting suggestions for situations that can also be found in other countries.

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Image Sources

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Fig.5a: Massera F., 2024

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Fig.6a: Massera F., 2024

Fig.6b: Massera F., 2024

Fig.7: NCPT Data Output, our elaboration 2024

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The levels and correlates of paratransit use in Egypt and Lebanon before and during the outspread of COVID-19

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Abstract

Although studies address informal public transportation or paratransit, investigating the behavior and preferences regarding this mode in the Middle East and North Africa has not been proportional to its importance. Furthermore, with the outbreak of COVID-19, the relationship between paratransit use and different behaviors and preferences had to be investigated. Thus, this study aims to determine paratransit use for commute and non-commute purposes during and after the pandemic. The data of this study (N=3,285) is based on a survey conducted in Lebanon and Egypt from 2021 till 2023. The study aimed to answer three questions: how the correlates of choosing paratransit for non-commute travels in Egypt and Lebanon changed during the COVID-19 pandemic compared to before it, how the correlates of choosing paratransit for commute travel in Egypt and Lebanon changed during the pandemic compared to before, and was paratransit use in the four cities of Cairo, Alexandria, Beirut, and Jounieh different before and during COVID-19. The results of Binary Logistic modeling and Chi-square test of independence indicate a significant difference in the level of paratransit use throughout the four cities. Moving forward, these results can regulate and guide policymaking of paratransit use in the MENA region.

Keywords

Urban transportation planning; Paratransit; Public transportation; Covid-19; Middle East and North Africa (MENA)

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1. Introduction

Urban mobility has become a vital aspect of modern city life, complexly connected to socio-economic development, governance structures, and the evolving needs of diverse populations. Distinct urban mobility patterns in developed and less-developed countries exhibit fascinating diversity. Developed nations often feature well-established formal transport systems institutionalized and regulated by the state, reflecting stability and social justice ideals. In contrast, less-developed regions witness the emergence of informal paratransit services, filling in the gaps in public service provision as the welfare states weaken.

Academic discourse has extensively examined paratransit as a transport mode, criticizing issues related to the service such as traffic congestion, environmental pollution, safety concerns, quality of the service, and its regulatory bodies, which positioned paratransit as incompatible with the common urban transport systems. These studies have contributed to the negative perception of paratransit relative to the well-established formal transport services. The literature review offers the study a background and understanding of the dynamics that shape the use of Paratransit. Also, it highlights the common cultural, social, and economic features that influence urban mobility in the major cities representing Egypt and Lebanon, while pinpointing the different challenges these cities face. Furthermore, the review continues to analyze the change in travel patterns in these contexts during the outbreak of the COVID-19 pandemic. Understanding the dynamics of urban mobility before and after worldwide pandemics, specifically the use of paratransit services in these contexts, provides valuable insights into the adaptability of transportation systems and the impact of external shocks on urban mobility patterns. The literature review leads the way to analyze the different levels and correlates of paratransit use for commute and non-commute purposes in Egypt and Lebanon, comparing them before and during the COVID-19 pandemic.

The findings are explored, compared, and justified after clarifying the case study areas, explaining the data collection process, identifying the variables, and specifying the suitable statistical models. The comparative analysis of paratransit usage in the different case study areas of Egypt and Lebanon provides an understanding of how distinct socio-economic and infrastructural contexts shape transportation choices and travel patterns while revealing the common and different findings and the levels and correlates of paratransit use. Furthermore, the COVID-19 pandemic added another level of analysis to investigate the difference in travel patterns and mode choice before and during the pandemic, highlighting the adaptability of transportation systems and, most importantly, the resilience of the paratransit service in meeting the evolving needs of commuters, while facing unprecedented challenges. This study aims to contribute to the broader discourse on urban transportation, offering valuable insights for policymakers, researchers, and urban planners seeking sustainable and inclusive mobility solutions. This document has been meticulously crafted to comprehend the research thoroughly. The process begins with an extensive examination of existing literature, followed by a thorough explanation of how the data was gathered and the subsequent descriptive statistics analysis. The statistical analysis part showcases a rigorous technique, followed by the presentation of the results. Lastly, the research wraps up with a thorough analysis that connects the primary findings and their consequences.

2. Literature review

2.1 Overview

The variation of public transportation modes throughout the world's cities and the adoption of different operating models pinpoints the diversity in the urban mobility patterns between developed and less-developed countries. On the one hand, western and wealthier countries follow the ideal models of the welfare state, acting as the main representative of the 'Public', ensuring stability and social justice through the provision of public goods and services (UN-ESCWA, 2020). As a result, Institutional or Formal public transport operators were considered the main providers of urban mobility services in their cities. Institutional or formal transport

is commonly referred to throughout the literature as the 'scheduled transport services planned by the state's institutions, networks developed to meet the quality standards designed by their authorities and operators with regulated routes and trip fares (Ferro, 2015). Conversely, as the welfare state weakens, especially in the less developed and the global south economies, informal practices move in to fill the public services provision gap. Paratransit services jump in to serve the urban mobility needs of the public (El-Moussawi, 2016). As the prefix Para- in the term 'Paratransit' originates from the Greek meaning of 'next to, besides, alongside, or beyond, the meaning of Paratransit is simply phrased as "transportation service that supplements larger public transit systems by providing individualized rides without fixed routes or timetables" (Paratransit, 2024). Meanwhile, the diversion from formal transport modes to paratransit adds more complexity to the definition. Academic research has mainly focused on pinpointing the complexity of the term: how to define paratransit in different urban contexts and analyze its different forms and urban contexts that affect the correlation between Paratransit and formal transport.

Considered a service that "does not fit the idea of a modern urban public transport system", most Western studies inspired by high-income development plans have criticized and highlighted the dark side of paratransit (Ferro, 2015). Studies by Gauthier & Weinstock (2010), and Cervero & Golub (2011) analyzed the problems associated with an increase in paratransit services ranging from traffic congestion, street chaos, air and noise pollution, and the increase in road accidents, to fare variation, unsafe or dangerous driving behavior or even unlicensed operators. Furthermore, questioning the quality of the service, as utilizing or overloading unsuitable vehicles to meet the increasing needs for mobility while diminishing passengers' comfort within an environment of weak law and regulations enforcement, locates the paratransit service in an inferior position to the well-established formal transport service.

Escalating levels of traffic congestion and environmental problems associated with rapid motorization and the increasing dependency on private transport modes are considered the main challenges that face urban transport planning and management worldwide. More demand for urban mobility is due to inefficient and scarce resources to maintain a decent coverage of public mass-transport services, specifically in less-developed countries. Admitting that the Paratransit sector continues to grow to feed the needs of mobility strongly, studies had to highlight and build on the positive influence of service and analyze its dynamics and advantages, while offering decision-makers and transport planners the ideal measures that regulate and solve the problems associated with the service. Previously ignored, Cervero's (2000) study, for example, carried out at the request of the United Nations Centre for Human Settlements (Habitat), managed to move paratransit into the focus of transport management plans. The study presented a global overview of the characteristics of the informal transport sector around diverse urban contexts worldwide. Furthermore, the in-depth study analyzed different case studies from Southeast Asia cities (ex: Bangkok, Manila, Jakarta) extending to several cities in Africa and South America (ex: Jamaica, Brazil) giving a broader scope of the various shapes, and sizes, forms, land-setting and organizational framework of this influencing sector, while also stressing that these informal services don't only exist in the less developed countries but also commonly exist to some extent in any low-income or remote neighborhoods around the world (Palermo et al., 2025). Ranging from small-sized medium (e.g. motorbikes, Tuk-tuks, tricycles, microbuses, minivans and wagons, minibusses) to fully-sized buses, from licensed or unlicensed operators, from feeders especially in urban compact areas with narrow roads, newly developed or remote urban areas, to trunk servers competing with the institutional transport modes and operating together on the same main routes, from low-performance vehicles driven by individuals, franchises or co-operative operators to convenient, comfortable vehicles, to even environmentally friendly modes like pedal-powered modes (e.g. pedicabs); the study emphasized the benefits of the paratransit, pinpointed the global lessons learned to enhance and regulate the service, while eliminating associated problems (Cervero & Golub, 2011).

2.2 Paratransit in Egypt and Lebanon

Egypt and Lebanon, representing (MENA's) North African and Levant regions, share similar cultural, social, environmental, and political features. Concerning urban mobility, insufficient and unjust transportation systems are common. Abu-Eisheh et al., 2020 in their comparative study between four MENA region countries (Egypt, Jordan, Lebanon & Palestine) to tailor future mobility transition goals, they had to analyze the similar factors and the specific different local contexts that directly shape mobility in each country. Both with a background of increasing social, economic & political injustice, similar governance systems and legislations that are at a far distance from sustainable or even traditional mobility planning, the status reached the following: overlapping or conflicting laws and governmental bodies and involved parties, lack of transparency throughout the decision-making process, high dependency on individual private cars and taxis, lack of active transportation infrastructure. Despite the difference in the modal-sharing systems operating in the two countries, Paratransit became a major public transport service operating, either because of the insufficient, inaccessible institutional public network in Egypt, or its disappearance or limited service throughout the cities of Lebanon.

Lebanon, despite being a small country in size and population compared to Egypt, has had its share of transportation problems that can be considered a unique example of a country that shifted dramatically to 'Informality' as a self-managed practice or community-based of most social services provision (e.g. electricity, water supply, waste collection, and mobility). Starting with 15 years of instability during the Civil war (1975-1990), followed by waves of Syrian refugees from early 2011 in addition to facing its worst economic crisis in 2019, collapsing currency paired with the continuous political tensions followed by the Covid-19 pandemic, this all had its impact on Lebanon's urban transportation patterns (Assaf, 2022). As a result, cities of Lebanon, specifically the capital Beirut and its surrounding suburbs, are considered unequal cities, with clear spatial segregation that has produced uneven mobility and accessibility patterns (Assaf, 2023) Less investment in public transport infrastructure while focusing on improving roads, Beirut has witnessed on one hand, the increasing number of private cars ownership mainly in the wealthier areas, associated with increasing congestion, poor accessibility in other areas, and major environmental problems. On the other hand, the scarcity and unreliability of mass public transport led to the emergence of privately operated transport systems to fill in this wide gap in the mobility service provision. With the lack of large public buses and their operators, taxis, shared taxis, mini-buses, and vans are considered the main public transportation providers (Attari et al., 2020). Either regulated and registered by associations and unions or even operated illegally, these services are referred to as the 'informal transport or paratransit service', differentiating them from the bus services operated by large organizations with fixed routes and schedules (Assaf, 2023).

Conversely, according to international standards, Egypt presents a case of low private motorization percentage, where more than 2.16 billion individuals depended on public transportation in 2019/2020. With the increasing levels of movement, the institutional transport services could not cope alone despite their continuous development and increase in their fleet's frequencies and coverage; informal paratransit services had to take advantage of the rising transport demand. By the end of 2021, paratransit services continued to play a major role throughout Egypt's urban and rural areas, as 45% of the registered buses in Egypt were privately owned compared to 8.5 % owned by government institutions (Galal, 2023).

Although public bus transport operates solely in the two megacities: Alexandria and the Greater Cairo region, private-firm buses and paratransit services still dominate the scene. Considered one of the largest paratransit systems, with vehicles ranging from 14-seaters, 7-seaters, pick-up trucks, and tuk-tuks, paratransit services depended on more than 80,000 unlicensed and unregulated vehicles in Greater Cairo alone (Shaker et al., 2022). A system of Tuk-tuks offering trips through the narrow routes of informal and old compact urban areas, fleets of small and medium-sized vehicles connecting low-income neighborhoods and remote urban areas, with the main routes, or even fleets of vehicles competing with the public buses on the same route, offering more flexible service in terms of frequency of vehicles and stops with comparatively cheaper fares while

contributing to more congestion problems and irresponsible, chaotic driving behavior. Alexandria and Cairo present an example of the complexity of urban mobility in the developing world (Abu-Eishesh et al., 2020).

2.3 COVID-19 pandemic and urban travel behavior

As the number of people infected by the COVID-19 virus worldwide reached nearly 16 million by January 2020, the World Health Organization (WHO) declared it a Pandemic, calling for the world to implement control measures (WHO, 2020). With no protective vaccine or effective medical procedures, countries had to take drastic measures to control the escalating spread of the virus, disrupting regular social and economic human habits. As the world reached a standstill, significant income reduction, high unemployment rates, and the closure of small businesses, investment, and trading disruption were expected. Urban mobility by shared travel modes, air travel, or mass transit was blamed for increasing the risk of vastly spreading the infectious virus worldwide. Countries had to impose mobility restrictions to control the level of virus transmission. Borders between countries, ports, and harbors closed, complete or partial lockdowns, curfews, individuals working and studying and shopping online from home, stopping public transport services, and movement was minimized to essential travel trips (Thombre & Agarwal, 2021; Cirianni et al., 2022). Consequently, research studies focused on the impacts of the COVID-19 pandemic on humanity in general, specifically on the reshaping and change in travel behavior. (Barbieri et al., 2021), In their attempt to analyze the impact of the COVID-19 pandemic on mobility around ten countries representing developing and developed economies, they shed light on the related risk of all transport modes. While examining the different mobility patterns before and during the pandemic restrictions, the study pinpointed the severe disruption and reduction of both commute and non-commute travel. Mass transport modes: airplanes, trains, and public buses had to be widely avoided, as they were considered the riskiest modes not complying with social distancing. Furthermore, the cross-country study stressed that socio-economic inequality, specifically between developed and developing countries, had an impact not only on health risks but also on travel behavior during the pandemic. COVID-19 had the most severe socio-economic impact on the less wealthy countries, with their weak healthcare and economic systems, and non-comprehensive responsive emergency plans. On one hand, this resulted in a behavior shift within the upper and middle class in these countries, depending solely on adequate internet accessibility for remotely working, studying, shopping, and socializing while depending on individual transport (either driver or passenger) and active modes for urgent travel needs. On the other hand, low-income households and informal workers had to continue going to work, especially individuals surviving on a daily income. Thombre & Agarwal (2021) focused on the paradigm shift within urban mobility while analyzing the travel behavior before, during, and after COVID-19 in India. A developing country with a demographic, social, and economic context like Egypt, with densely populated cities where commuters depend heavily on public transport. Based on the uncertainty of how long the pandemic might take to disappear, the study highlighted that individuals (commuters and drivers) had to eventually accept the chance of getting infected in crowded, shared transport modes while deciding to travel. Paratransit, the informal way to travel, had to continue operating, securing the daily income for their drivers' wages, rentals, operational costs, and maintenance, while offering transport services to commuters risking infection while prioritizing their daily essential commute trips.

As the whole world was challenged socially and economically by the new COVID-19 pandemic, Lebanon, on the other hand, was already struggling. A country still not recovered from the effects of the civil war, the country faced one of the worst financial crises from early 2019, continuous political, economic, and social problems, followed by the Port of Beirut Explosion in August 2020 during the COVID-19 pandemic (World Bank, 2021). Lebanon had to rapidly respond like all countries worldwide to the pandemic by imposing strict public health and social measures to hinder the number of cases and hospitalization rates (Abou Hassan et al., 2023) Studies focusing on the shift of travel behavior in Lebanon had to acknowledge the early impact of the economic crisis that continued to affect the behavior and perception of commuters before and during the

COVID-19 pandemic. Hatoum & Barraj (2023) investigated the changes in travel behavior in the Greater Beirut area by analyzing the socio-economic factors that influenced the commuters' mobility decisions early before COVID-19 hit the country. Their study highlighted the decrease in all commuting and non-commuting trips with the prolonged economic crisis, which declined dramatically with the shift to online work and study during the pandemic. Apart from the wealthier urban areas, the economic crisis had already influenced the usage and ownership of private cars, as they could not secure operating, fuel prices, parking, and maintenance expenses; more middle-class commuters had to shift to less-expensive alternative transport modes. With the shift from private cars to other modes of transportation, but faced with poor, unreliable institutional public transport service with limited accessibility, commuters were not offered many choices. Carpooling, car sharing, and even motorcycles were an option for individuals previously using their private cars, shared taxis, and private paratransit services, leading to a higher risk of infection during the pandemic.

3. Methodology

Given the significant role of informal public transport modes in the MENA region, the study had to adopt a quantitative research approach to analyze the behavioral patterns and preferences related to paratransit use in Egypt and Lebanon before and during the COVID-19 pandemic illustrated in Fig.1.

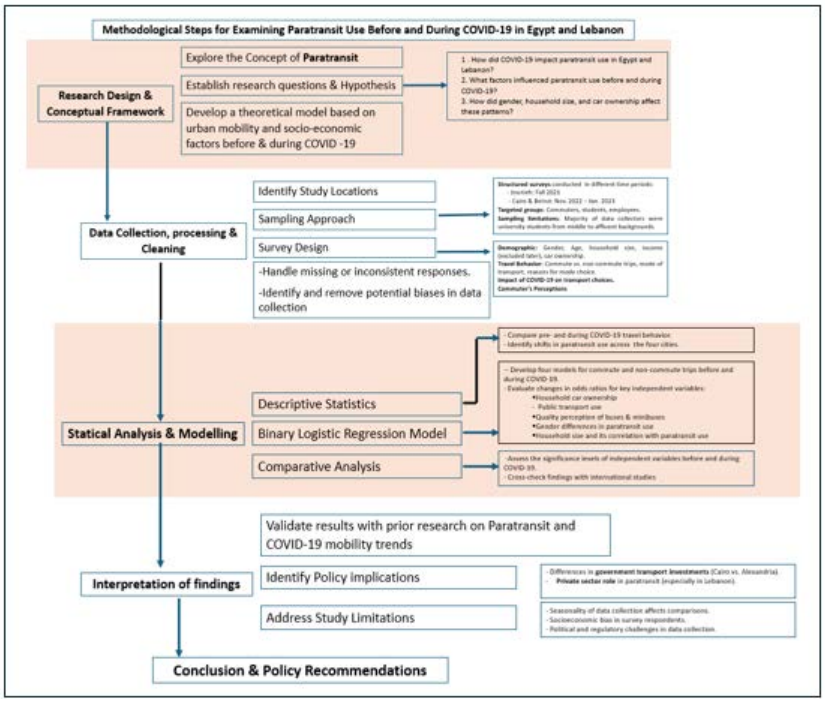

Fig.1 The Methodological steps for examining Paratransit Use before and During COVID-19 in Egypt and Lebanon

3.1 Research questions and hypotheses

The present study provides answers to the following questions: (1) How have the correlates of choosing paratransit for non-commute travels in Egypt and Lebanon changed during the COVID-19 times compared to before it?, (2) How have the correlates of choosing paratransit for commute travel in Egypt and Lebanon changed during the COVID-19 times compared to before it?, and (3) was the paratransit use in the four cities of Cairo, Alexandria, Beirut, and Jounieh different in times before and during COVID-19?

The study hypothesizes that although the levels of paratransit use are different in the case study cities, because of geographical and cultural similarities, the correlations can be considered generally. These socioeconomic and mobility-related correlations have partially changed after the outbreak of COVID-19.

3.2 Case-study cites

The targeted cities of the research, Cairo, Alexandria in Egypt, Beirut, and Jounieh in Lebanon are chosen based on and guided by several specific contextual factors, one of which is the diversity of their residents (ethnicity, religion, gender, etc.), allowing for the highly accurate conclusion of a generic picture. Another is that, like Beirut in Lebanon, Cairo is Egypt's capital and largest city. Like Jounieh in Lebanon, Alexandria is a linear seaside city in Egypt. The population of the case cities is 10.27 million in Cairo, 5.56 million in Alexandria (CAPMAS, 2023), 5.57 million in Beirut, and 150,000 in Jounieh (UN-Habitat Lebanon, 2021). They thus provide a strong foundation for a general sample that will optimize the accuracy of your study. 3,084.67 Km² and 2,818.77 Km², respectively, are the city's sizes (CAMPAS, 2023) and 111.22 Km² and 8.5 Km² (UN-Habitat Lebanon, 2021). These cities also have the most intricate transportation networks and the broadest distribution of paratransit, making them excellent candidates for study and a fantastic source of the data needed. These unique characteristics of cities provide an excellent case study for the usage of paratransit and its correlates both before and during the COVID-19 pandemic. We may learn more about the unique characteristics of these groups and how different factors influence the variations in paratransit behavior for the groups before and during COVID-19 that were chosen for this study.

3.3 Data and variables

This study is based on a general urban mobility survey conducted within the four major cities of Lebanon and Egypt, mainly focusing on the main travel behavior of commuters before and during the COVID-19 pandemic. The data collection for the general survey first started in Jounieh, Lebanon, during the Autumn of 2021. The same study was conducted a year later for three months in Beirut, Lebanon, and Cairo, Egypt, from November 2022 to January 2023. The same set of data was collected from the city of Alexandria, Egypt, over six months starting from November 2022 till May 2023. Furthermore, to guarantee covering the diversity of the social, and economic backgrounds, especially in the large cities of Cairo and Alexandria, the survey was conducted in diverse neighborhoods ranging from compact urban areas near the city center and the historic core to areas offering structured grid patterns mixed with organic urban fabric, to low-density suburban areas located at the peripheries of the city.

The population of Cairo and Alexandria Governorates was recorded as 10,100,166 and 5,469,480, respectively (CAPMAS, 2023). The adult population was 4,720,227 for Cairo, and 2,452,602 for Alexandria according to the 2017 census (CAPMAS, 2023). Furthermore, the estimated population of Jounieh and Beirut in 2022 was 94,000 and 1,870,000, respectively, and the adult population of Jounieh was around 72,000 and Beirut 1,444,500 (ZhujiWorld, 2023). As a result, around 3,285 face-to-face interviews were conducted, between 1,193 in Cairo, 617 in Alexandria, 938 in Jounieh, and 537 in Beirut.

Due to the expectation of high population variability in opinions, perceptions, and misinterpretation of the terms presented in the survey, along with potential inaccuracies during data collection, the margins of error for the sample sizes collected in Cairo and Alexandria were 2.84% and 3.95%, respectively. Adding to these factors, Jounieh and Beirut with a comparatively smaller population, higher margins of error for their sample sizes were 4% and 5%, respectively.

The survey was designed through 39 questions, over six sections that covered the demographic, social, and household profile, mobility and commuting habits, and personal preferences before and during the Covid-19 pandemic, and perception of public transport commuters and ride-sourcing users. The socio-demographic profile is formulated through questions targeting gender, age, employment status, education level, car and house ownership. Diverse and changing commuting behaviors were tested as the respondents were asked, for example, how many commute and non-commute trips were made within the last week. What transport mode was used for commute and non-commute trips, before and during the Covid-19 pandemic? Furthermore, the survey guided the questions to measure the level of satisfaction, perceived security, and perception of

commuters in public transport, in addition to the level of ease while using ride-sourcing applications. The level of satisfaction and perception was answered by a 0-100 numerical scale, where 0 is the lowest and 100 is the highest level. The overall variables generated from this questionnaire are 39, 6 questions focused on non-commute mobility habits before and after COVID-19, and 9 questions focused on commuting determinants before and after the COVID-19 pandemic. The data exploration phase initiated with four dependent variables: paratransit use for commute and non-commute purposes during and after COVID-19, along with 12 variables. Some variables were eliminated during the iteration process, which will be further elaborated in the analysis methods (section 3.4). The variables were quantified according to the methods elaborated in Tab. 1 and 2, and 3, which summarize the frequencies of the dependent variables and their breakdown throughout the four case study cities. Tab.4 shows the descriptive statistics of the continuous variables, while Tab.5 illustrates the frequencies of the categorical variables of the study.

	Variable	Type of variable	Quantification Method
Dependent Variable to be investigated	Paratransit use for non-commute purposes before Covid-19	Dummy	(No) or (Yes)
	Paratransit use for non-commute purposes during COVID-19		
	Paratransit use for commuting purposes before COVID-19		
	Paratransit use for commute purposes during COVID-19		
	Age	Continuous	The reported age of the respondent.
	Household car ownership	Continuous	The reported number of cars owned by the household members.
	Household size	Continuous	The number of household members reported by the respondent.
	Trip generation for commute purposes during the past 7 days	Continuous	The respondent reported the number of trips for commute purposes during weekdays.
	Trip generation for non-commute purposes during the past 7 days	Continuous	The respondent reported the number of trips for non-commute purposes during weekdays.
	Public transport Use	Continuous	The reported number is based on a numerical usage scale from 0 to 100. Which 0 is no usage, and 100 is the highest level of transportation usage
	Evaluation of the quality of buses and minibuses	Continuous	The reported evaluation uses a scale from 0 to 100, where 0 is the worst quality and 100 is the best quality.
	Perceived security when using public transportation	Continuous	The reported perception is using a scale from 0 to 100.
	Gender	Categorical	Female & Male
	Possession of an individual driving license	Categorical	No & Yes
	Commuting to work or study most of the days	Categorical	No & Yes
	Smartphone use for transport purposes	Categorical	No & Yes

Tab.1 Variables used in the study

Variable	Category	N	%
Paratransit use for non-commute purposes during COVID-19	No	3,194	97.2
	Yes	91	2.8
Paratransit use for non-commute purposes before Covid-19	No	3,157	96.1
	Yes	128	3.9
Paratransit use for commute purposes during COVID-19	No	3,206	97.6
	Yes	79	2.4
Paratransit use for commuting purposes before COVID-19	No	3,172	96.6
	Yes	113	3.4

Tab.2 Frequencies of the dependent variables

Variable	Category	Cairo (N=1193)		Alexandria (N=617)		Beirut (N=537)		Jounieh (N=938)	
		N	%	N	%	N	%	N	%
Paratransit use for non-commute purposes during COVID-19	No	1,181	99.0	560	90.8	533	99.3	920	98.1
	Yes	12	1.0	57	9.2	4	0.7	18	1.9
Paratransit use for non-commute purposes before Covid-19	No	1,176	98.6	540	87.5	532	99.1	909	96.9
	Yes	17	1.4	77	12.5	5	0.9	29	3.1
Paratransit use for commuting purposes during COVID-19	No	1,181	99.0	576	93.4	529	98.5	918	97.9
	Yes	12	1.0	41	6.6	8	1.5	20	2.1
Paratransit use for commuting purposes before COVID-19	No	1,175	98.5	560	90.8	529	98.5	908	96.8
	Yes	18	1.5	57	9.2	8	1.5	30	3.2

Tab.3 Frequencies of the paratransit use broken down on cities

Variable	N	Min.	Max.	Mean	Std. Deviation
Age	3,207	12	86	30.63	12.291
Household car ownership	3,206	0	10	1.66	1.26
Household size	3,272	0	14	4.15	1.57
Trip generation for non-commute purposes during the past 7 days	3,194	0	15	2.71	2.03
Public transport use	3,281	0	100	34.77	34.37
Evaluation of the quality of buses and minibuses	3,282	0	100	37.64	27.53
Trip generation for commute purposes during the past 7 days	3,000	0	70	5.86	4.48
Perceived security when using public transportation	2,845	0	100	47.50	32.38

Tab.4 The descriptive statistics of the continuous variables

Variable	Category	N	%
Gender	Missing	1	0
	Female	1,271	38.7
	Male	2,013	61.3
Possession of an individual driving license	Missing	8	0.2
	No	995	30.3
	Yes	2,282	69.5
Commuting to work or study place most of days	Missing	169	5.1
	No	876	26.7
	Yes	2,240	68.2
Smartphone use for transport purposes	Missing	32	1.0
	No	1,234	37.6
	Yes	2,019	61.5

Tab.5 The frequencies of the categorical variables

3.4 Analysis methods

The research utilized Binary logistic regression modeling to explore how the correlation with using paratransit modes for commuting and non-commuting purposes changed during COVID-19 to answer the research questions 1 and 2. A total of four models were designed the first two models ls for the correlations among the use of paratransit modes of transportation as an independent dummy variable for commute and non-commute travels in Egypt and Lebanon, and a set of categorical and continuous variables (e.g., gender, possession of an individual driving license, commuting to work or study place most of the days, use of a smartphone for transportation for categorical variables, and age, household car ownership, household size, trip generation for commute and non-commute purposes during the past seven days, use of public transportation, evaluation of the quality of buses and minibuses, trip generation for commute purposes during the past seven days, and perceived security when using public transportation for continuous variables).

These models have been altered by eliminating insignificant variables to obtain the best model. The best model fit was achieved by eliminating the following variables:

- For non-commute: possession of an individual driving license, perceived security when using public transportation, trip generation for non-commute purposes, trip generation for commute purposes, age, and commuting to work or study place most of the days;
- for Commute: perceived security when using public transportation, trip generation for commute purposes, possession of an individual driving license, commuting to work or study place most of the days, age, perceived quality of buses and minibuses, phone use for transportation.

The other two models have the same structure and were for paratransit use for commute and non-commute before COVID-19. The models were tested using two types of validation testing: the Omnibus test and the Hosmer and Lemeshow test (Archer & Lemeshow, 2006; Badi, 2017). Omnibus testing models with confirmed coefficients of 0.001 with P values of less than 0.05 indicate a valid model fit when using the Omnibus test. P values of more than 0.05 confirm the model validity for the Homser and Lemeshow test.

To answer the third research question, a Chi-square test of independence was performed on the tabular data to test if the levels of paratransit mode of transportation use vary significantly among cities in Egypt and Lebanon. P-values less than 0.05 were considered significant, and values between 0.05 and 0.10 were considered marginally significant. Proportional Reduction in Error (PRE) methods were used to show the association between the tested variables. Since the variables were nominal, Phi was applied to test the levels of association. In contrast, values of less than 0.2 showed a weak correlation, values between 0.2 and 0.4 reflected moderate correlation, and values higher than 0.4 showed a strong association.

4. Findings

4.1 Model fit

To answer the first two questions, four binary logistic models were developed to study how the correlations of using paratransit for commuting and non-commuting purposes changed during COVID-19. With four dependent variables: mode choice for non-commute trips before COVID-19, mode choice for non-commute trips during COVID-19, mode choice for commuting before COVID-19, and mode choice for commuting during COVID-19. The final models include 12 explanatory independent variables. The insignificant variables were eliminated, starting with two models for "during" iterations. P-values greater than 0.10 were considered insignificant. The following independent variables were considered after the alteration process for the four models: gender, household car ownership, household size, public transport use, evaluation of the quality of buses and minibuses, and smartphone use for transportation after the alteration process. Tab. 6 summarizes the four models.

The Nagelkerke R² value (Nagelkerke, 1991) for non-commute travel during COVID-19 is 0.21, indicating that the model explains 21% of the variances of the dependent variables, 22% of the variances of the dependent variables for non-commute travels before COVID-19, 16 % of the variances of the dependent variables for commute travel during COVID-19, and 14% of the variances of the dependent variables for commute travels before COVID-19. Two types of validation tests were performed on the models: omnibus and the Hosmer and Lemeshow Test, as shown in Tab.7. The omnibus test is a statistical concept that analyses the general fit of a model, where the P values for non-commute and commuting during and before COVID-19 are 0.001, confirming the model's validity. In contrast, the Hosmer and Lemeshow Test is used in logistic regression to assess the model's goodness-of-fit to the observed data. The test organizes the data based on estimated probability and compares observed and expected frequencies within these groupings. The null hypothesis states no difference exists between observed and predicted values, where B values greater than 0.05 refer to model fit. The results of P values for the four models were as follows for non-commuting travels during COVID-19: 0.07 for non-commute travels before COVID-19, 0.254 for commute travels during COVID-19, 0.12 for commute travels before COVID-19, and 0.27. These test results reflect the validity of the models.

Variable	Non-commute travels						Commute travels					
	During Covid-19 (Nagelkerke R²=21.2%)			Before Covid-19 (Nagelkerke R²=22.4%)			During Covid-19 (Nagelkerke R²=16.9%)			Before Covid-19 (Nagelkerke R²=14.2%)		
	B	P	β	B	P	β	B	P	β	B	P	β
Gender	-	0.158	-	-	0.330	-	-	0.099	-	-	0.082	-
Gender=Female	22.301	1.000	4,841,859,570	21.926	1.000	3,328,210,275	22.826	1.000	8,185,887,992	-19.731	1.000	≈0
Gender=Male	-0.539	0.055	0.583	-0.345	0.136	0.708	-0.634	0.032	0.530	-0.532	0.025	0.588
Household car ownership	-0.598	<0.001	0.550	-0.523	<0.001	0.593	-0.275	0.058	0.759	-0.252	0.032	0.777
Household size	0.115	0.081	1.122	0.149	0.009	1.161	0.110	0.121	1.117	0.065	0.291	1.067
Public transport use	0.025	<0.001	1.025	0.029	<0.001	1.029	0.029	<0.001	1.029	0.029	<0.001	1.029
Evaluation of the quality of buses and minibuses	-.011	0.025	0.989	-0.009	0.040	0.991	-0.003	0.617	0.997	-0.009	0.029	0.991
Smartphone use for transportation	-	0.009	-	-	0.052	-	-	0.324	-	-	0.574	-
Smartphone use=Yes	1.618	0.043	5.043	1.076	0.176	2.933	1.192	0.133	3.294	0.712	0.361	2.038
Smartphone use=No	0.690	0.009	1.993	0.484	0.029	1.623	0.053	0.842	1.054	-0.093	0.675	0.911
Constant	-4.571	<0.001	0.010	-4.690	<0.001	0.009	-5.203	<0.001	0.006	-4.229	<0.001	0.015

Tab.6 Binary logistic models explaining paratransit use for commute and non-commute trips before and after COVID-19

Non-commute travels						Commute travels					
During Covid-19			Before Covid-19			During Covid-19			Before Covid-19		
X²	df	P	X²	df	P	X²	Df	P	X²	Df	P
Omnibus Test											
148.073	8	<0.001	194.691	8	<0.001	107.254	8	<0.001	114.652	8	<0.001
Hosmer and Lemeshow Test											
14.304	8	0.074	10.159	8	0.254	12.772	8	0.120	9.880	8	0.274

Tab.7 The results of the Omnibus, Hosmer, and Lemeshow Tests for the four binary logistic models

4.2 Correlates of paratransit use for non-commute trips

To answer the first research question, the research compared the results of binary logistic models for non-commute trips before and after COVID-19 to see how the correlations changed during COVID-19 by comparing the significance levels and percentages for the explanatory independent variables.

The findings of binary logistic models for non-commute trips during and before COVID-19 indicate that three independent variables, household car ownership, public transport use, and evaluation of the quality of buses

and minibuses, are significantly correlated with non-commute paratransit use with no change in significance level before and during COVID-19. While the significance level of two independent variables, smartphone use for transportation, changed from marginally significant before COVID-19 to a highly significant correlation with paratransit use during COVID-19, the significance level of household size changed from highly significant before COVID-19 to a marginally significant correlation with paratransit use during COVID-19. The significance level of gender male changed from not significant before COVID-19 to marginally significant during COVID-19, in correlation with paratransit use. The findings confirm the inverse relationship between paratransit use for non-commute travel and male gender before and after COVID-19. At the same time, the percentages of using paratransit modes of transportation for males changed from 34% lower percentages before COVID-19 to 54% lower percentages during COVID-19. Also, each extra car owned by the entire household is correlated with a significantly increased likelihood of not using paratransit modes of transportation for non-commute purposes (52%). This ratio climbed to 59% during COVID-19. On the other hand, each subsequent increase in household size correlates with a significantly higher likelihood of using paratransit modes of transportation for non-commute purposes (15%) before COVID-19. This ratio has been reduced to 11% during COVID-19. Similarly, each increase in public transportation use is associated with a significantly higher probability of using paratransit modes of transportation for non-commute purposes (2.9%) before COVID-19. During COVID-19, this ratio was reduced to (2.5%).

4.3 Correlates of paratransit use for commute trips

To answer the second research question, the same procedure was used as the research went through the results of the binary logistic models for commute trips before and during COVID-19 to compare the results and find out how the correlations changed during COVID-19 by comparing the significance levels and odds for the explanatory independent variables. The findings of the binary logistic models for commute trips before and during COVID-19 revealed that two independent variables: male gender and public transport use are significantly correlated to paratransit use for commute purposes, with no change in significance level during and before COVID-19. While the significance level of two independent variables, household car ownership, changed from being highly significant with paratransit use for commute purposes before COVID-19 to marginally significant during COVID-19, the evaluation of the quality of buses and minibuses changed from being highly significant before COVID-19 to not significant correlations with paratransit use during COVID-19. The findings of the model confirm the inverse relationship between male gender and paratransit use for commute purposes both before and during COVID-19, as the odds of using paratransit for commuting purposes changed from 53% less odds before COVID-19 to 63% less odds during COVID-19 as the male gender increases. Similarly, each additional car owned by the household corresponds with a substantially higher probability of not using paratransit modes of commuting (27%) during COVID-19. However, this number has since fallen to 25% during COVID-19. On the other hand, each increase in public transportation use corresponds with a higher likelihood of using paratransit modes of transportation for commuting purposes (29%) before COVID-19, with no change during COVID-19.

4.4 Paratransit use at the city level

To answer the third research question, a Chi-square test of independence was conducted to explore how the paratransit use in the four cities of Cairo, Alexandria, Beirut, and Jounieh changed during COVID-19.

Tab. 8 shows the results of the Chi-square test of independence, which shows the levels of paratransit use for non-commute trips in the cities are highly significantly different ($P<0.001$). The higher levels of paratransit have probably caused this difference use both before and after the pandemic in Alexandria, where the choice of paratransit is higher than the other three cities (Tab.3). In Alexandria, 12.5% of the respondents used paratransit as a dominant mode before COVID-19, which this figure was 1.4% in Cairo, 0.9% in Beirut, and

3.1% in Jounieh. Paratransit use changed to 9.2%, 1%, 0.7%, and 1.9%, respectively. Likewise, the levels of paratransit use for commute trips in Alexandria were 9.2%, higher than the other three cities (1.5%, 1.5%, and 3.2% in Cairo, Beirut, and Jounieh). These figures were weakened to 6.6%, 1%, 0.9%, and 3.1% during the pandemic.

The results of the PRE-analysis reveal a weak or moderate correlation between city and paratransit use. In other words, the paratransit use changes by changing the city with different strengths for the correlations as the Phi values (as a PRE-measure) represent the strength of the correlation between city and paratransit use where the phi value 20-40% considered as a moderate strength correlation and the Phi values less than 20% considered weak correlation. The test findings confirm a moderate correlation between city and paratransit use for non-commute purposes before COVID-19, which has changed during COVID-19 to a weak strength correlation with city. While the other two variables, paratransit use for commute purposes during and before COVID-19, show a weak strength correlation with the city.

Variable	Pearson X^2 value	df	Two-sided P	Phi
Paratransit use for non-commute purposes during COVID-19	120.33	3	<0.001	0.191
Paratransit use for non-commute purposes before COVID-19	155.08	3	<0.001	0.217
Paratransit use for commute purposes during COVID-19	61.95	3	<0.001	0.137
Paratransit use for commuting purposes before COVID-19	82.16	3	<0.001	0.158

Tab.8 The results of the Chi-square test of independence and Phi values for paratransit use versus city

5. Discussion

The novel coronavirus, COVID-19, has radically transformed travel behavior in urban areas throughout the world. A rapidly rising demand for transport alongside a lack of government response has led to the emergence of a Paratransit mobility sector that works alongside formal mobility systems. This study examined the correlation between independent variables and paratransit transportation use as dependent variables in Egypt and Lebanon before and during COVID-19. The results demonstrate some notable findings that contribute to this understanding. It will also shed light on some findings that need further investigation. One of the findings compared the results of binary logistic models for non-commute or commute trips before and after COVID-19 to see how the correlations changed during COVID-19 by comparing the significance levels and odds for the explanatory independent variables. Non-commute or commute trips during and before COVID-19 indicate that three independent variables: household car ownership, public transport use, and evaluation of the quality of buses and minibuses, are significantly correlated to non-commute paratransit use with no change in significance level before and during COVID-19. The use of private cars instead of transportation increased, and transportation decreased in general during COVID-19. Several studies supporting this finding were carried out in the US (Wilbur et al., 2023; Sevi & Shook, 2022), Germany (Eisenmann et al., 2021), The Netherlands (Chen et al., 2022), Istanbul (Aydin et al., 2022), Switzerland (Molloy et al., 2021), and in various countries around the world (Möllers et al., 2022; De Vos, 2020; X. Chen et al., 2021; Paul et al., 2022; Abdullah et al., 2020).

Additionally, this manuscript's findings confirm the inverse relationship between paratransit use for non-commute or commute travel and male gender both before and during COVID-19. The percentage of males using paratransit modes of transportation changed from 34% before COVID-19 to 54% during COVID-19 for non-commute travel. It changed from 53% before COVID-19 to 63% less during COVID-19 for commuting travel. These results align with travel survey studies conducted in the Netherlands and King County, Washington, USA (Eisenmann et al., 2021).

When comparing the results, each subsequent increase in household size correlates with a significantly higher likelihood of using paratransit modes of transportation for non-commute purposes (15%) before COVID-19. This ratio has been reduced to 11% during COVID-19, which aligns with studies (X. Chen et al., 2021; Molloy et al., 2021).

In the four case-study cities of this study, statistical assessments of paratransit use before and during COVID-19 have identified that presenting these results can assist policymakers in better planning and defining objectives in sustainable transportation and mobility plans. The study highlights the significant difference between the cities in the levels of paratransit use for non-commute trips before Corona, where the choice of paratransit is 12.5% in Alexandria,1.4% in Cairo, 0.9% in Beirut, and 3.1% in Jounieh. Paratransit use changed to 9.2%, 1%, 0.7%, and 1.9%, respectively, during COVID-19. The level of paratransit use for commute trips in Alexandria was 9.2%, higher than the other three cities (1.5%, 1.5%, and 3.2% in Cairo, Beirut, and Jounieh). These figures were weakened to 6.6%, 1%, 0.9%, and 3.1% during the pandemic. It confirms previous findings of a decrease in paratransit use during COVID-19.

Hegazy (2022) explains in his study that one of the reasons for the significant difference between Cairo and Alexandria is that public investments in transportation are focused on the Greater Cairo region, where new types of transportation are diversified. A further explanation is that paratransit is a mode of transportation that can adjust to each place's particular geographic, social, cultural, and economic circumstances, providing greater accessibility for the most marginalized members of society. In cities like Alexandria, paratransit is one of the few viable modes of transportation that can serve inner neighborhoods due to its versatility and relatively simple navigation of minor, uneven roadways, and the road network context (Abdelrahman, 2020; Masoumi, 2019; Shaheen et al., 2023).

Due to political, geographical, and sectarian power dynamics in Beirut, Lebanon, private efforts in paratransit services rose to prominence due to the failure of state-led transport policies. Furthermore, due to the high ownership of cars in Lebanon (Beirut and Jounieh), the choice of paratransit has declined (Chalak et al., 2016; Samaha & Mohtar, 2020).

As the data in Jounieh was gathered earlier in the fall of 2021, the same data was subsequently gathered for a further three months, from November 2022 to January 2023, in Cairo and Beirut; the numbers may not match. Data gathered during the summer months in Jounieh matches the months of Egypt's academic year. Therefore, data collection should occur at several seasons of the year to precisely reflect the true behavior of the commuters. Additionally, a longer duration for the data collection method yields a larger sample size, improving the predictive power of commuter behavior. Additionally, most people who collected the data were employees and students at private universities. 90% of study participants from middle-class to affluent families may represent only a tiny portion of the population. Given that when gathering data, students might not appropriately consider the significance of diversity and social inclusion. This assumption was raised by examining the variables related to household income, size, and number of cars owned. The political climate in every nation presented another challenge for data collection. The unease among street people resulted in some students being harassed by other passengers. Additionally, authorities wanted certain study conductors to confirm that their research was legitimate to their colleagues.

Due to currency fluctuations between Egypt, Lebanon, and the Euro, questions about expenses and income were eventually dropped from the survey. Since the Egyptian pound is the sole currency, the values collected were expressed in Egyptian pounds. It was not confirmed if all the values collected from Lebanon were in US dollars or if any responses were given in Lebanese money. The collected data raised these questions, as well as how the numbers demonstrated a significant difference between Beirut and Jounieh. This rendered all the model's income and expense statistics.

We advise decision-makers, trailblazers, and the transportation industry to use the results and conduct more research to confirm the importance of the criteria. Informal public transit options, or paratransit, are a crucial

component that improves the quality of life in cities on social, economic, and environmental fronts. To maintain accuracy and save time, it is advised that future research have a larger sample size and access to big government data. This will enable the researchers to use more potent parametric tools to analyze data, which will have higher precision in the commuter behavior forecast.

6. Conclusion

The study clarified the concept of paratransit at the beginning, then explored, evaluated, and drew conclusions from the data regarding the study's viability and potential benefits. It also concludes the vision of developed countries for this type of transportation and its negatives. Then it discussed why it spread in developing countries, especially Egypt and Lebanon. It described how COVID-19 has affected the world. Four binary logistic models were developed to examine how the correlations of using paratransit for commuting and non-commuting purposes changed during the pandemic to understand better its impact and the differences between the pre- and post-epidemic periods. The study concludes that COVID-19 has drastically changed how people commute in cities across the globe. During COVID-19, the usage of private vehicles as a form of transportation increased while the use of public transportation fell. A family's likelihood of utilizing paratransit also rose with the size of the family. The research validated the distinction between the Egyptian cities of Cairo and Alexandria and the Lebanese cities of Beirut and Jounieh concerning their dependence on paratransit.

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Urban planning research from 2014-2024: a systematic literature review using text mining techniques

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Abstract
Urban planning is a crucial aspect of city development as it addresses issues such as mobility, environmental concerns, and urban design. The discipline of urban planning has evolved to meet the needs and challenges of urban areas. Recent research on urban planning has focused on understanding the field's interdisciplinary nature, thus integrating aspects of design, policy, law, social sciences, and engineering. The importance of data and digitisation in urban planning as well as urban planning's crucial role in achieving sustainable cities have also been recognised. The current study examines the evolution of urban planning research through a systematic review of the literature (SRL) published between 2014 and 2024, with text-mining techniques being employed for this endeavour. The present SRL is an analysis of a corpus of 65,368 scientific articles published in Scopus. The inclusion of the term 'urban planning' in the title of the article is a fundamental criterion. In addition, a categorisation of words into three primary subgroups was conducted, based on the predominant themes that underpin scientific study and research activities. The subgroups were designated as follows: Research topics, Methods and techniques and Spatial dimensions and place. The results indicate that there is a growing emphasis on interdisciplinary approaches, complex and data-rich information integration. During the observation period, some of these approaches became more stable and significant, particularly for the words included in the Methods and Techniques and Spatial Dimensions and Places groups. For instance, the progressive affirmation of words is closely associated with the implementation of solutions involving spatial information systems and the importance of urban planning in achieving sustainable cities.

Keywords
Urban planning; text mining; research topics

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1. Introduction

Urban planning, also known as town planning, city planning, regional planning, or rural planning, is an activity that includes different steps related to knowledge, decision, management and control of a specific territory's economic, social, and environmental aspects (Papa, 2009). The extension of territory may include metropolitan areas, cities, towns, and rural areas (Batty, 2008). Urban planning aims to ensure the efficient distribution and utilization of resources within the analyzed territories (Haghani et al., 2023).

Urban planning practice involves multiple disciplines to improve the quality of life for the citizens that live in the urban areas (Kepenek et al., 2025). To reach this goal is to create better public spaces and urban environments that balance the built and natural elements. Urban planners aim to address community needs while respecting cultural significance, and they consider sustainable prosperity in urban and regional areas. Over time, urban planning theories and professional activities have evolved, moving beyond physical surveys, design, mapping, and infrastructure engineering to encompass broader social, environmental, and economic issues (Taylor, 1998).

From the beginning of the 20th century, the new methods, techniques and approaches significantly influenced urban planning theories, research, and practice (Row & Jacobs, 1962). Especially in the last decades, the urban planning domain has seen greater inclusion of knowledge from different disciplines. This trend is driven by political transformations, climate change, rapid urbanization, and technological developments. New urban paradigms such as smart growth, compact city, inclusive city, health city, resilient city, and smart city have emerged (Gordon & Richardson, 1997; Gerometta et al., 2005; De Miguel González et al., 2023).

Research and urban planning practice have different timescales for studying and including these new paradigms. Most of the past and current literature on this subject is based on subjective methods, and it is unclear which divisions have persisted, which ones have declined or disappeared, and which urban planning research and practice areas are emerging (Carpentieri & Guida, 2022).

Since 2010, more than 50% of the global population has resided in urban areas, and by 2024, the total urban population was approximately 4.5 billion (World Bank, 2023). By 2050, it is estimated that about 68% of the world's population will live in urban areas (UN DESA, 2018). The World Bank indicates that the level, pace, and processes driving urbanisation are uneven around the world, with significant differences existing between developing (2.6% urban population growth rate) and developed countries (0.8% urban population growth rate). To sustainably manage urban population growth and its related phenomena, technicians must develop appropriate urban planning solutions and tools to support adequately decision processes (De Noia et al., 2024). Additionally, obtaining information about urban areas and their characteristics is crucial to urban planning (Lynch, 1984), with this knowledge encompassing the spatial organisation of urban development, particularly in the context of urbanisation (Levy, 2016). Thus, urban planning is indebted to both the practical application of planning and the academic pursuit of knowledge construction (Pinson, 2004). Castells (2005) identified three key considerations for urban planning that are particularly relevant in the current global context: (a) the planning of mobility and connectivity to address the challenges presented by networked communication and information and communication technologies (Bertolini, 2012); (b) environmental planning as a response to the multi-dimensional nature of urban life, including quality of life and pressing environmental concerns (Myers, 1988; Northridge & Freeman, 2011; Mouratidis, 2021); and (c) urban design and architecture, which aim to imbue meaning in the urban landscape (Ahern 2013; Heymans et al., 2019). Ultimately, urban planning entails the human and social sciences considering a range of problems in urban issues as well as promoting the integration of technicians' and researchers' knowledge with that of specialists in other fields. Researchers have scientifically investigated the different phenomena that are included in urban areas so as to develop new methods and tools to support the process of urban planning (Kapelan et al., 2005).

Throughout history, the discipline of urban planning has continually evolved to meet people's needs and overcome the challenges in the field (Anttiroiko, 2012). The numerous and complex economic, social, and

environmental challenges that will have to be faced in the coming decades in terms of governing urban and territorial transformations will require the use of new approaches that can orient the development of these territorial contexts towards social, economic, environmental, and institutional sustainability (Özkan et al.,2025; Santangelo et al., 2018). Transformation choices and interventions must guarantee citizens an adequate quality of life and conditions that reduce the adverse effects of environmental, social, and economic issues (Sanfilippo et al., 2025).

In the last decades, research on urban planning has undergone significant developments in various areas: (a) there has been a growing emphasis on understanding the interdisciplinary nature of urban planning by integrating aspects of design, policy, law, social sciences, and engineering (Bibri & Krogstie, 2017); (b) the importance of data and digitisation in urban planning as well as the need to incorporate and analyse complex and data-rich information have been recognised (Papa & Fistola, 2016; van Winden & de Carvalho, 2017); (c) the patterns and dynamics of urban agglomeration and dispersion have been explored, with a particular focus on population density and development policies (Johnson & Munshi-South, 2017); (d) the crucial role of urban planning in achieving sustainable cities has been increasingly acknowledged, with an emphasis on overcoming social, economic, and environmental challenges (Gargiulo & Russo, 2017); and (e) there has been increasing awareness of the impact of urbanisation on the quality of life of various categories of citizens, particularly those who are vulnerable (Barquilla et al., 2023; Guida & Carpentieri, 2021).

This study seeks to understand how the state of knowledge for urban planning discipline has evolved and the modification of its relationship with other topics of interest in urban areas in the international scientific debate. The study proposes an alternate perspective on the development of urbanization studies and presents a systematic bibliometric analysis of published urban planning in the last decade. This analysis aims to reveal categorical, temporal, and geographical patterns in scientific. The significance of the study for the discipline is highlighted by the consideration that the findings could also help identify future urban planning trends in the scientific research sector and urban planning practice.

This article examines the past trajectories of urban planning research from a scientific standpoint using a systematic review of the literature on urban planning. This study's main focus was on the past decade's publications (2014-2024), but the literature analysed starts in 1926, when the oldest article included in this SLR was published. Scopus database was used as the source of analysed data. It is structured as follows: Section two focuses on the text mining methods and techniques used for systematic literature reviews (SLRs); Section three describes the data collection process, which entailed obtaining research from the Scopus database published between 2014 and 2024; Section four describes the steps taken in the analysis and the specific software used for this; Section five presents the results obtained from the text analyses; and the last section discusses the results and conclusions of this study on the evolution of urban planning in the scientific community between 2014 and 2024.

2. Systematic literature reviews

The systematic literature reviews (SLR) offers a scientific and rigorous approach to identifying, analysing, and interpreting the available evidence for a specific research question (Esfandi et al., 2024; Mohamed and Yamu, 2023). They are conducted to provide a complete and valid understanding of the topic, and they involve planning, conducting, and reporting the reviews in a structured manner. SLRs are different from traditional literature reviews as they aim to identify all studies that address a specific question and minimise bias through rigorous methodology. It is the method of choice for evidence-based practice projects, and they are used to identify the most precise and reliable estimate of an intervention’s effectiveness. The SLR process has been adapted from medicine to serve the needs of various disciplines, and it involves developing a review protocol, selecting databases, defining inclusion and exclusion criteria, characterising the corpus, and synthesising the findings.

To obtain significant results from the SLR of urban planning papers, this study employed the tools and resources of text mining (Carpentieri et al., 2023; Gobster, 2014). Also known as text data mining, this process involves extracting previously unknown knowledge from textual data (Feng et al., 2017). This technique has been used on a wide range of documents, including patent data for technology trend analysis (Lim, 2025), customer opinions to provide insights into customer behaviour (Jansen et al., 2009), feedback (Ordenes et al., 2014), and scientific documents to provide an understanding of specific research fields (Wang et al., 2021; Jo et al., 2009). Recently, machine learning algorithms have been applied to text data to discover knowledge hidden within it (Hickman et al., 2020; Popoff et al., 2020). For instance, clustering algorithms have been used to identify unknown categories of documents (Aggarwal & Zhai, 2012), while classifiers have been used to automate the classification of spam mail and identify significant words (Yu et al., 2008). One of the most prominent algorithms for text mining is the topic modelling algorithm, which uses techniques such as latent Dirichlet allocation (Blei et al., 2003) and non-negative matrix factorisation (Lin, 2007) to uncover hidden topics within a set of documents. The effective interpretation of the results from a text data analysis requires visualisation as most text mining analyses involve numerous features and require semantic interpretation (Lim et al., 2021). For example, a visualisation of the network between different keywords can be used to understand the key links between the keywords, thereby allowing them to be efficiently categorised (De Jong et al., 2015).

Moreover, this study also employed textometric analysis, which is a quantitative method for analysing textual data. It is used to identify the frequency of words and phrases as well as the relationships between them, thus gaining insights into the topics and relationships in the text (Helme-Guizon & Gavard-Perret, 2004). Textometric analysis has been used in various fields, such as spatial planning, in which it was used to identify the key themes and concepts discussed in the literature on spatial planning (Bart, 2011), track the evolution of spatial planning theorisation over time, compare different stakeholders' views on spatial planning issues, identify gaps in the literature on spatial planning, and determine emerging trends in spatial planning (Marchand & Ratinaud, 2012). Buhler et al. (2018) used textometric analysis to identify the key themes in urban policy discussions on urban transport plans in France, Bueno et al. (2021) used it to identify the key themes in urban resilience research, and Carpentieri and Guida (2022) employed it to track the evolution of urban planning in Italy.

Thus, these studies demonstrated textometric analysis's ability to provide insights into spatial planning. However, it is important to note that textometric analysis is a complex technique that requires careful planning and execution. Moreover, researchers need to be aware of its limitations, such as its ability to only identify explicit themes and concepts that are mentioned in the text. Overall, while textometric analysis is a valuable tool that can be used to gain insights into spatial planning literature, it needs to be used in conjunction with other methods such as qualitative analysis to obtain a complete understanding of the issues being studied.

The analysis herein entails calculating the "proximity" between words by analysing the words that recur less and more often, according to centrality values (Mandják et al., 2019).

In particular, this technique involves distinguishing the most recurrent and connected words from the peripheral (i.e., the less recurrent and connected) words. The frequency of single words is examined, and the direct links between words in terms of proximity within the sentences of the analysed text are also analysed (Gonçalves Júnior et al., 2021). The frequencies and proximity links are illustrated using a tree diagram, the branches of which represent the connections between the different words. These branches or "segments" are created from the distribution of the words in the text, with the proximity and proximity recurrency indicating the existence of an encompassing conceptual framework: the closer the words are to one another, the stronger the indication that they are included in a conceptual framework. Moreover, although two concepts may seemingly pertain to different lexical fields, a high frequency of occurrence in the same connection segment indicates that they share a conceptual link.

3. Data collection and analytical approach

This SLR utilised Scopus as a source database due to its substantial content coverage, convenience, practicality, and reliable impact indicators. Scopus was also chosen as it potentially provides more specialised coverage in urban planning, which is particularly pertinent to this review. Furthermore, compared to the Web of Science database, the Scopus database includes a more extensive collection of scientific journals and numerous published articles supporting a more comprehensive urban planning debate analysis.

The first selection considers the words *urban* and *planning* included in the titles, abstracts, and keywords published in English and indexed in the Scopus database. This selection includes 105,166 documents published from 1926 to 2025. Until 1960, the Scopus database contained only a few articles per year. This likely reflects the uncommon practice of publishing in international scientific journals or book series during this historical period, which favored alternative local or national forms of disseminating research results. In this first time interval, United States research institutions published the majority part of these articles. In 1970, the number of articles published per year was over 100. Only since 2002 have the indexing articles been over 1,000 documents, predominantly published by the United States, the United Kingdom, and Canadian research institutions. Since 2014, the number of annual publications has reached 3,266 documents, surpassing 3,000 publications per year for the first time.

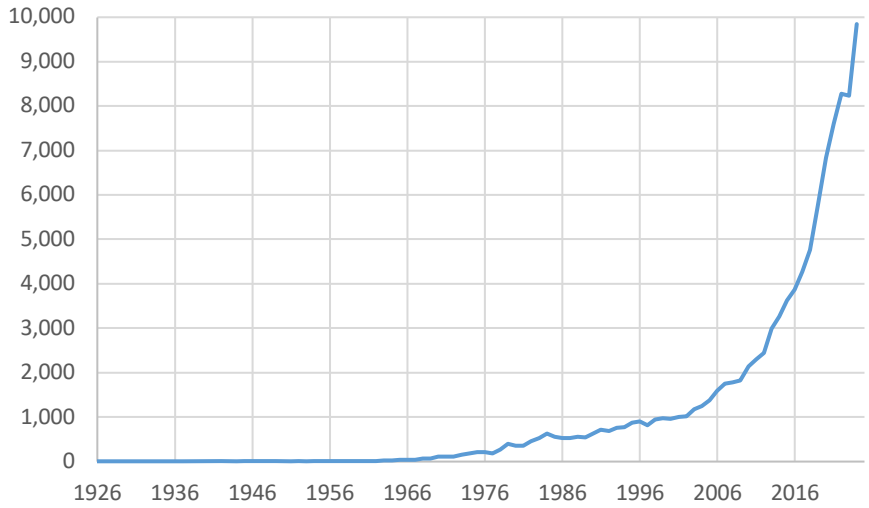

Fig.2 Number of articles for each year from 1926-2024

This method involves choosing clear and reproducible survey techniques, allowing for a comprehensive overview of the literature. It helps to accurately identify the current key issues and highlights the main topics raised by the scientific community within the selected time frame.

This study focuses on the past decade (2014-2024), because this time interval is the most productive in terms of the number of index publications (over 62% of total publications indexed in Scopus from 1926 to 2024) compared with the previous decade and considers the recent trends that interest the discipline researches (e.g. Climate changes, COVID, energy transition, inequalities, …). The outcomes of this analysis could offer the possibility of better understanding the future research directions in this field. To achieve the objective of this research, the criteria for selecting articles from the Scopus database are outlined as follows:

- *urban* and *planning* needed to be included in the papers' titles, abstracts, and keywords;
- the article needed to be published between 2014 and 2024;
- the documents could only be peer-reviewed journal articles or full-article proceedings collected from Scopus;
- the articles had to be in English;
- the articles that were published were the final versions.

The code of the query generated for the Scopus search module was TITLE-ABS-KEY (urban AND planning) AND PUBYEAR > 2013 AND PUBYEAR < 2025 AND (LIMIT-TO (SRCTYPE , "j")) AND (LIMIT-TO (PUBSTAGE , "final")) AND (LIMIT-TO (DOCTYPE , "ar")) AND (LIMIT-TO (LANGUAGE , "English")).

These criteria resulted in the Scopus tool returning 65,368 articles. This number of articles aligned with the investigation of the ongoing evolution in urban planning research according to the topics, methodologies, and geographical areas of interest.

The software Iramuteq (http://www.iramuteq.org/) was used to conduct different text analyses, such as the basic lexicography related to lemmatisation and word frequency, descending hierarchical classification, post-hoc correspondence factor analysis, and similarity analysis. Moreover, comprehensive vocabulary distributions are presented in graphical representations that are derived from the lexicographic analysis. These analyses can be performed using texts centred around specific themes (text corpus) that are grouped in one text archive or comprising spreadsheet data (matrices with individuals in a row and words in a column), such as the dataset derived from free evocation tests.

This study focuses on the analysis of the words included in the titles of selected documents. The analysis of words considers the titles of selected scientific documents, this is a consolidated approach to tracing the processes of discourse formation and the cognitive structure of fields or disciplines (Milojević et al., 2011). Much has been written about the importance of titles in scientific journal articles, but little research has been carried out on the text analyses of titles (Hartley, 2005). There are two primary aspects to consider about the significance of titles for scientific publication (Lewison & Hartley, 2005). First, titles must attract readers: "Here is something important you need to read". Second, titles must also inform readers immediately of the contents of the papers.

The methodological approach adopted includes three steps, as outlined by Lavissière et al. (2020):

1. The software lemmatises content words such as nouns, verbs, adjectives, and adverbs, resulting in the grammatical information, such as the plural or verb tense, being removed from the corpus;
2. The software divides the corpus into segments that become the basic unit of context used in the statistical analyses;
3. The software performs a basic statistical analysis to determine the following information: (a) the number of texts in the corpus; (b) the number of words in the corpus; (c) the number of active forms in the corpus; (d) the number of hapaxes in the corpus; and (e) the average number of words per text. In addition, four tables are created in this step:
   - active forms ranked from most to least frequent;
   - supplementary forms, including grammatical words such as "a," "the," and "for," which are not counted as part of the active forms category;
   - hapaxes (i.e., words that occur only once in the corpus);
   - the total number of words, including both the active and supplementary forms.

With the support of this analysis, it extracted quantitative information through the systematic identification of words and the related information useful to better understand the evolution of discipline in the selected decade (Illia et al., 2014; Sarrica et al., 2020).

4. Findings

From the application of the method described in section 3, it was selected a sample of 65,368 papers included a total of 999,531 occurrences (total words), 33,146 forms (unique words), and 17,896 Hapax legomena (analysed words). Tab.1 details these data for each year. The paper proposes two approaches to analysing the results obtained by the frequency analysis: The first entails using a word cloud to analyse the results obtained from all articles, and the second comprises comparing the results for each year to identify the variation in the use of words in the papers' titles.

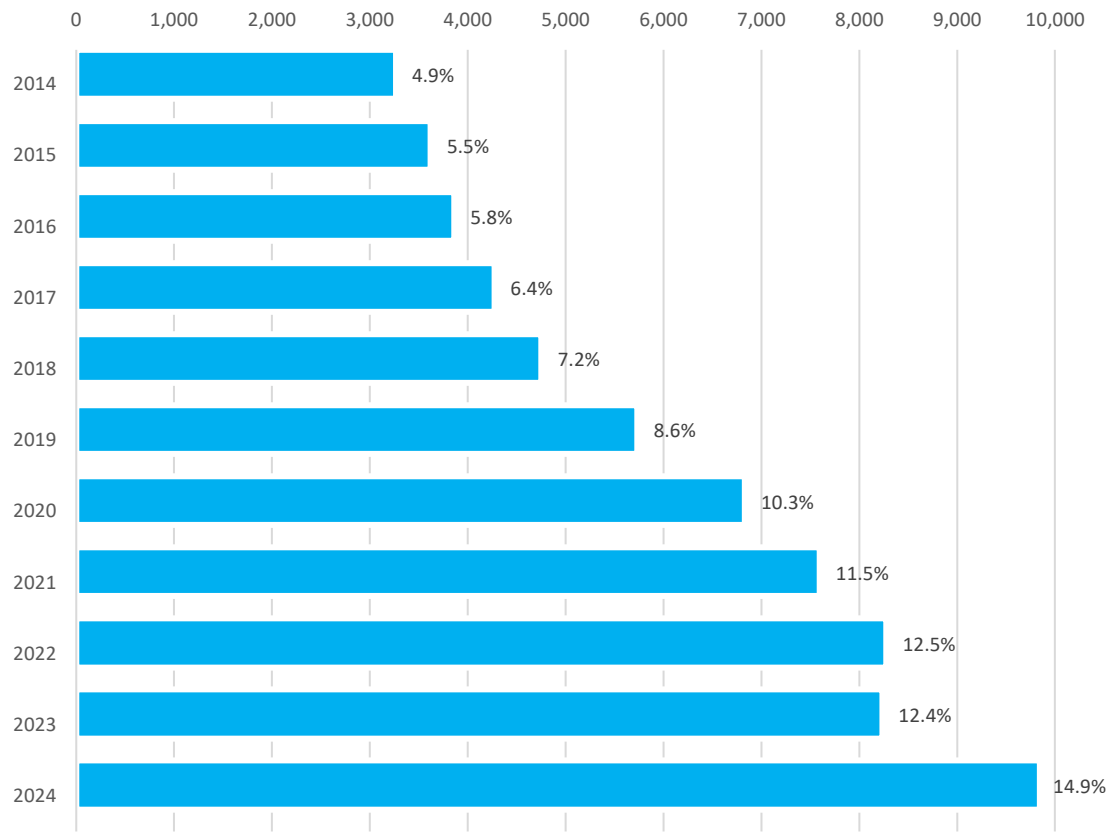

Fig.2 Number of articles for each year from 2014-2024

Year	No. of articles	Occurrences	Forms	Hapax legomena
2014	3,266	46,750	6,481	3,525
2015	3,624	51,505	6,755	3,632
2016	3,862	55,131	6,927	3,720
2017	4,273	61,537	7,204	3,846
2018	4,755	69,168	7,625	4,129
2019	5,735	84,637	8,518	4,575
2020	6,831	101,738	9,457	5,111
2021	7,595	115,094	9,724	5,146
2022	8,278	125,348	10,289	5,509
2023	8,242	130,966	10,427	5,563
2024	9,907	157,632	11,362	6,032

Tab.1 Data for each year from 2014-2024

As indicated in Tab.1, the number of articles increased steadily in this decade, suggesting that the scientific debate on urban planning became increasingly consistent. Fig.3 details the number of articles on urban planning per country.

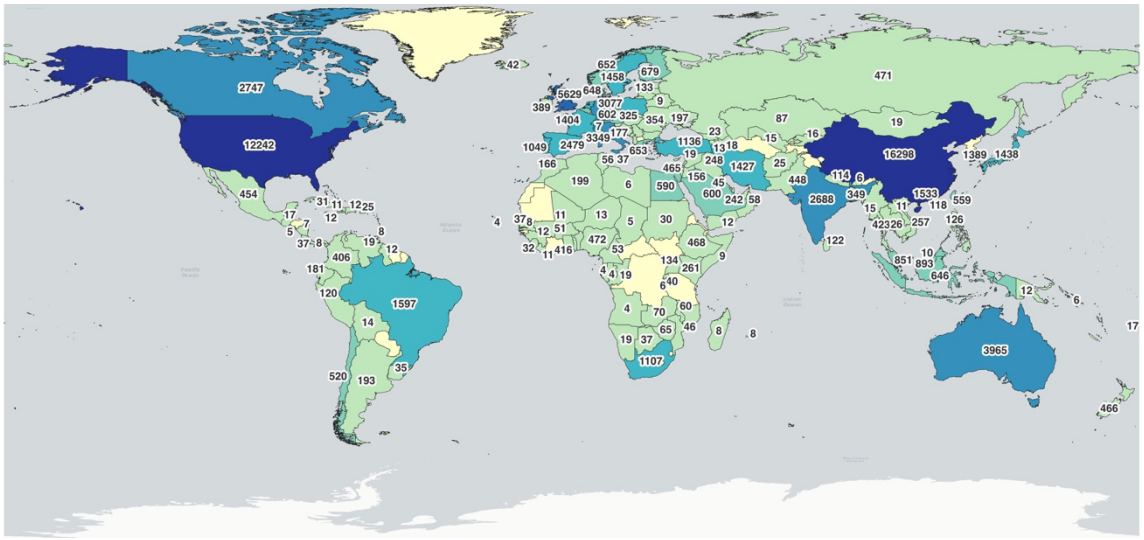

Fig.3 The Number of articles per country from 2014-2024

Fig.3 indicates that urban planning is a global field of research. The China published the majority of the total articles (24.6%), followed by United States (18.4%), but the following countries also made significant contributions: The United Kingdom (8.5%), Australia (6.0%), and Italy (5.0%). The distribution of scientific publications in this decade shows a focus on developed countries that have consolidated urban contexts (e.g., Europe) and developing countries (e.g., some Asian countries), in which new urban areas are being created to meet citizens' needs. Urban planning is a growing field of research and is becoming increasingly important in the face of rapid urbanisation and other significant issues that affect urban areas.

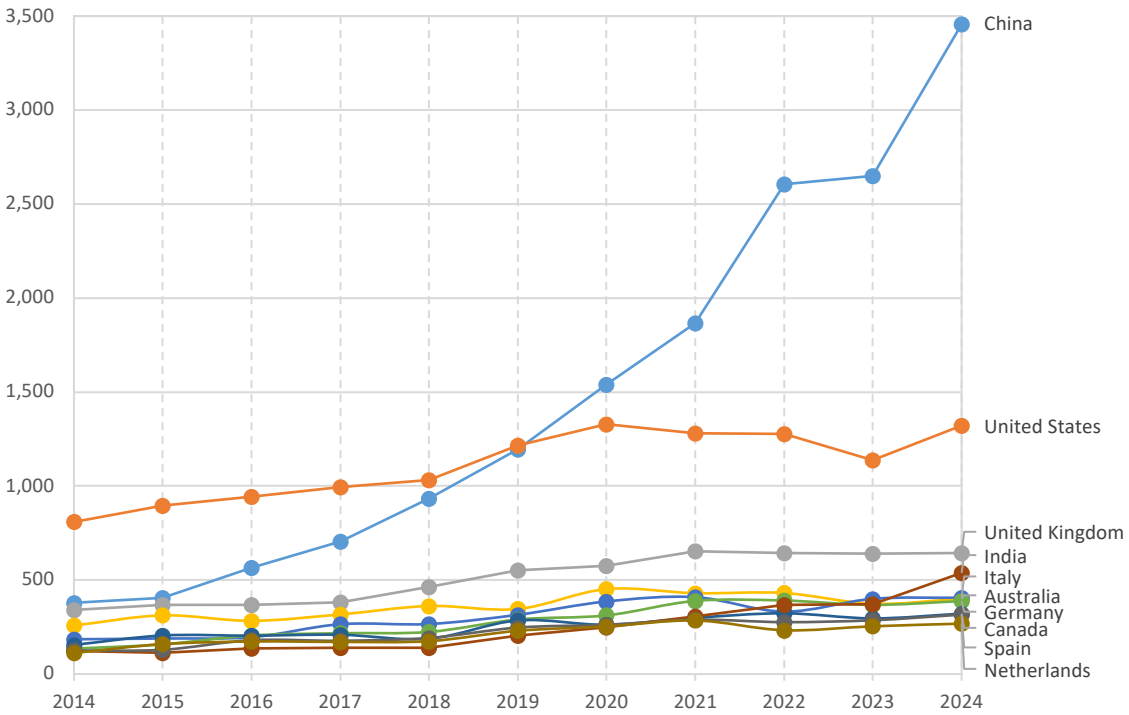

Fig.4 The ten countries that produced the majority of the studies on urban planning from 2014-2024

In terms of institutions' studies (see Tab.2), the Chinese Academy of Sciences published the highest number of urban planning papers in this time span. Indeed, only four of the 15 institutions in the world that produced the highest number of publications were not Chinese. Chinese institutions' growing interest in the scientific debate on urban planning is evidenced in Fig.4, which indicates that Chinese research institutions have been

progressively catching up to the United States by more than doubling their scientific output between 2019 and 2024.

Rank	Institution	Nationality	No. of articles
1	Chinese Academy of Sciences	China	1,760
2	Ministry of Education of the People's Republic of China	China	1,223
3	Wuhan University	China	887
4	University of Chinese Academy of Sciences	China	800
5	Tongji University	China	721
6	University College London	United Kingdom	717
7	University of Melbourne	Australia	662
8	Institute of Geographical Sciences and Natural Resources Research, Chinese Academy of Sciences	China	615
9	Peking University	China	606
10	The University of Hong Kong	China	597
11	Delft University of Technology	Netherlands	539
12	Beijing Normal University	China	504
13	Zhejiang University	China	498
14	Sun Yat-Sen University	China	490
15	The Hong Kong Polytechnic University	China	476

Tab.2 The institutions with the highest number of urban planning publications

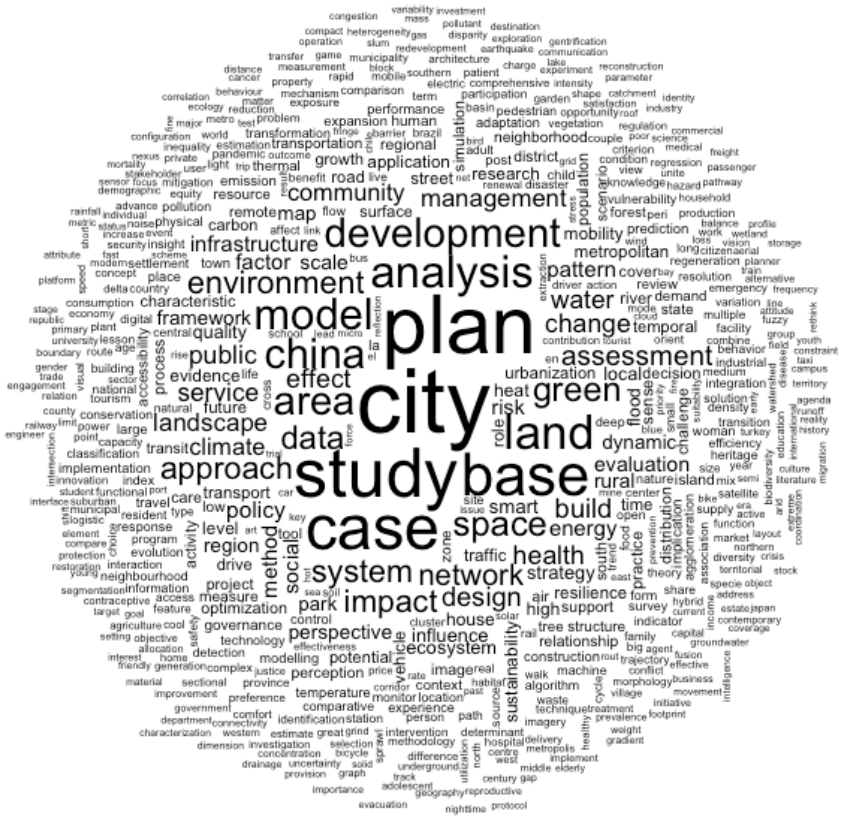

Fig.5 Word cloud of the selected urban planning articles indexed in the Scopus database from 2014-2024

The word cloud in Fig.5 shows the relevance of the words extracted for the current analysis. The size of the text is proportional to the frequency of words in the titles. From the cloud, the most frequents words in the selected text are: *city*, *plan*, *study, case*, *base*, *land*, *analysis*, *model, China* and *development*. These main ten words further underlined some aspects of both the centrality in this discipline of the technician tools and spatial dimension. Furthermore, it emerged from the above data related to the high interest in urban planning from the Chinese scientific community in theoretical and practical studies. To better understand the results obtained, it was decided to divide the words into three subsets based on tematic, technical and localization aspects. The three main subgroups of words were identified according to the leading parts on which scientific study and research activities focus to understand the results better and acquire more information on the evolution of the discipline. The subgroups of words were identified by analysing the words included in the 65,368 selected titles of papers. The three subgroups were named as follows: *Research topics*; *Methods and techniques*; and *Spatial dimensions and places*. A limitation of this thematic analysis of the words is that not all the words were included in the three macro groups because some could be included in other possible thematic subgroups, the identification of which could be the subject of future research.

4.1 Research topics

This group comprises the words related to specific topics of research or arguments of interest in urban planning, thereby providing an overview of the leading topics in urban planning research during the last decade. Table 3 details the 20 most commonly used words in the selected titles from 2014-2024 in this group, and it also lists the order of the words according to how frequently they are used in the group (Group rank) and the order of the words according to how frequently they are used in the entire sample (General rank).

Rank	Word	General rank	Frequency
1	*land*	6	5,431
2	*development*	10	4,498
3	*green*	14	3,595
4	*environment*	16	3,223
5	*sustainable*	20	2,833
6	*health*	25	2,419
7	*public*	27	2,384
8	*water*	28	2,359
9	*service*	29	2,347
10	*landscape*	30	2,258
11	*climate*	33	2,108
12	*policy*	34	1,968
13	*energy*	37	1,835
14	*infrastructure*	38	1,820
15	*social*	42	1,727
16	*risk*	43	1,714
17	*rural*	46	1,631
18	*smart*	54	1,489
19	*ecological*	57	1,416
20	*ecosystem*	58	1,391

Tab.3 The words used most frequently in articles' titles in the Scopus database from 2014-2024

The word *land* was the most frequently used word in this group but was sixth in the inter-group of words obtained from the titles, thereby indicating that studies on land were common in urban planning. Other

frequently occurring words included *environment*, *sustainability*, and *green,* suggesting that studies on environmental issues were significant in urban planning. Furthermore, several words were related to social issues, such as *health*, *public*, and *service*. The word *climate* was also used frequently, suggesting that urban planning is increasingly focused on addressing the challenges of climate change. These results highlights that urban planning studies concern cities' and their citizens' physical, social, and economic well-being.

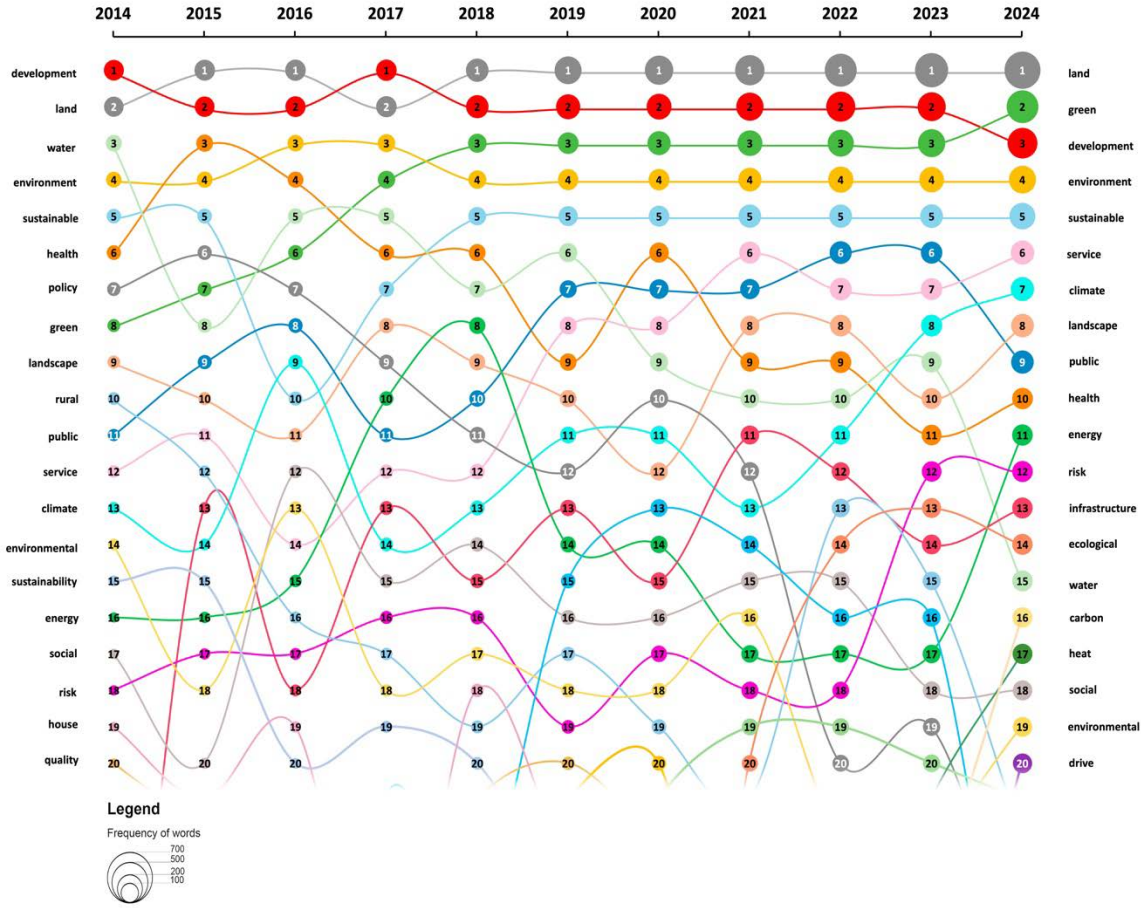

Fig.6 The Variation in rank and frequency (dimension of point) of words in the research topics group per year

Considering the words included in this group, some subgroups can be determined: The first subgroup conteins words related to the discipline's identity arguments, such as *development*, *policy,* and *risk*; the second sub-group relates to environmental issues, encompassing the words *green, environment*, *sustainable*, *ecological, ecosystem* and amongst others; and the third denotes socioeconomic issues, indicated by the words *health*, *public*, *service*, *social*, and the like. Fig.6 is a bump chart that details the frequency variation per year from 2014-2024. The variation in word frequency was used to identify the evolution of key concepts and issues discussed in urban planning research, which can help understand new focus, ideas, and solutions in future urban planning studies. Three main groups of variations can be delineated according to the frequency variation per year: The first group of words is very stable, the second group has a moderate variation level, and the third group has high variation during the years of observation. In details, the words *development, environment,* and *land* had the highest frequency values in all years, with some position variation between them and a constant frequency increase. Alternatively, the use of the word *green* progressively increased, moving from the 8th position in 2014 to the 2nd position in 2024. In addition, the word *social* stayed in the 17th position in 2022 and in the 18th in last years of analysis but, over the ten years, its position varied. Furthermore, the use of the words *environmental, sustainability* and *policy* over the years significantly decreased, and the words *service*, *climate* and *risk* increased in frequency in the later years of the time span analysed. These results suggests that some concepts innovative technologies and approaches as well as cities' abilities to withstand

shocks and stresses are becoming increasingly important issues in urban planning. Overall, urban planning research increasingly focused on the topics of cities' physical, environmental, and economic sustainability. The highest frequency words reflect these topics and provide a basis for understanding the future development of the discipline.

4.2 Methods and Techniques

This group includes words related to approaches, techniques, data, and instruments that were popular in urban planning between 2014 and 2024. Tab.4 lists the 20 words used most frequently in the titles of the papers belonging to this group. The table also lists the order of the words in the group (Group rank) and the order of the words in the total words analysed (General rank).

Group rank	Words	General rank	Frequency
1	*plan*	2	10,147
2	*analysis*	7	5,033
3	*model*	8	4,832
4	*spatial*	12	4,422
5	*assessment*	21	2,686
6	*management*	31	2,238
7	*multi*	35	1,906
8	*method*	40	1,784
9	*evaluation*	44	1,676
10	*framework*	49	1,577
11	*dynamic*	50	1,545
12	*optimization*	94	1,001
13	*process*	97	967
14	*simulation*	102	952
15	*perception*	108	926
16	*remote*	115	888
17	*GIS*	118	876
18	*tool*	121	850
19	*scenario*	122	834
20	*prediction*	139	738

Tab.4 Most frequently used words in the methods and techniques group from 2012-2022

Tab.4 highlights that only *plan, analysis* and *model* ranked within the top-most used words in the General rank of this group. At the same time, *spatial* was the twelfth most-used word (eleventh position in General rank), also confirming its significance in the discipline studies. In support of this, there is also the word *GIS*, which is the most frequent for this group. The words of this group can be categorised into the sub-group of methods and approaches, indicating the widespread discussion of this topic in urban planning phenomena and processes, exemplified by the words *model*, *assessment*, *multi*, *method* and more. The second subgroup included the words that refer to various techniques that support applying quantitative and qualitative methodologies to analyse urban planning phenomena, such as *analysis*, *spatial*, *management*, *evaluation*, *framework*, and more.

Fig.7 is a bump chart detailing the results obtained from analysing the frequent evolution of words over ten years for this group. Generally, the frequency of all words increased annually alongside the growing number of articles published on urban planning. Three main groups of words were identified from this analysis: The first group (at the top of the chart) includes words that remained stable over time, the second group shows a moderate variation in their positions, and the third group (at the bottom of the chart) consists of words that

frequently shifted their positions, especially during the first part of the decade. The first group includes five words (plan, model, analysis, spatial and assessment) that did not vary over the ten years of analysis to confirm the centrality of these words for the scientific debate. The second group of words showed moderate variation in this period (*management*, *evaluation*, *framework*, *dynamic* and *method*). The third group of words, from the word *dynamic*, varied significantly during the ten years of observation. The words *GIS*, *tool*, and *process* have shown a progressive reduction in their frequency in the debate compared to other words that have seen greater success over the years, such as *remote*, *prediction* and *optimisation*. The progressive decline of *GIS* and *tool* may indicate a shift from traditional mapping techniques toward integrated digital platforms and real-time analytics. The rise of *remote*, *prediction* and *optimisation* words suggests a growing reliance on data-driven and AI-based approaches in urban planning discipline. Some words, such as *perception, simulation*, and *scenario*, did not change rank between the first and last year, but their positions changed significantly in the intervening years.

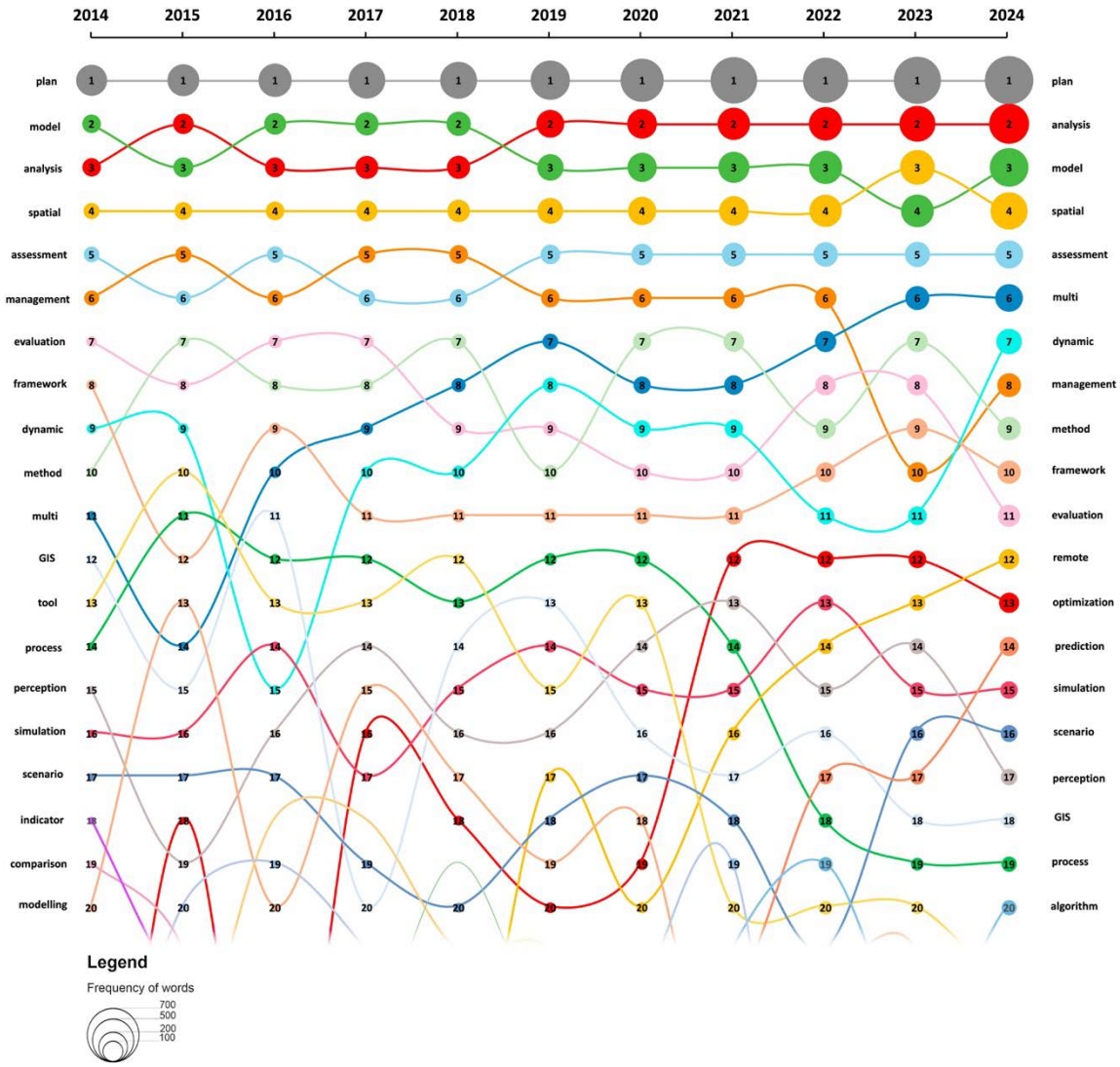

Fig.7 The variation in rank and frequency (dimension of point) of the words in the methods and techniques group per year

4.3 Spatial dimensions and Places

This group contains the words related to the scales of analysis and geographical locations. Tab.5 lists the 20 most frequently used words in this group as well as the order of words in the group (Group rank) and the order of words in the list of total words analysed (General rank). The word *city* was the most frequently used

word in this group as well as all the words analysed in this study. The subgroup of Spatial Dimensions included nine of the twenty words: *city*, *area*, *network*, *region*, *neighbourhood*, *local*, *metropolitan*, *district*, *town* and *costal*. The subgroup of Places contained eight words of the twenty: *China*, *park*, *river*, *India*, *South*, *island*, and *Beijing*.

Group rank	Words	General rank	Frequency
1	*city*	1	11,229
2	*China*	9	4,640
3	*area*	11	4,425
4	*network*	19	2,945
5	*scale*	45	1,639
6	*region*	51	1,544
7	*map*	52	1,538
8	*park*	53	1,506
9	*local*	60	1,337
10	*metropolitan*	73	1,150
11	*river*	88	1,049
12	*India*	95	978
13	*South*	103	949
14	*regional*	104	948
15	*district*	111	914
16	*island*	113	896
17	*neighborhood*	116	886
18	*Beijing*	133	780
19	*town*	144	709
20	*costal*	155	658

Tab.5 Most frequently used words in the spatial dimensions and places group from 2014-2024

Fig.8 delineates the most frequently used words in the Spatial Dimensions and Places group in a bump chart, showing that the frequency of all words increased each year in correlation with the number of articles published on urban planning. These words can be divided into two subgroups: the top of the chart, which includes words with high stability, and the bottom, which indicates increased instability. From the results presented in Fig. 8, the instability increases as the value decreases. This aligns with the results achieved by the other groups. In particular, the rank positions of the first four words (*city, area, China,* and *network*) did not vary significantly during the observation period. The stability of terms such as *city* and *area* reflects their foundational role in urban planning discourse. The results obtained for *China* confirm the analysis proposed in the previous paragraph, which highlights China's significant role in the global urban planning debate. In line with this result, it is notable that the progression of the word *Beijing*. The results also evidence the significant role of another country in the urban planning debate, which is *India*.

The words *region, and park* varied progressively during the ten years of observation. Moreover, *local* varied significantly in each year, progressing from the 6th position in 2014 to the 10th position in 2024, and *metropolitan* progressed from the 8th position in 2014 to the 13th position in 2024.

Another interesting result is the progression of the word *map*, which moves from the 13th position in 2014 to the 6th position in 2024, indicating the importance of this term suggests an increasing reliance on geospatial technologies and data-driven approaches. In conclusion, these results indicate that urban planning research is shifting towards a more data-driven approach, where spatial analytics and digital mapping will play a key role in addressing the challenges faced by urban environments worldwide.

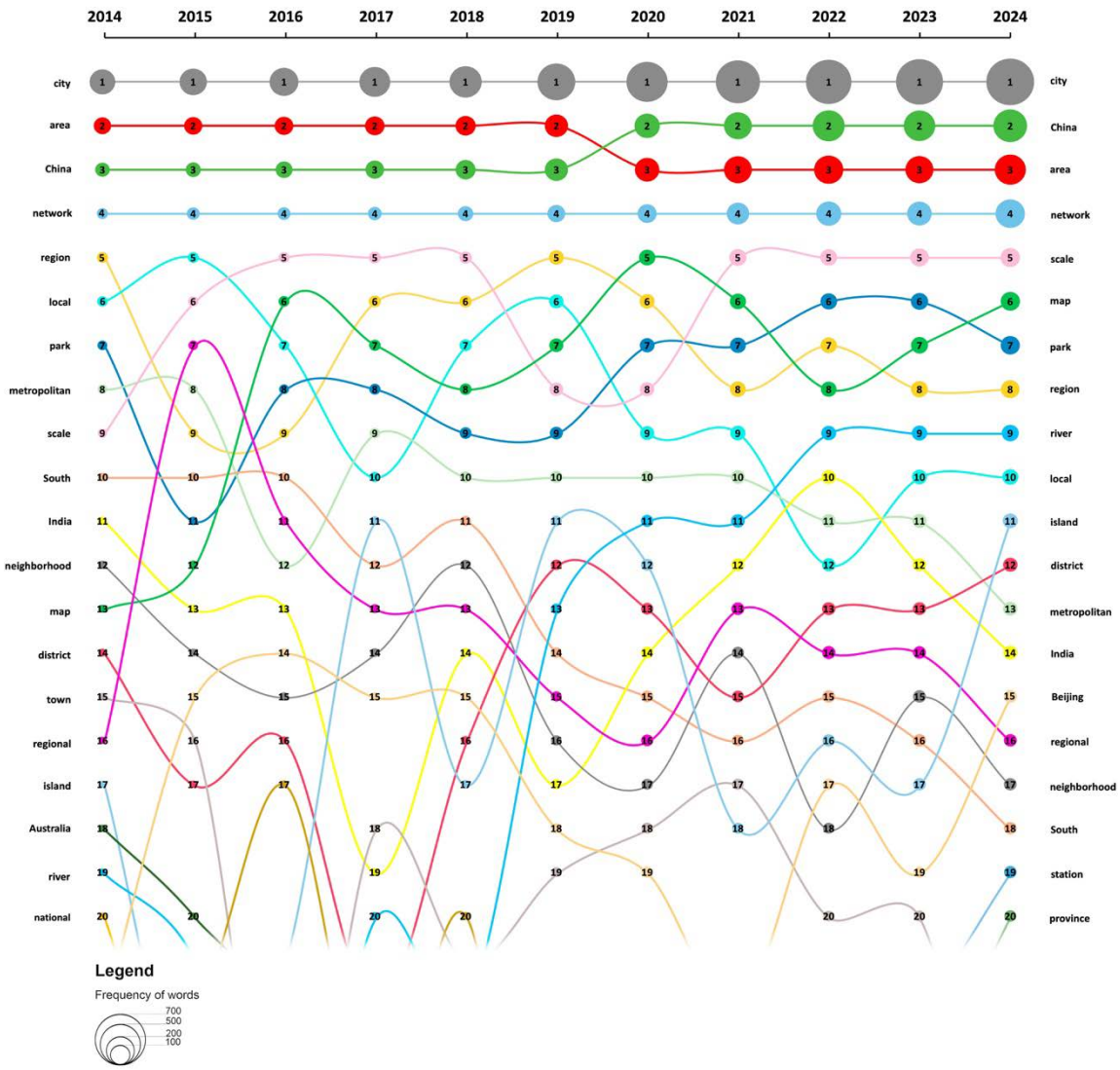

Fig.8 Variations in rank and frequency (dimension of point) of words in the spatial dimensions and places group per year

5. Conclusions and research limitations

Over time, the evolution of urban planning research has been studied by a wide range of academics across various points of view and different approaches, considering specific related topics or the discipline in its entirety. This study contributes to a better understanding of the global scientific trends of urban planning research through an SLR of scientific papers indexed on the Scopus database. Using textometric analysis, this study employed word-counting and relation techniques to identify the primary topics and concepts within the scientific literature and track how they evolved over this period. Articles' titles were systematically examined to uncover the predominant words and concepts, providing insights into the evolution of discipline debate and potential future sectors of interest.

This systematic review provides a comprehensive overview of global urban planning research trends from 2014 to 2024, highlighting thematic, methodological, and geographical evolutions. The study offers two main categories of results. The first category includes the outcomes related to the variation of discipline topics, methodologies, tools and areas of experimentation. In particular, the analysis highlighted a significant evolution of the topics investigated in the discipline over this decade, with some new subjects progressively gaining increased prominence. From the results, it is clear that some innovative terms initially exhibited high variation in their rank positions. For examples, the word "green" climbs from eighth to second place. Considering other words that have become more frequent in 2024, such as "climate" and "risk", this could

highlight climate change mitigation and adaptation policies that have been integrated into urban planning processes and are moving toward nature-based solutions. Moreover, during the time interval of observation, some of them became more stable and significant, especially for the words included in the "Methods and Techniques" and "Spatial dimensions and Places" groups. For example, the progressive affirmation of words is strongly related to implementing solutions involving spatial information systems. Indeed, the central role of words like *plan*, *model* and *analysis* alongside the increased frequency of the words *prediction*, *optimization* and *remote* could highlight the growing prominence of data-driven approaches and spatial analytics suggests that future urban planning will increasingly rely on predictive models and integrated digital platforms.

Second, this study revealed that academic communities' interest in the discipline is predominantly focused on advanced countries such as China, the United States, and European countries. Furthermore, the data analysis indicated that most discipline-related debates centred around these countries. Lastly, China's scientific output in urban planning during the observation period is particularly noteworthy, with a steadily increasing number of publications and institutions working on urban planning. This aspect is further highlighted by the results obtained in the paragraph "Spatial dimensions and Places" with words China (4,640 repetitions) and Beijing (780 repetitions).

In conclusion, this work presents an extensive and detailed framework for understanding the evolution of the urban planning discipline worldwide, highlighting how it has increased scientific production in the field in terms of the number of scientific products published and the geographical provenance of researchers. The proposed focus on the decade from 2014 to 2024 offers a deeper analysis of the changes that have occurred over the last decade in terms of topics, tools, and experimentation.

This study offers a detailed framework for examining how urban planning research has evolved and paves the way for future interdisciplinary methods. Its findings can aid the scientific community in recognising established and emerging topics within the field, while also supporting future research initiatives and international collaborations through insights into global themes, approaches, and experiments.

This study had several limitations and offers some suggestions for future research. The findings were influenced by the data collected, which may be subject to change if a different data source or time interval is used. Thus, although the data used in this study were sourced from the Scopus databases, it may be beneficial to expand the scope of data to other databases or specific domains, such as urban planning journals. In addition, the data collected from January 2014 to December 2024 provided an extended list of research topics and factors related to smart cities, but this was not addressed herein. Moreover, as this study only reviewed articles containing the words *urban* and *planning*, its scope was larger, as studies that only contained one of these terms may have been included. This study's outcomes may have also been influenced by the specific keywords used in the databases. Lastly, while this study provides valuable insights into the evolution of international research on urban planning within a specific timeframe, the search for particular keywords on a database may have limited the generalisability of the findings.

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Image Sources

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REVIEW NOTES
International Regulation and Legislation for the Energy Transition

From RED II to RED III: Renewable Acceleration Areas as a new challenge for urban and territorial planning

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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 RED III Directive (2023/2413) introduces more ambitious targets for renewable energy than RED II and provides for Renewable Acceleration Areas (RAAs) to expedite plant authorizations. This gives a more prominent role to urban and regional planning, which must integrate energy, environmental, and infrastructure criteria into location decisions. The Italian case demonstrates how multilevel governance, along with operational tools such as strategic assessments and digital platforms, is crucial in defining RAAs. Cities thus assume a central role in decarbonization processes. This paper highlights opportunities and critical issues towards a faster, fairer, and more sustainable energy transition.

Keywords
Energy transition; Urban panning; Renewable acceleration areas; RED III

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1. Introduction

Contemporary cities face unprecedented energy and climate challenges. Despite occupying less than 3% of the planet's surface, urban agglomerations are home to the majority of the population and consume over 65% of the world's energy, producing more than 70% of CO_2 emissions. This concentration of energy consumption makes cities highly vulnerable to problems such as dependence on fossil fuels, rising energy prices, and air pollution (EEA, 2023). To address these challenges, clean energy transitions have accelerated, driven by government policies and industry strategies that have promoted actions for greater energy independence, in response to geopolitical instability caused by open conflicts around the world and soaring energy prices (IEA, 2024). In this context, urban areas can become drivers of the energy transition: thanks to the density of supply and demand, cities offer opportunities for the widespread installation of renewable sources (from solar panels on rooftops and facades to wind farms in peri-urban areas), the development of sustainable district heating networks, and the promotion of local energy communities (Russo et al., 2025; Volpatti et al., 2024). In other words, cities and local administrations have the potential to play a central role in decarbonization, integrating energy objectives into urban planning and contributing to national and European climate targets (EC, 2023; Amado & Poggi, 2022). The European Union has recognized this urban centrality, directly involving cities in initiatives such as the "100 climate-neutral cities by 2030" mission and, above all, updating the regulatory framework on renewable energy to strengthen the link between energy policies and territorial planning (D'Amico, 2023; Ulpiani, 2023). In particular, the recent evolution from Renewable Energy Directive II to Renewable Energy Directive III introduces innovative tools, including Renewables Acceleration Areas, which represent a new challenge and opportunity for urban and regional planning.

2. From RED II to RED III: more ambitious targets and acceleration zones for renewables

The RED II Directive (2018/2001/EU), part of the Clean Energy for All Europeans package, consolidated the European framework for renewable energy by 2030, setting a binding target of at least 32% renewable energy in the EU's energy consumption. It introduced principles for simplifying authorization procedures (time limits on procedures) and tools to actively involve citizens in the transition, such as renewable energy communities. Despite this progress, the accelerating climate crisis and recent geopolitical turbulence have pushed the EU to revise its ambitions upwards. In 2019, with the Green Deal and the Fit for 55 packages, the Commission proposed updating the directive (EC, 2019). This resulted in RED III, formalized as Directive (EU) 2023/2413, which raises the binding target to 42.5% renewable energy in the EU mix by 2030 (EU, 2023). In addition to quantitative targets, RED III introduces significant qualitative changes, particularly in the areas of permitting and planning. Renewable energy plants are now explicitly recognized as projects of primary public interest, which lays the legal foundation to facilitate their construction by overcoming bureaucratic bottlenecks. One of the key elements, innovative compared to RED II, is the establishment of Renewables Acceleration Areas (RAAs). These are geographic areas particularly suited to the installation of renewable energy plants, where permitting procedures are simplified and application processing times are approximately halved compared to ordinary procedures. In these priority areas, projects will benefit from accelerated procedures (maximum 12 months for permit decisions, compared to the 24 months required outside of RAAs). The designation of RAAs will occur through a national planning process coordinated with local authorities. RED III requires each Member State to map its territory (land, inland waters, and territorial sea) to identify renewable energy potential, cross-referencing it with future energy demand, the presence of grids and storage, and environmental constraints. Based on this mapping, Member States must identify the most suitable areas (divided by technology: for example, photovoltaic, wind, etc.). European legislation provides guidelines for the characteristics that these RAAs must have. Acceleration areas are those parts of the territory where the construction of a certain type

of renewable energy plant would not have significant environmental impacts. In practice, this means prioritizing sites with low environmental and territorial sensitivity: the Commission cites brownfields, industrial zones, landfills, or brownfield sites, as well as already developed areas (such as rooftops or parking lots for photovoltaic systems) as ideal candidates for RAAs. Environmentally protected areas, such as natural parks, Natura 2000 sites, and the like, are excluded from RAAs, and in general, areas of high ecological sensitivity must be avoided. This concept of "intelligent" selection is accompanied by the requirement to conduct prior environmental assessments at the planning level: the designation of acceleration zones must be carried out through a Strategic Environmental Assessment (SEA) to ensure that the concentration of plants in RAAs does not compromise the protection of ecosystems and landscapes, shifting the environmental review to the planning stage rather than the individual project. In other words, RED III aims to plan the energy transition by integrating environmental and territorial criteria from the outset, thus expediting individual permits in the selected locations. This represents a significant shift in approach compared to the past, where assessments were conducted on a case-by-case basis: the current approach is to plan ahead where plants can be built more quickly and with fewer conflicts, thanks to renewable energy zoning.

3. Implementation in Italy

In recent years, Italy has moved to implement European directives on renewable energy, albeit through a complex and sometimes fragmented regulatory process. RED II (2018) was implemented with Legislative Decree no. 199/2021, which updated the national regulations for the promotion of RES (Rocchetti et al., 2025). Among the innovations introduced was a system for planning suitable and unsuitable areas within the national territory. Article 20 of Legislative Decree 199/2021 (Disciplina per l'individuazione di superfici e aree idonee per l'installazione di impianti a fonti rinnovabili) provided for the identification, through specific criteria, of the surfaces and areas deemed favorable for the installation of renewable energy plants, with the aim of expediting the authorization procedures for projects located in these preferential areas (Gazzetta Ufficiale della Repubblica Italiana, 2021). This concept predates the European RAAs, although Decree 199/2021 initially delegated the task of defining suitable areas within regional borders to the Regions through their own planning acts.

A decisive push toward rationalization came through the Piano Nazionale di Ripresa e Resilienza (PNRR) and related reforms. The Italian PNRR, specifically the RepowerEU component, envisaged a structural reform to streamline the authorization process for renewables, including the identification of acceleration zones at the subnational level and the adoption of a Testo Unico FER by 2025. Based on this mandate, Legislative Decree No. 190/2024, known as the Testo Unico FER, was issued in 2024, coordinating the authorization regimes for energy production from RES in a single provision (Gazzetta Ufficiale della Repubblica Italiana, 2024a). In parallel with the Testo Unico, Italy has defined the operational criteria for suitable areas within the country. Ministero dell'Ambiente e Sicurezza Energetica (MASE) issued the il "Decreto Aree Idonee" (Ministerial Decree 14/09/2023, published in July 2024). This provision, composed of 9 articles, establishes the principles and criteria for identifying areas considered suitable or unsuitable for RES plants and, more importantly, sets a regional distribution of new renewable capacity targets for 2030. Specifically, the 19 regions and 2 autonomous provinces of Italy are assigned a share of the 80 GW of additional power to be installed nationwide by 2030. Each region therefore has an annual capacity target to achieve and must plan its installations taking these quantities into account (Gazzetta Ufficiale della Repubblica Italiana, 2024b).

These areas, designated as suitable by the decree, formed the basis for future Renewable Acceleration Areas (RAAs). Indeed, a recent Legislative Decree (Legislative Decree no. 73/2025) further specified that the RAAs must be identified within the suitable areas already defined by law and must necessarily include all existing industrial areas in the territory (subject, of course, to environmental constraints). Regions will, however, have the right to propose additional acceleration zones in their Plans, including other types of sites deemed suitable (e.g., marginal agricultural areas, portions of land with little landscape value, etc.) (Gazzetta Ufficiale della

Repubblica Italiana, 2025). To implement these provisions and meet European deadlines, the MASE relies on the technical and operational support of Gestore dei Servizi Energetici (GSE), the public company that promotes RES in Italy. Specifically, GSE has developed two key tools: the Piattaforma Aree Idonee (PAI) and the national mapping of acceleration zones. The Piattaforma Aree Idonee (PAI) (Fig.1) is an IT portal designed to support regions and autonomous provinces in the management and planning of areas designated for renewable energy plants (https://areeidonee.gse.it/). It allows for the collection, visualization, and sharing of data on identified suitable areas, creating a unified information framework.

Fig. 1 Piattaforma Aree Idonee (PAI)

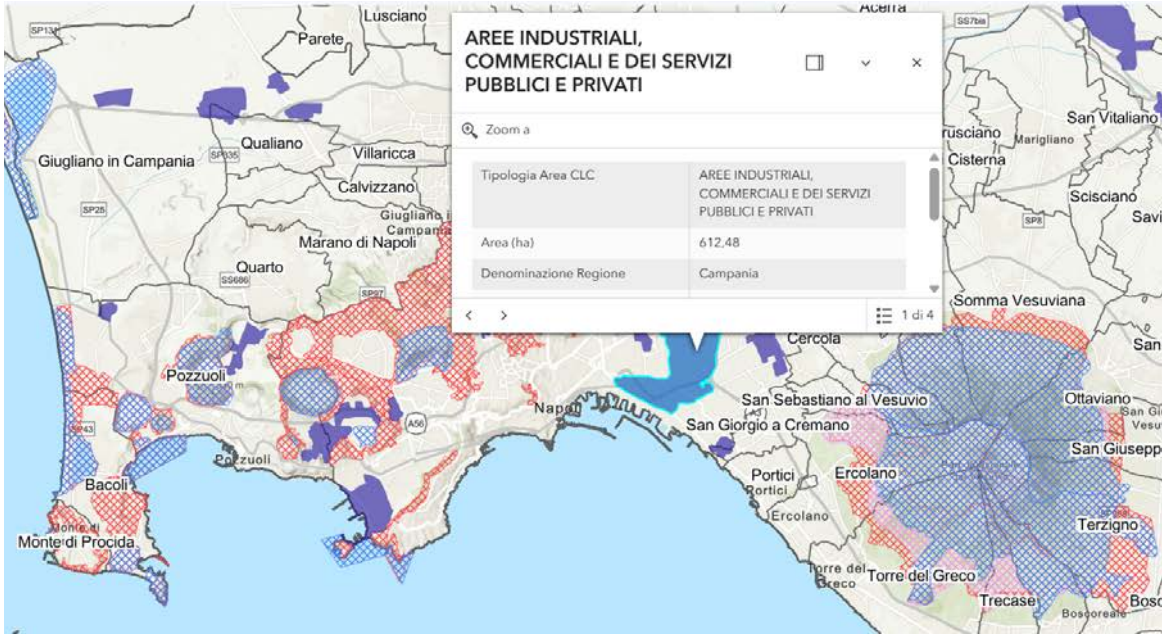

Fig. 2 Interactive Map of Acceleration Zones

Based on the information uploaded to the Piattaforma Aree Idonee, the GSE then developed and published the Interactive Map of Acceleration Zones (Fig.2). This map, available online from May 21, 2025 (https://areeaccensione.gse.it/), provides a cartographic representation of all potential RAAs across the country, offering a comprehensive overview at the national scale. In this first version, the RAAs represented primarily coincide with the industrial areas and other suitable areas already registered by the PAI: it is in fact specified that the areas represented were identified based on the information available on the PAI.

The national map will provide a starting point that can be integrated and refined by the Regions: the latter will be required to verify and report any misalignments or errors in the cartography to the GSE and will be able to propose adding further details to the RAAs. The publication of the national map has a dual value: on the one hand, it increases transparency for citizens and investors, showing where the State intends to focus transition efforts; on the other, it serves as a multilevel coordination tool, aligning all stakeholders (ministries, local authorities, operators) on the same reference territorial data.

From a territorial governance perspective, the next step is the institutionalization of the RAAs in the Regional Plans. Current legislation requires each Region (or Autonomous Province) to develop an Acceleration Area Plan, which must be subjected to a Strategic Environmental Assessment and formally adopted within a strict timeframe. According to the latest provisions, the Regions must complete the approval process by February 21, 2026. In short, Italy is translating the European concept of RAAs into a national planning system for suitable areas, coordinated centrally but implemented at the regional and local levels with the support of innovative tools. The implementation of RED III offers the opportunity to strengthen the link between energy policies and territorial governance: through the Decreto Aree Idonee, the GSE-MASE platforms, and future regional plans, we are moving toward a model in which decisions on the location of renewable energy plants are integrated into territorial planning. This institutional and information integration promises to accelerate the authorization process (reducing uncertainty and appeals) and improve the overall sustainability of location decisions, thanks to ex ante strategic assessments and the area suitability filter. The multilevel governance introduced by the State, Regions, local authorities, and technical agencies such as the GSE will have to prove itself worthy of a complex but crucial task: implementing the vision of a greener Europe on the ground, overcoming bureaucratic obstacles without sacrificing community involvement and the protection of the environmental and cultural heritage of the territories (Papa et al., 2021).

4. Conclusions

The transition from RED II to RED III marks a substantial evolution in European renewable energy policies, with more ambitious goals and innovative tools that intensify the intertwining of energy and territorial planning (Poggi & Amado, 2024; Zhu et al., 2025).

RAAs emerge as the emblem of this new phase: designed to streamline and accelerate the deployment of green plants, they require an integrated and forward-looking planning approach (Ceglia et al., 2022; Mazzeo & Polverino, 2023).

As we have seen, identifying RAAs requires a prior assessment of the territories from both a technical (energy potential, grid availability) and an environmental and social perspective (ecological awareness, local consensus). For European cities and local governments, this challenge also represents a historic opportunity. Never have energy and climate policies recognized such a central role at the urban and regional level: municipalities, cities, and regions are becoming co-actors in implementing European objectives, called upon to map their territories and shape future energy choices. If they seize this opportunity, they will not only be able to effectively contribute to decarbonization, but also catalyse local environmental, economic, and social benefits from the transition. For example, the careful allocation of RAAs could trigger processes of urban and regional regeneration, redevelop abandoned sites and attract clean energy production chains. In parallel, complementary policies for participation and the redistribution of benefits can ensure that no community is

left behind: the energy transition must also be a just transition, in which costs and benefits are equitably shared, and the most vulnerable groups emerge strengthened (Blečić et al., 2025).

In conclusion, the transition from RED II to RED III highlights a strengthening of the link between energy policies and territorial governance, paving the way towards a more integrated sustainable development model (Fan et al., 2022; Martinelli, 2025). The new European provisions, if implemented with strategic vision, could make cities and regions protagonists of the energy transition, reconciling decarbonization and equity. The success of this ambitious plan will depend on the ability of all stakeholders to harmonize European directives with effective local governance, equipping themselves with appropriate technical and regulatory tools and keeping citizen participation at the core (Soares et al., 2025). Only in this way can the Renewables Acceleration Areas truly translate into spaces for accelerating not only renewable energy, but also a just and integrated transition within European urban and regional spaces.

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Fig.1: Gestore dei Servizi Energetici (GSE). (2025). Retrieved from; https://areeidonee.gse.it/;

Fig.2: Gestore dei Servizi Energetici (GSE). (2025). Retrieved from: https://areeaccelerazione.gse.it/.

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REVIEW NOTES
Urban strategies, programmes and tools

Digitalization in urban planning: how Europe is building its digital future

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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.
This contribution aims to provide an overview of the policy tools employed by the European Union for digital transformation, and how they apply specifically to the governance of urban and territorial transformations. Digital transformation is a complex and ongoing undertaking, and the EU is mobilizing a range of tools to shape its digital future. Some of the key levers of this strategy are examined, including the Digital Decade Policy Programme (DDPP), financial instruments such as the Recovery and Resilience Facility (RRF) and the Digital Europe Programme (DIGITAL), and the INSPIRE regulatory instrument.

Keywords
Digital cities; Europe; Urban strategies; Technologies; Digitalization

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1. The digital future of the EU

Digital society and digital technologies open up unprecedented horizons in the ways we learn, entertain, work, explore, and achieve our goals. They also bring new freedoms and rights, and offer citizens the opportunity to transcend physical communities, geographic locations, and social positions. Furthermore, digital technologies help governance and research effectively address the growing complexity of contemporary challenges.

The Covid-19 crisis has seen an acceleration in digitalization and its use in everyday life but also in work and services (D'Amico, 2025a; Boujari et al., 2024). The Covid-19 crisis has further highlighted the critical role of digital technologies and infrastructures in our lives and demonstrated how our societies and economies rely on digital solutions.

The digital transformation of the European Union is "a central driver for ensuring that Europe remains competitive, resilient, reduces its excessive dependencies and enhance its technological sovereignty, while reinforcing its strategic autonomy" (European Commission, 2025). To this end, the Digital Decade Policy Programme (DDPP), adopted in 2021, has provided the EU with a structured governance framework and demonstrates the EU's commitment to decisive, long-term action, promoting coordination among Member States, aligning their efforts, and addressing the urgent need for digital transformation.

Digital transformation isn't just about driving innovation and growth, it's also becoming important as a way to leverage resources to make a country more stable and influential globally.

The Digital Decade Policy Programme 2030 sets the framework for the EU's digital transformation. The political programme encourages Member States to work together to achieve common objectives encompassed in four thematic areas: digital skills, digital business, and digital public services. The Commission monitors its evolution each year with a report on the State of the Digital Decade.

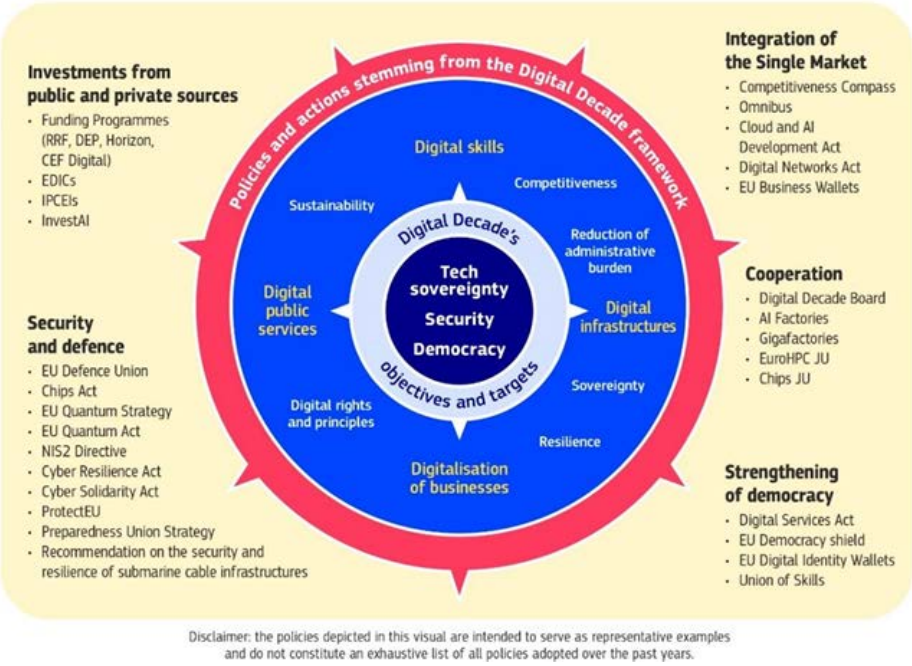

Fig.1 The Digital Decade and EU digital priorities (European Commission, 2025)

The report maps the progress made towards the 2030 targets and objectives, examines relevant developments in digital policies and the progress made by each Member State. Starting from the targets and objectives of the Digital Decade, 5 representative clusters of priority policy issues have been drawn up (see Fig.1):

- investments from public and private resources;
- security and defense;
- integration of the Single Market;

– cooperation;
– strengthening of the democracy.

With regard to urban transformations, the DDPP pushes for the creation of platforms that simplify cross-border and administrative processes, essential for a more efficient Public Administration in governing the territory, which digitizes and speeds up its services and guarantees data interoperability.

More generally, while EU countries have generally increased their efforts and national roadmaps for the Digital Decade, including measures worth €288.6 billion, the 2025 Report highlights the need for further public and private interventions and investments to strengthen the EU's technological capacity, ensuring better infrastructure and digital skills development. Despite progress in areas such as the digitalization of public services, the deployment of essential 5G, and the deployment of edge nodes to process data faster and smarter, there are still structural challenges to address. For example, the adoption of AI, cloud, and big data by businesses has increased but still needs to accelerate. Furthermore, the EU remains too dependent on external providers for AI and cloud services, which are often used in public administration as well.

A key priority for the EU is to position itself as a truly leading continent in AI. This obviously requires a combination of resources, capabilities, advanced skills, and highly efficient infrastructure and the Digital Decade Policy Programme 2030 can guide a series of actions towards this goal. Fig.2 illustrates and specifies the seven pillars on which the EU is relying to become an AI leader:

– 1.Digital infrastructure;
– 2.Energy infrastructure;
– 3.Data availability & Governance;
– 4.Talent & Skills;
– 5.Innovation & Research;
– 6.Regulation & Ethics;
– 7.Industrial Coordination.

With respect to these seven pillars, Fig.2 also illustrates the possible actions that the Digital Decade Policy Programme can implement to support them.

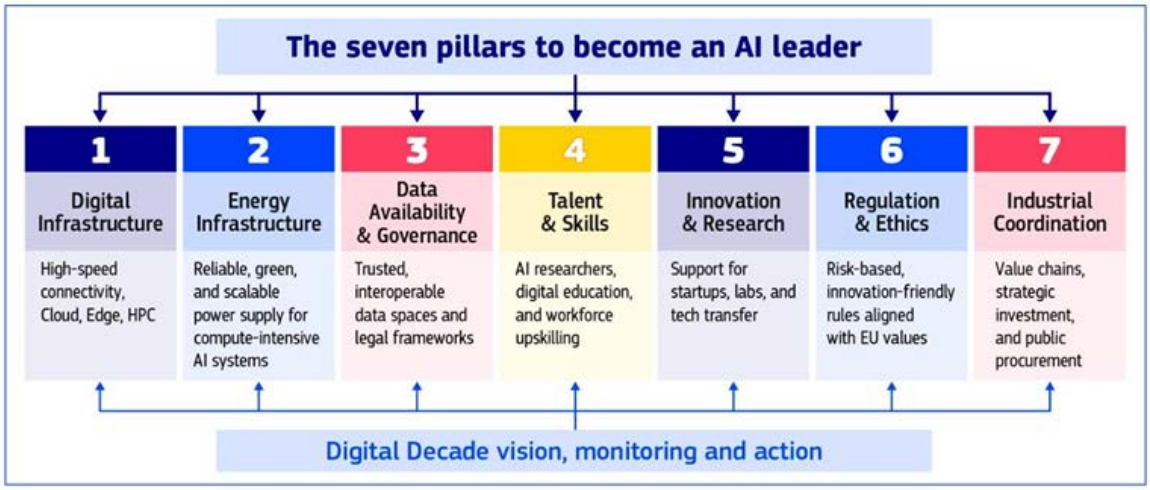

Fig.2 The seven pillars for becoming an AI leader and the role of the Digital Decade (European Commission, 2025)

In line with the EU objectives defined by the DDPP is the Digital Europe Programme (DIGITAL) which aims to shape the digital transformation of European society and economy. The Digital Europe Programme is a part of the long-term EU budget, the Multiannual Financial Framework 2021-2027, with an overall budget of over €8.1 billion. These funds provide strategic financing for the contribution of digital technology to businesses, citizens, and public administrations.

The mission of the DIGITAL program focuses on:

- building essential capacities and advanced skills in key digital technologies, contributing to the EU's open strategic autonomy;
- accelerating their deployment and making the best use of them in areas of public interest and the private sector.

The Digital Europe Programme focuses on strengthening the EU's digital capabilities in the key areas of artificial intelligence (AI), cybersecurity, advanced computing, data infrastructures, data governance and processing, the deployment of these technologies and their best use for critical sectors like energy climate change and environment, manufacturing, agriculture and health (European Commission, 2021).

In order to fulfil its mission, Digital Europe Programme will deploy a network of European Digital Innovation Hubs (EDIH) offering access to technology testing and support in their digital transformation for private and public organisations all across Europe, including government at national, regional or local level, as appropriate. Figure 3 shows only some of the objectives already achieved through funding from the DIGITAL Programme, many projects are still ongoing as funding will end in 2027.

Fig.3 Some results achieved through funding from the DIGITAL program (Digital Europe Programme, 2025)

The DIGITAL Program also contributes to supporting the development of smart city initiatives (D'Amico, 2025b; European Commission, 2023; Nastjuk et al., 2022) and the Sustainable Development Goals (Giuliodori et al., 2023; Rosário & Dias, 2022). Indeed, sustainability and digitalisation are considered key drivers that together are essential to driving a fair global transformation of the European Communities (Garau et al., 2023).

Specifically, regarding SDG11 "Make cities and human settlements inclusive, safe, resilient and sustainable", a number of activities funded by DIGITAL Programme are expected to contribute to more inclusive and sustainable cities and communities. One example is the data space for tourism (over EUR 8 million and over 40 participants), which aims to enable more efficient crowd management at tourist destinations, among other outcomes. This goal is also supported by the data space for smart communities (with over EUR 17.9 million in funding), allowing cities to have the right data to model aspects such as energy use in buildings or infrastructures. In addition, DIGITAL Programme is supporting the large-scale roll-out of local digital twins (Caprari et al., 2022) across the EU (EUR 20 million in funding). As a further step, virtual reality / augmented reality and metaverse technology (over EUR 6.4 million involving 29 beneficiaries) will be introduced, creating an immersive environment for citizens and businesses: the "Citiverse" can be used for virtual/real spatial planning, management or navigation while also enhancing the social, architectural, green and cultural heritage dimensions of living spaces (Digital Europe Programme, 2025).

Regarding data, interoperability, and the single market, Europe has been focusing significant efforts for years. Policy-relevant assessments and analyses are often based on a combination of different types of data, including

environmental and geographic data, such as land use, administrative boundaries, altitude, hydrology, transport networks, population density, etc. Data relevant to environmental and territorial policies are often geo-referenced. However, the geographic information required for good governance at all levels is often not readily available, of adequate quality, or effectively stored.

It is in this context that the EU Infrastructure for Spatial Information (INSPIRE) was launched in 2007. INSPIRE is a European spatial data infrastructure supporting EU environmental policies. It enables easy cross-border access and sharing of data and provides interoperable services to support policy makers and implementers, as well as businesses, science and citizens.

Although it is a Directive and not a funding program, INSPIRE is a fundamental tool for digital territorial governance. It establishes the legal framework for the establishment of an interoperable spatial and geographic data infrastructure (GIS) in Member States, requiring administrations to standardize and share geographic and spatial data, laying the foundation for the construction of national and regional geoportals.

Digital technologies are increasingly placing new demands and expectations on the public and private sectors. Realizing the full potential of these technologies has therefore become a key challenge to achieve a wide range of benefits, greater efficiency, and savings for governments, citizens, and businesses.

Next Generation EU is another tool implemented by the European Union post-pandemic to promote a new growth model based on a clean, innovative, and inclusive economy and on digital and technological sovereignty. With loans and grants provided to Member States through the Recovery and Resilience Facility (RRF), NextGenerationEU has been investing in a series of critical areas, including digital transformation. Indeed, each Member State must dedicate at least 20% of the total allocation of its recovery and resilience plan to measures that contribute to the digital transition or address the challenges arising from it.

Reforms and investments in digital technologies, infrastructure, and processes are crucial to increasing the Union's resilience and innovative capacity. These actions are also crucial to diversifying supply chains and making Europe less dependent on external sources. The Recovery and Resilience Facility (RRF) actively supports reforms and investments aimed at expanding very high-capacity networks, the digitalization of public services and government processes, the digitalization of businesses -with a specific focus on small and medium-sized enterprises (SMEs)-, the development of digital skills, and, finally, initiatives that incentivize digital Research and Development (R&D) and the adoption of next-generation technological solutions.

2. Conclusion

This contribution aims to provide an overview of the policy tools deployed by the European Union for digital transformation, highlighting how this process is a crucial factor for the EU's competitiveness, resilience, and technological sovereignty and how it applies specifically to the governance of urban and territorial transformations. Digital transformation represents a strategic imperative for the European Union and a central pillar for improving competitiveness, resilience and technological sovereignty. Indeed, in recent years, with a view to actively shaping the continent's digital future, the European Union has mobilized and launched a broad and diverse set of policy instruments and strategic investment programs.

However, there are still many challenges related to digital transformation. Digital transformation is a complex and ongoing undertaking, where the EU is mobilizing resources and regulatory frameworks to ensure that new technologies are fully available, integrated into the economy, society and, crucially, the effective governance of urban and territorial transformations.

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REVIEW NOTES
Urban practices

Competitive climate adaptation. Startups and urban innovation ecosystems driving 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 concludes a three-parts series exploring the potential driving role of climate tech startups in supporting urban planning processes for effective climate change adaptation in cities. It first provides an overview of urban planning tools that enable cities to integrate innovation ecosystems into goal-oriented urban transformation processes. These tools highlight the strong interconnection between advancing climate change adaptation and enhancing urban competitiveness. Subsequently, a set of representative case studies of climate startups that have successfully scaled up and are driving tangible adaptive transformations in urban contexts is examined. The note then outlines practical recommendations and future research directions. Overall, the case studies demonstrate that climate startups are not only highly promising allies for urban adaptation but are already shaping the pathways toward climate-resilient cities. Innovation ecosystems emerge as crucial actors in scaling up global efforts for urban resilience and competitiveness.

Keywords
Climate change adaptation; Urban practices; Competitiveness; Climate startups; Innovation Ecosystems

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1. Cities at the core of climate action and sustainability transitions

When dealing with climate action, cities play a pivotal role. Their population and infrastructures' density, the lifestyle they embody, and their critical systemic functions make them crucial both for the reduction of greenhouse gas emissions and the safeguard of vulnerable people and assets against harmful impacts (UN-Habitat, 2024). Accordingly, the international debate on mitigation and adaptation strongly involves urban areas and how to guide their socio-technical transition towards more sustainable configurations, that are also net-zero and climate-resilient, in line with the perspective of sustainability transitions (European Commission, 2020; Kuhl, 2019). The historical development of the academic debate has fostered a flourishing branch of literature on sustainability transitions (Köhler et al., 2019). As environmental issues began to be understood as systemic phenomena, the integration of evolutionary economics and innovation studies led to the recognition that solving complex, systemic challenges require long term, nonlinear and structural changes in how societal systems function (Li et al., 2024; Schandl et al., 2025). Innovation progressively gained a central role in the effective uptake of new sustainable models and structures, becoming a bridge between socially and environmentally sound development and economic sustainability (Silvestre et al., 2019). This trajectory has been articulated in approaches such as the Multi-Level Perspective (MLP), which conceptualizes how transitions occur through the emergence of niche innovations and the influence of broader landscape pressures on dominant regimes (Geels, 2019). As the urgency of climate change has grown in recent decades, together with rising interest from policymakers, the literature has further evolved, with cities increasingly emerging as key arenas for sustainability transitions, and with governance shifting from top-down control towards coordination, experimentation and learning (Frantzeskaki, 2018). These complex challenges involve multiple stakeholders and call for the application of management strategies also in the public domain, through tools and processes that support more action-oriented and economically sustainable forms of urban development. In urban planning, this has translated into new types of plans that explicitly integrate mitigation, adaptation and broader sustainability goals (C40 Cities, 2024; Davide et al., 2025; Giacomelli et al., 2025). These include, but are not limited to: strategic plans, climate action plans, climate adaptation strategies and plans, sustainable development plans, action plans for sustainable energy and the climate, and many other declinations of these. At the same time, the climate finance gap remains wide (UNEP, 2025), and the debate on sustainability transitions continues to expand, increasingly addressing transition arenas, stakeholder engagement and innovative processes as conditions for accelerating change. Within this broader framework, this review completes a series of three notes that examine the crucial, innovative role that climate tech startups can play in leading urban climate transitions (Pennino, 2025a, 2025b). Building on previous work that has highlighted the potential of Italian and European startups in mobilizing investments for climate action, often supported by dedicated European policies, this note explores examples of strategic plans that already integrate startup ecosystems as key stakeholders, and discusses two startups that are actively contributing to urban climate action on the ground.

2. Startups as innovation catalysts in transition arenas: a brief review

Startups represent quintessential niche innovations, defined by their emerging status as newborn companies, the deployment of novel technologies or business models, and the ambition to rapidly scale disruptive solution within incumbent-dominated markets (Blank & Dorf, 2020). In the context of sustainability transitions, startups and their surrounding innovation ecosystems serve as experimental arenas facilitating rapid iteration of solutions under uncertainty (Bevilacqua et al. 2023). These ecosystems foster multi-stakeholder engagement, spanning public, private and civic sectors, while creating vertical networks linking local governments to broader transnational innovation infrastructures (UNDP, 2025). Consequently, startups should be viewed not merely as economic agents but as integral governance partners capable of co-producing urban sustainability transitions (Olteanu & Fichter, 2022). Climate tech startups are notably active in sectors historically examined

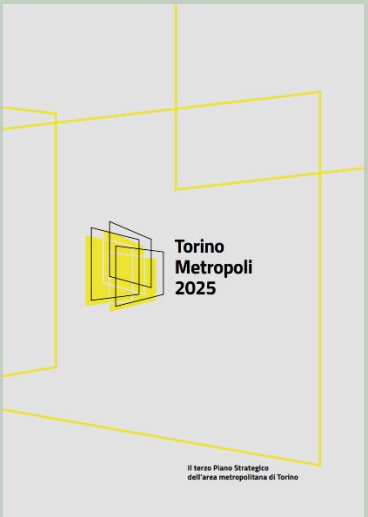
through the lens of transition theory, such as energy systems and urban mobility. Indeed, the European Union has firmly placed startup-led innovation at the core of several EU initiatives for sustainable development and competitiveness, a long-standing choice that has been further analyzed within academic research (Gargiulo et al., 2022; Pidalà, 2025).

Recent scholarship highlights the pivotal role startups and innovation ecosystems play in enhancing urban climate adaptation and resilience. Boyd and Juhola (2020) underscore how urban experiments, including those deploying green technologies and infrastructures, embody principles of adaptive governance conducive to systemic change. Horta-Bellido et al. (2023) further argue that climate tech startups deliver innovative services that complement city councils' climate policies by enabling scalable urban climate solutions. Extending this discourse, Berniak-Wozny et al. (2024) emphasize startups' centrality in integrating risk and asset management within urban planning frameworks, proposing a sustainability-focused model for incubator-city collaborations. Whether framed within adaptive governance or broader transitions theory, startups are increasingly recognized as critical non-state actors participating in multi-level governance of climate-resilient urban planning. They contribute to shifting power dynamics by facilitating bottom-up innovation and fostering active citizen engagement, thus enriching urban climate governance with diverse perspectives and capacities.

3. Urban pilots

While academic literature on sustainability transitions and urban climate governance has expanded, several cities have already begun to translate these concepts into innovative strategic plans that explicitly mobilize startups and innovation ecosystems as partners in key sectors. These plans move beyond a purely infrastructural or regulatory approach and instead frame entrepreneurial innovation as a lever for experimenting with solutions in areas such as mobility, energy, digital services, and urban regeneration. In doing so, they position startups not only as economic actors, but as strategic stakeholders in the co-production of climate-resilient, competitive, and sustainability-oriented urban futures.

1.1 Turin. Strategic planning and innovation-driven entrepreneurship



Turin was the first Italian city to adopt a Strategic Plan in 2000, opening a path that many other cities later followed. By 2020, the city had elaborated three strategic plans (2000, 2006, 2015), each reflecting a different phase in its socio-economic transition and progressively strengthening the link between urban development, innovation and entrepreneurship. The first plan ("for the promotion of the city") emerged in a context of deep crisis of the Fordist manufacturing model and aimed to preserve Turin's capacity to generate wealth and innovation through diversification of the productive system and a radical renewal of the city's international image, culminating in the 2006 Winter Olympic Games. The second plan subsequently focused on the "knowledge economy", emphasising universities, research, advanced services and human capital as key resources for future development.

To manage this intense strategic planning activity, the association Torino Internazionale was created in 2000, with the mandate to promote strategic planning methods, animate local debate on development, and foster the emergence of new agencies, actors, themes and policy goals. In 2016, in the context of rationalizing municipal non-profit entities, the association was dissolved and its relational and project legacy was transferred to Urban Lab, which now acts as a key interface on urban transformation and innovation in Turin.

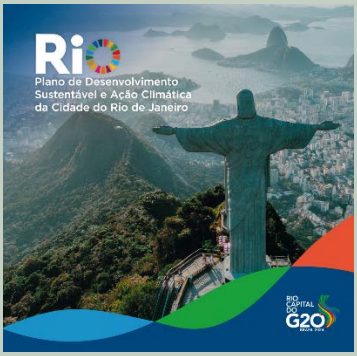
The third Strategic Plan, "Torino Metropoli 2025 – City of Opportunities", explicitly positions the metropolitan area as an "enabling and inclusive environment" that encourages innovation, business creation and talent attraction. The vision is articulated through objectives such as retaining and

growing firms, boosting research and technological innovation, and increasing qualified human capital, all of which are directly linked to the development of a vibrant startup and entrepreneurial ecosystem. In this framework, the plan identifies dedicated instruments to support new enterprises – such as venture accelerator programmes (e.g. "AcceleraTO"), civic tech and social innovation incubators, and coordinated actions with existing university and private incubators, to help nascent businesses reach critical mass and scale rapidly in strategically selected sectors.

Taken together, Turin's three strategic plans trace a clear trajectory: from crisis management and image repositioning to the construction of a knowledge-based economy, and finally to the deliberate cultivation of an urban innovation ecosystem where startups, incubators and accelerators are recognized as central actors in renewing the local productive base and contributing to more sustainable, competitive metropolitan development.

Source: https://urbanlabtorino.it/pianificazione-strategica/

1.2 Rio de Janeiro. Climate-oriented innovation districts and startup engagement



Rio de Janeiro's recent planning and climate policy frameworks present the city as a laboratory for integrating climate action, social vulnerability reduction and innovation-driven economic development. As a coastal metropolis highly exposed to climate risks such as flooding, landslides and heatwaves, Rio has adopted strategies that combine traditional infrastructure measures with nature-based solutions, risk-sensitive land-use planning and data-driven decision-making. Within this agenda, the city increasingly emphasizes the role of digital technologies, innovation hubs and partnerships with private and civil-society actors as levers to design and implement adaptation and mitigation measures in a more flexible and inclusive way.

A key feature of Rio's approach is the promotion of innovation districts and pilot areas where new technologies and services can be tested before being scaled up across the metropolitan area. These districts typically bring together universities, research institutes, startups, larger firms and municipal departments around themes such as smart mobility, environmental monitoring, resilient infrastructure and social innovation. By concentrating experimentation in specific neighbourhoods, Rio seeks to reduce the risks associated with novel solutions, gather evidence on their performance, and build collaborative relationships between public and private actors. This model has been used, for example, to trial sensor-based systems for urban heat and flood monitoring, shared mobility services and digital tools for community engagement in risk-prone areas.

Within these innovation districts and pilot projects, climate tech startups are encouraged to act as solution providers for municipal climate priorities. The city and regional partners support this through calls for projects, innovation challenges and collaboration agreements that invite startups to co-develop and deploy technologies for early-warning systems, urban climate analytics, nature-based solutions and resource-efficient services. In practice, this means that startups can access real urban datasets, test their products in complex environments and receive feedback from both municipal technicians and local communities, while the city gains access to agile, often lower-cost innovations that would be difficult to develop in-house. Although the institutional architecture and scale of support are still evolving, Rio's experience illustrates how a climate-vulnerable city can begin to treat startups as embedded actors within its urban innovation ecosystem partners that help translate high-level climate strategies into tangible interventions in streets, public spaces and critical infrastructures.

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1.3 Rome Tech Business 2030. Startups as pillars of the urban tech ecosystem

The Strategic Plan "Tech Business Roma 2030" positions Rome as a Mediterranean hub for tech business and innovation, explicitly linking digital transformation, smart city policies and sustainable development in line with the UN 2030 Agenda. The plan recognizes that Rome's ecosystem is already rich in universities, research centres, incubators and innovative SMEs, but fragmented, and therefore uses thematic working tables and a Town Meeting to involve institutions, large firms and startup representatives in co-defining data needs, priorities and strategic actions in areas such as digital infrastructure, startups and innovative SMEs, sustainability and skills.
Operationally, the plan contains several measures that frame startups and innovation ecosystems as co-producers of urban transformation. It calls for investment in high-capacity connectivity, cloud and data infrastructures (5G, IoT, AI, blockchain, cybersecurity) as prerequisites for smart city services and new business models, and analyses the structure and challenges of Rome's startup population (sectoral specialization, funding, limited accelerators, gaps in technology transfer). To address these, it proposes to strengthen open innovation networks connecting startups, corporates, venture capital, universities and the municipal administration, and to deploy tools such as Roma Open Lab – Casa delle Tecnologie Emergenti, Invest in Roma one-stop shop and smart districts as platforms where startups can test solutions on real urban challenges. In doing so, the plan explicitly identifies climate- and sustainability-oriented startups as strategic actors for developing green mobility, circular economy services and digital tools that support a more resilient, low-carbon city.

Retrieved from: https://www.comune.roma.it/web-resources/cms/documents/Piano_Strategico_Tech_Business_Roma_2030_12mb_giu2021.pdf

4. Startups Pilots

Alongside cities that proactively integrate startups into their strategic plans, a small but growing group of climate tech startups has managed to scale up and deliver adaptation services at the urban level. These companies no longer operate only as experimental "niches", but as service providers that support municipalities in achieving their climate goals through bottom-up, project-based collaborations. By offering deployable solutions for heat mitigation, green infrastructure and data-driven planning, they translate local pilots into replicable models that can complement and accelerate city-led climate adaptation.

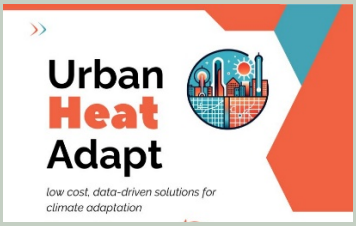
2.1 Roofscapes. Adapting the city from the roofs!

Roofscapes is a Paris-based startup founded by a group of architects and engineers with links to MIT, focused on transforming underused rooftops into lightweight, accessible green structures that enhance climate resilience in dense European cities. The company responds to a very specific urban constraint: in historic city centres such as Paris, limited ground-level space and highly mineral surfaces amplify heatwaves and limit the deployment of conventional green infrastructure. Roofscapes addresses this by designing timber-based systems that can be laid over existing zinc roofs without major structural works, creating new surfaces for vegetation, shading and social use while respecting heritage constraints.
In partnership with the City of Paris, Roofscapes implemented a flagship pilot on the roof of the Académie du Climat, a former town hall repurposed as a climate hub. The project installs a green roof system instrumented with sensors to monitor temperature, humidity, biodiversity and water retention

performance over time, providing robust evidence on the adaptation benefits of green rooftops under real heatwave conditions. Early results indicate temperature reductions of up to 17°C under the green roof compared to exposed zinc surfaces on hot summer days, alongside improved user comfort and the creation of a small urban habitat attracting insects and birds.
From a governance perspective, Roofscapes' work illustrates how a startup can act as a distributed adaptation partner for cities. Through public innovation procurement and R&D collaborations, the startup helps Paris test new design standards for rooftops and explore how regulatory tools, incentives and retrofit programmes could scale this solution across the city's extensive roofscape. In this sense, Roofscapes operationalizes climate adaptation at building and neighborhood scale, while offering municipalities a replicable model to integrate private rooftops into their broader climate and resilience strategies.

Startup page: https://www.roofscapes.studio/home-english

2.2 Urban Heat Adapt. Providing high resolution data for climate adaptation.



Urban Heat Adapt is a climate tech startup dedicated to providing cities with actionable, low-cost services for adapting to increasing urban heat. The company combines modular sensor systems designed for dense urban environments with an AI-enabled web platform that processes high-resolution climate data into decision-ready indicators. Its goal is to become a comprehensive service provider for urban climate adaptation, translating complex temperature and comfort data into maps, dashboards and scenarios that planners, health authorities and other stakeholders can use in practice.
The startup's approach addresses a critical barrier in many municipalities: the lack of fine-scale, operational information on where heat risks are highest, who is most exposed, and which interventions are most effective. By deploying mobile and fixed sensors, Urban Heat Adapt can generate neighborhood-scale datasets on heat stress, often at resolutions of around 100–200 metres, and derive indicators such as tropical nights, heatwave days, outdoor comfort and potential health impacts. These insights support cities in prioritizing adaptation measures – ranging from nature-based solutions and cool materials to shading, water features and targeted communication – where they are most needed.
Urban Heat Adapt typically works in close collaboration with municipal departments and regional climate agencies, embedding its tools into planning and early-warning processes. The platform allows users to test different adaptation scenarios, compare their potential impact on heat exposure and health outcomes, and align these with existing spatial plans and investment pipelines. In doing so, the startup not only supplies technology, but also helps build institutional capacities for data-driven, equitable heat adaptation, positioning itself as a long-term partner in cities' efforts to protect vulnerable populations and redesign public space under a warming climate.

Source: https://www.f6s.com/urban-heat-adapt

5. Conclusions

This review shows that cities and startups can form a mutually reinforcing nexus for advancing competitive climate adaptation, provided that their roles are deliberately aligned within sustainability transition frameworks. On the one hand, cities are increasingly recognized as key arenas of socio-technical change, where strategic plans, smart city strategies and innovation policies are beginning to explicitly integrate startups and innovation ecosystems as stakeholders in delivering climate-relevant solutions. On the other hand, a small but growing group of climate tech startups, such as Roofscapes and Urban Heat Adapt, have demonstrated

their capacity to scale from niche experiments to urban-scale service provision, supporting municipalities in translating climate goals into concrete interventions on roofs, streets and public space.

The cases examined suggest that startups can contribute to urban climate adaptation in at least three complementary ways: by providing highly specialized technologies and services (e.g. green roof systems, high-resolution heat monitoring); by acting as intermediaries that connect research, citizens and local administrations in experimental projects; and by helping to redesign governance arrangements around data, risk and infrastructure. However, they also highlight persistent challenges, including fragmented innovation governance, dependence on short-term projects, and the need for stable regulatory and financial frameworks that allow cities to systematically procure and scale startup-driven solutions.

Overall, the analysis confirms that climate tech startups can meaningfully support cities in leveraging more sustainable and competitive climate action, but that their potential is far from fully realized. Stronger alignment between urban strategic planning, climate policy, and innovation ecosystems – through dedicated urban labs, mission-oriented procurement, and clear pathways from pilot to scale – appears crucial to move from scattered experiments to structural change. Further research should therefore investigate which policy mixes, governance arrangements and financing instruments are most effective in institutionalizing city-startup cooperation for climate adaptation, and how these can be adapted to different urban, socio-economic and regulatory contexts.

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Author's profile

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REVIEW NOTES
Urban planning literature review

Exploring open and green space characteristics for climate change adaptation: a focus on energy consumption

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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 third 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 energy consumption. 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
Open space; Green areas; Literature review; Climate change adaptation; Energy consumption

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1. Introduction

In recent decades, the increase in energy consumption in urban areas has become one of the main environmental issues, closely linked to urbanisation processes and climate change. The growth in energy demand for air conditioning in buildings, public lighting, transport and industrial production has led to significant pressure on natural resources and energy infrastructure. Cities are responsible for 66% of global energy consumption and 70% of emissions.

The current energy crisis makes it more imperative than ever to integrate energy saving and efficiency into the governance of urban and territorial transformations, from strategies to tools, at all scales of the city: from buildings to neighbourhoods, from large urban areas to the territory as a whole. In this context, open and green spaces are strategic tools for climate mitigation and adaptation, with direct and indirect effects on reducing urban energy consumption. These benefits include microclimatic regulation of urban green spaces, which reduces ambient temperature and consequently decreases energy demand for cooling buildings, as Zhang et al. explained in 2014. Similarly, good morphological design of open spaces can improve natural ventilation and lighting, thereby boosting energy efficiency in the built environment. The challenge is to translate these ecological benefits into integrated planning strategies that can guide the sustainable development of cities.

Increasing the urban vegetation cover can bring down the average temperatures by 1.07° to 2.9°C. This has enormous implications on energy demand for summer cooling. Marando et al. (2022) contend that a 16% rise in urban green space can be translated into a reduced temperature of approximately 1°C. Green spaces in summer are reported to absorb approximately 3.33×10^{12} kJ of heat through the process of evapotranspiration. This has indeed caused an annual decrease in air conditioning demand of 3.09×10^{8} kWh, hence reducing the CO_2 emissions from power plants by more than 243,000 tonnes (Zhang et al., 2013).

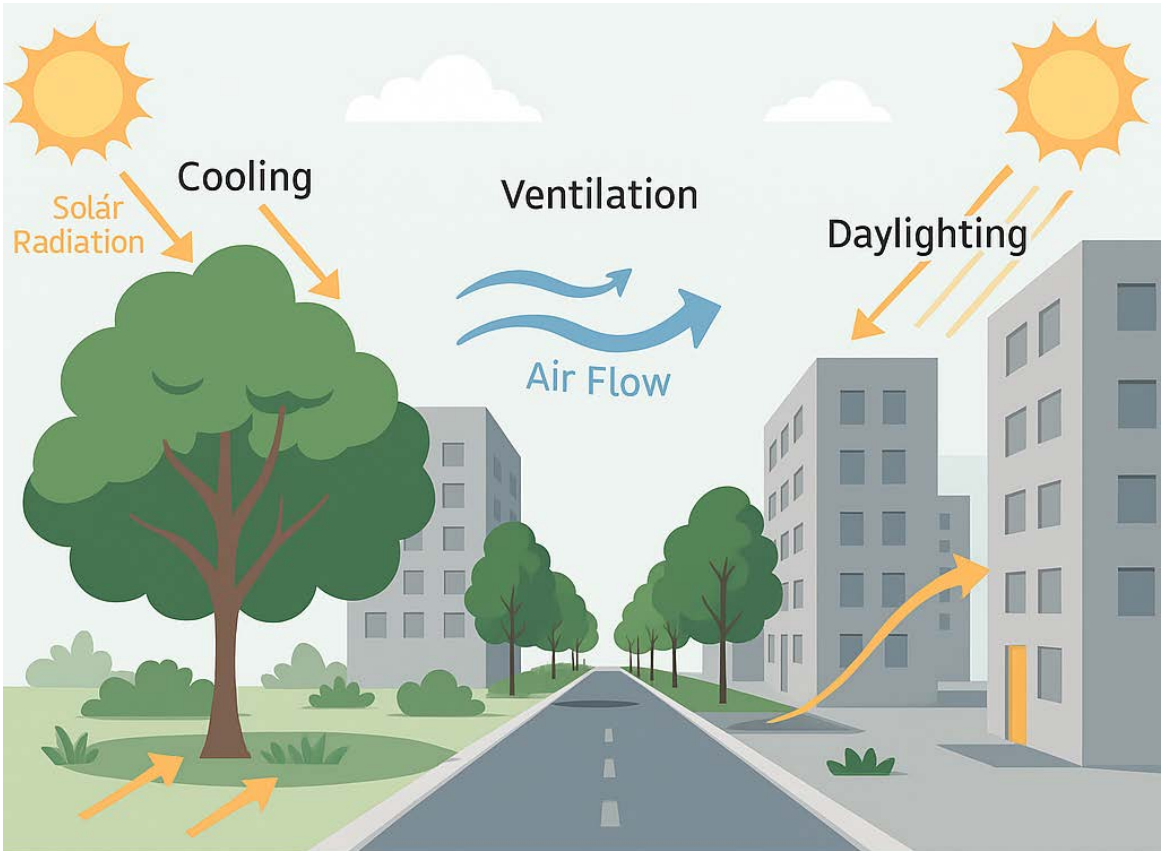

Fig.1 Open Space System in Urban Area with Energy and Thermal Benefit (Generated with AI)

Therefore, it is strategic to adopt a targeted approach to the distribution of greening measures, concentrating them in key areas of the city rather than evenly distributed. This methodology maximizes the benefits in terms of energy savings and emissions reduction, while optimizing costs (Massaro, 2023).

2. Agreements and strategies developed at international level

Climate mitigation and adaptation policies worldwide recognize the role of open spaces as essential elements for urban energy saving (Ascione et al., 2025). The United Nations 2030 Agenda fosters an integrated approach to sustainable urban planning through the Sustainable Development Goals, especially Goal 11 (Sustainable Cities and Communities) and Goal 13 (Climate Action) (United Nations, 2015). Finally, the Paris Agreement of 2015 summed up the commitment of the signatory states in reducing emissions and fostering energy efficiency thanks to urban adaptation measures.

Low-carbon urban planning relies on the principle that open and vegetated spaces can play a very important role in energy demand reduction and mitigation of the urban warming effect. The European Union's Strategy on Adaptation to Climate Change and the Biodiversity Strategy for 2030 place green infrastructure at the center of urban regeneration policies. These are implemented through the support of several local and international financing and planning instruments that foster resilient and sustainable cities.

First and foremost among these is the European Green Deal, presented in 2019, which represents the roadmap of the EU with respect to achieving climate neutrality by the year 2050. The focus of its main priorities is on contributing to a circular economy, reduction of emissions, and greening solutions. In urban areas, the Green Deal promotes the increase of green spaces, energy efficiency of buildings, and sustainable mobility.

These investments will be realized through urban reforestation programs, green roofs, ecological corridors, and infrastructure for sustainable rainwater management.

Another tool is Horizon Europe, 2021-2027, the principal European programme in the field of research and innovation that finances projects for sustainability and energy saving.

Among its most important missions for urban planning are:

- Climate-Neutral and Smart Cities: will help transform at least 100 European cities into climate-neutral ecosystems by 2030.
- Adaptation to Climate Change: Develop solutions not only to manage extreme weather conditions but also reduce energy consumption by reconfiguring open spaces.
- It fosters biodiversity and ecosystem services, hence encouraging the conservation and proper utilization of natural resources within city settings.

Fig.2 Horizon Europe Portal Banner

LIFE Programme operational since 1992 is the EU financial instrument dedicated to the environment and climate action. In the 2021-2027 programming period, LIFE supports projects that integrate energy efficiency and climate mitigation measures by promoting green and blue infrastructure. Typical interventions involve the redevelopment of disused urban areas through the transformation and greening of open spaces, improving the energy resilience of public spaces, and providing innovative technologies for the sustainable management

of energy and water resources. Ministry of Environment and Energy Security 2024. Besides thematic programs, the ESIF and NRRP represent additional financial support instruments.
In principle, in many countries - such as Italy - NRRP resources are committed to creating green infrastructures, energy upgrading of public buildings, and ecological transition of cities.

3. Morphological characteristics of open spaces and their role during flooding events

Urban morphology has a decisive influence on the energy behavior of a city. Open spaces, squares, car parks, and internal courtyards have in common the function of regulating the microclimate due to three basic mechanisms: Evapotranspiration: plants release moisture into the atmosphere, contributing naturally to the cooling of the air, while reducing the thermal load on buildings. Shading: trees and vegetation protect artificial surfaces, reducing the absorption of solar radiation.
Finally, natural ventilation: the distribution of open spaces allows for and improves air circulation, enhancing thermal comfort while diminishing the demand for air conditioning.
The morphological characteristics which most influence energy benefits include:

- the size and continuity of green areas;
- the existence of trees;
- the integration of water features such as fountains or ponds;
- soil permeability, and the use of reflective materials;
- the orientation of the structures in relationship to predominant wind patterns.

4. Conclusions

Open and green spaces are not only elements that connect the urban fabric, but also fundamental tools for energy consumption reduction and adaptation to climate change.
Scientific literature also confirms that an integrated approach in urban planning, environmental design, and green infrastructure management can lead to significant energy benefits.
NBS integrated into urban transformation strategies contribute to reducing energy demand for cooling and heating, improving citizens' quality of life through better microclimatic comfort. In order to maximise these benefits, though, the promotion of coordinated policies at both a local and supra-local level is needed, with increasing adaptive planning practices and continuous energy result monitoring. The future of sustainable cities is linked to being able to conceive open space as an active energy infrastructure that is fundamental to strategies of adaptation to climate change.

UNEP Copenhagen Climate Centre (CCC)

UNEP-CCC
UNEP Copenhagen Climate Centre

Il UNEP Copenhagen Climate Centre (CCC) è un centro di eccellenza che promuove soluzioni energetiche efficienti e basate sulla natura per affrontare le sfide climatiche globali. In risposta alle ondate di calore record, il CCC sostiene tecnologie a basso consumo energetico e infrastrutture verdi per ridurre le emissioni e rafforzare la resilienza urbana. Collabora con enti internazionali per proteggere i più vulnerabili, migliorare la qualità dell'aria e favorire uno sviluppo sostenibile.

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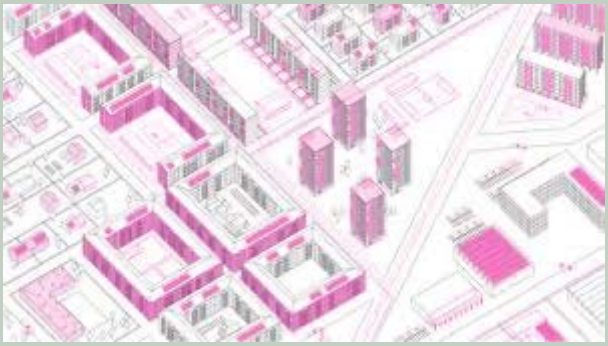
From Energy Renovation to Urban Renovation



Lo studio pubblicato da Agenzia delle Entrate esplora come gli strumenti finanziari per l'efficienza energetica possano essere utilizzati per rigenerare il tessuto urbano. L'approccio proposto mira a superare la scala del singolo edificio, promuovendo interventi integrati su spazi pubblici e privati. Il documento evidenzia il potenziale di sinergie tra finanza pubblica e investimenti privati per migliorare la qualità urbana.

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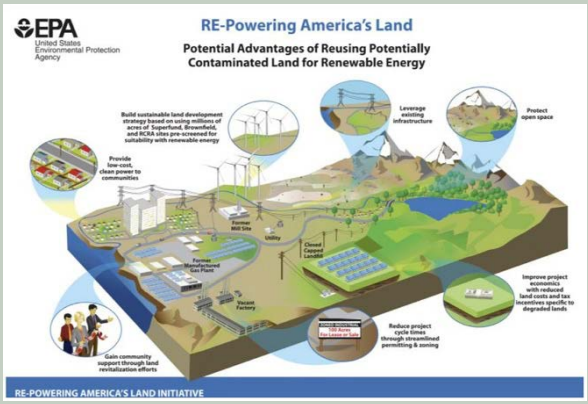
Re-powering the Nature-Intensive Systems



L'articolo propone un approccio innovativo per collegare gli interventi di permeabilizzazione negli spazi aperti con la transizione energetica. Attraverso l'analisi di concetti comuni come capitale naturale, servizi ecosistemici e infrastrutture energetiche, il lavoro evidenzia il potenziale dei sistemi accoppiati NbS-ET per affrontare le sfide urbane e ambientali. Il contributo offre una base teorica utile per sviluppare strategie integrate di sostenibilità.

Retrieved from: https://www.frontiersin.org/journals/sustainable-cities/articles/10.3389/frsc.2022.860914/full

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REVIEW NOTES
Urban planning literature review

Global warming reports: a critical analysis of R&D centres 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 second issue of TeMA Journal volume no. 18, this section provides a critical analysis 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 seeks to explore the perspectives of research and development (R&D) centres on climate change, highlighting their function in advancing scientific knowledge and supporting its translation into actionable insights for society, while also critically evaluating the strengths and possible shortcomings of their approaches to reporting.

Keywords
Global warming, Research centres, Climate change, Adaptation

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1. Introduction

Due to the continuous increase in extreme weather events, climate change has become a challenge for all cities around the world. Scientific literature on climate change has grown significantly in recent decades, indicating the urgency and global importance of the issue (Herziger & Hurst, 2025; Almulhim & Cobbinah, 2024). Since the late 1980s, with the establishment of the Intergovernmental Panel on Climate Change (IPCC) and the adoption of the United Nations Framework Convention on Climate Change (UNFCCC), more and more research centres have been focusing on climate change, developing an increasingly complex network (Haunschild et al., 2016). Their work shows that the crisis embraced different filed from ecological stability, socio-economic resilience, to global equity (Stiuso, 2025).

The research centres play a key role in transforming scientific knowledge into climate planning, providing the basis and tools to support policy decisions (Isola et al, 2024). Their activities focus on different thematic areas, from mitigation strategies, energy transition and adaptive urban planning, while others focus on climate modelling and impacts. Strong, localized climate observation and data transparency are the building blocks of good governance (Francini et al., 2021). They are also necessary for setting baseline conditions and proving that interventions are needed right away (Nyashilu et al.,2024).

In addition to developing research in various scientific areas, research centres can be of different types. There are academic institutes, linked to universities, which focus on theoretical and applied research, and then there are independent institutes or "think tanks" that carry out policy-oriented research and have no affiliation (Etzkowitz & Kemelgor,1998). Finally, there are institutions that actively collaborate with government agencies in supporting policy decisions. It is worth specifying the distinction between research centers with IGOs and NGOs. The former are responsible for coordinating the policies of member states, while the latter are more focused on raising awareness and implementing local projects. This distinct institutional landscape is important because the problem needs a mix of solutions: measuring the crisis in real life, making existing systems more useful, and completely changing how people consume (Pratt, 2023; Drescher & Skoyles, 2024).

The aim of this review is to offer a critical reading of the role of scientific research in supporting adaptation to climate change. To this end, three reports produced by three different national and international research centres have been analysed, highlighting the main issues and assessing the strengths and possible weaknesses of their approaches in reporting and supporting policy makers.

2. Reports summary

This section provides a detailed analysis of three reports published by different research centres, offering insight into the diverse perspectives and approaches adopted. 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 institutions frame and implement climate action across sectors.

The selected reports are presented in the following Tab.1

Title	Organization	Publication date
Climate in Italy in the 2024	National System for Environmental Protection (SNPA)	2024
Risk Analysis. Climate Change in Italy	Mediterranean centre for climate change (CMCC)	2020
A Climate for Sufficency. 1.5 Degree Lifestyle	Hot and Cool (HC)	2025

Tab.1 Overview of the reports analysed, including their title, publishing organization and year of publications

Climate in Italy in the 2024

The report Il Clima in Italia nel 2024 (The Climate in Italy in 2024) is published by the National System for Environmental Protection (SNPA) and coordinated by ISPRA. It provides a detailed overview of the state and evolution of the climate in Italy over the last few decades, taking into account the global and European climate context. Unfortunately, the article has only been published in Italian, but there are numerous images that aid understanding of the text. The central theme of the report is the monitoring and climatic evolution of extreme events. The aim is to inform policy makers of the context in which they must act and, at the same time, to help them with territorial planning in a climate crisis scenario. The report is divided into two main parts. The first describes and illustrates climate indicators in Italy, starting with variables related to temperature and precipitation. The second part focuses more on the national, regional and local scales, concentrating on extreme events that impact the urban environment. In summary, the report also illustrates how 2024 was the hottest year in Italy since 1961, with minimum temperatures being particularly high. Italy is currently divided into two parts: the north, affected by heavy rainfall, and the south and islands, affected by severe water shortages.

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Risck Analysis. Climate Change in Italy

The report Risk Analysis: Climate Change in Italy was produced by the Euro-Mediterranean Centre on Climate Change (CMCC). It addresses the issue of climate change in Italy, focusing on risk analysis. The aim of this document is to provide a scientific basis to support public decision-makers and, at the same time, to disseminate information and raise public awareness. The report is structured in five chapters, each of which explores the different steps of risk analysis, starting from the scenarios expected for Italy. Climate and impact projections were defined using IPCC emission scenarios (RCP 2.6, RCP4.5, RCP8.5), thus allowing for the evaluation of different mitigation and adaptation policies. Regional climate models such as CSMO-CLM and EURO-CORDEX were also used, which have a different spatial resolution, allowing local variability to be captured. In addition to examining the expected risk for key sectors such as the urban environment, hydrogeological risk, water resources, agriculture and fires, the report also focuses on the economic assessment of impacts, analysing the economic opportunities to be exploited in order to adapt in the best possible way. Finally, the last chapter of the report presents examples of local adaptation initiatives, considering them as best practices. The chapter concludes with an appeal to policy makers, stating the urgent need to take action by integrating adaptation. Finally, the last chapter of the report presents examples of local adaptation initiatives, considering them as best practices. The chapter concludes with an appeal to policy makers, stating the urgent need to act by integrating adaptation into local urban planning, not only in terms of climate action but also as an opportunity for sustainable development and improving the resilience of the territory.

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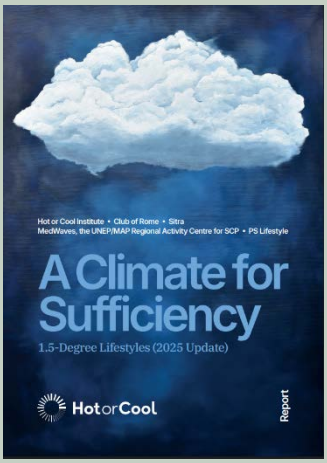
A Climate for Sufficiency. 1.5 Degree Lifestyle



The report A climate for sufficiency: 1.5 Degree Lifestyles was produced by the Hot or Cool Institute, an independent research centre located in Berlin, in collaboration with other research centres. The report presented in this review, in particular, is an update of the previous one and adapts to the new carbon budget, which has been significantly reduced. The aim of the report is to redefine lifestyles by adapting to rising temperatures and reducing consumption in order to stay within the 1.5-degree limit. The report is divided into four chapters. It begins by explaining why reducing consumption is the fastest and most effective strategy, and then clearly quantifies and outlines the changes needed in specific areas. The climate targets for limiting the global average temperature increase to 1.5 °C are translated into practical and tangible measures and actions for citizens. For example, in the Mobility and Food sectors, limits on car use and the quantity and type of food to be consumed are defined, while other areas considered include Housing and Goods and Services. With this report, the Hot or Cool research centre wants to demonstrate that time is not on our side and that reducing consumption is no longer an ideological choice but an urgent necessity.

Retrieved from: https://hotorcool.org/wp-content/uploads/2025/10/A_Climate_for_Sufficiency_report_FULL_REPORT-1.pdf

3. Critical overview and comparative analysis

Together, the three reports offer a comprehensive overview of the climate crisis. Each focus on three different phases of climate challenge. The first report analyses and monitors climate trends in Italy, providing a scientific basis for understanding the situation. The second CMCC report focuses on adaptation strategies, providing useful information for managing the now inevitable impacts by seeking to limit damage and maximise the resilience of the urban system. Finally, the latest report from the Hot or Cool Institute focuses on mitigation strategies, on how to meet the 1.5°C limit by changing lifestyles and limiting unnecessary consumption. In summary, the three reports can also be read consecutively, starting with the SNPA report, which provides information on the current situation, followed by the risk analysis to understand how to "protect" urban environments, and finally the Climate for Sufficiency report, which offers a possible solution on how to address the cause.

Although these documents use different approaches, they agree on the ongoing climate crisis, particularly on the speed at which increasingly frequent extreme weather events are spreading and how Europe, but especially Italy, are climate hotspots, whose warming is above the global average.

A more in-depth analysis of the individual reports, considering their strengths and weaknesses, shows that the SNPA report, given the reliability of the institution, is well structured and consistent. The data used are also homogeneous and validated in accordance with World Meteorological Organisation (WMO) standards. However, some of the variables used are the result of different interpolation methodologies, which may justify the difference in variable values compared to the data produced by individual regional services. The CMCC report focuses on translating risks into adaptation strategies, and one of its strengths is its multidimensional approach to risk, starting from the IPCC's definitions of risk components. In addition, the impacts are analysed with reference to modern climate models and with a spatial resolution of 8 km. An interesting aspect addressed by the report concerns the available financial resources and the analysis of expected costs. This highlights the importance of integrating climate issues into spatial planning tools. Finally, the Hot and Cool Institute report addresses the challenge of climate change from a different perspective. It certainly takes an innovative

approach, shifting the debate from how to produce sustainably to how much to consume. In this way, it seeks to directly address the increase in consumption (rebound effect) that undermines efforts to improve technological efficiency. Although this report represents a different point of view, based on the principle of social justice and equity, i.e. arguing that all individuals should be limited to the same carbon budget, its practical application could present significant challenges that need to be addressed. Sufficiency inevitably implies limitations that may not be in line with certain economic growth models in some sectors and may not be welcomed, especially by populations in high-income countries with significantly high per capita emissions.
A summary of all the considerations discussed is provided in Tab.2.

Report	Focus	Approach	Target Audience
Risk analysis. Climate Change in Italy	Vulnerability and Sectoral Climate Risk in Italy	Bottom-up. Highlights concrete actions	Policymakers, Public Administrations
A Climate for Sufficiency	Drivers of the Crisis and Inequality through the analysis of Lifestyle Carbon Footprints and the concept of Sufficiency.	Top-down; based on a survey Transformative/Ethical: Proposes systemic change (Sufficiency and taxation on the ultra-rich) to remain within the 1.5°C limit equitably global leaders' perceptions.	Global Leaders, Researchers, Citizens (with the potential for high impact, especially in high-income countries)
Climate in Italy in the 2024	Status and Trends of the Italian Climate in 2024 (T, P, SST) and analysis of Extreme Events (floods, drought).	Rigorous and homogeneous measurement of climate data according to WMO standards	Technical experts, Policymakers, and Citizens (as a basis for official knowledge)

Tab.2 Summary of key findings, similarities, and differences among the reports

4. Conclusions

Analysis of reports from some of the most authoritative research centres has shown that climate change is one of the most urgent and complex challenges of the 21st century (Lai & Zoppi, 2023). The position of research centres is now very clear: climate change is no longer a future threat, but a current crisis. Data provided by SNPA and CMCC show that Italy is experiencing a period of significant warming. 2024 was the hottest year since the 1960s, with an anomaly of +1.33°C compared to the decade 1991-2020. Faced with this reality, there are two paths to pursue. On the one hand, implementing adaptation strategies (Wamsler et al., 2013; Carter et al., 2015; Zucaro & Morosini, 2018): the CMCC report shows the urgency of managing risk and moving from vulnerability analysis to climate policies and tools for governing urban and territorial transformation. On the other hand, we must continue with mitigation strategies, seeking to minimise carbon emissions (Fawzy et al., 2020). The perspective offered by the Hot and Cool Institute is certainly innovative. It highlights that an approach based solely on efficiency is not enough, but that we must address the root cause of the crisis, namely consumption and excessive consumption driven by inequality.
In conclusion, the reports converge on the need for integrated, immediate and equitable action. Their critical comparison has made it possible to describe an essential framework for assessing the validity of the various strategies promoted at both national and international level.

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