TeMA

Journal of
Land Use, Mobility and Environment

print ISSN 1970-9889 e-ISSN 1970-9870
FedOA press - University of Naples Federico II

DOAJ anvur Rivista scientifica di classe A - 08/F1 Scopus WEB OF SCIENCE

NEW CHALLENGES FOR XXI CENTURY CITIES

Global warming, ageing of population, reduction of energy consumption, immigration flows, optimization of land use, technological innovation

Vol.17 n.1
April 2024

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 2024 volume of TeMA Journal propose articles that deal the effects of global warming, the ageing of population, the reduction of energy consumption from fossil fuels, the immigration flows from disadvantaged regions, the technological innovation and the optimization of land use.

TeMA is the Journal of Land Use, Mobility and Environment and offers papers with a unified approach to planning, mobility and environmental sustainability. With ANVUR resolution of April 2020, TeMA journal and the articles published from 2016 are included in the A category of scientific journals. The articles are included in main scientific database as Scopus (from 2023), Web of Science (from 2015) and the Directory of Open Access Journals (DOAJ). It is included in Sparc Europe Seal of Open Access Journals, and the Directory of Open Access Journals.

TeMA Journal of
Land Use, Mobility and Environment

NEW CHALLENGES FOR XXI CENTURY CITIES:
Global warming, ageing of population, reduction of energy consumption, immigration flows, optimization of land use, technological innovation

1 (2024)

Published by
Laboratory of Land Use Mobility and Environment
DICEA - Department of Civil, Architectural and Environmental Engineering
University of Naples "Federico II"

TeMA is realized by CAB - Center for Libraries at “Federico II” University of Naples using Open Journal System

Editor-in-chief: Rocco Papa
print ISSN 1970-9889 | online ISSN 1970-9870
Licence: Cancelleria del Tribunale di Napoli, n° 6 of 29/01/2008

Editorial correspondence
Laboratory of Land Use, Mobility and Environment
DICEA - Department of Civil, Building and Environmental Engineering
University of Naples "Federico II"
Piazzale Tecchio, 80
80125 Naples

web: www.serena.unina.it/index.php/tema
e-mail: redazione.tema@unina.it

The cover image shows older people climbing Via Raffaele Morghen's stairs in Naples (Source TeMA Journal Editorial Staff).

TeMA. Journal of Land Use, Mobility and Environment offers researches, applications and contributions with a unified approach to planning and mobility and publishes original inter-disciplinary papers on the interaction of transport, land use and environment. Domains include: engineering, planning, modeling, behavior, economics, geography, regional science, sociology, architecture and design, network science and complex systems.

With ANVUR resolution of April 2020, TeMA Journal and the articles published from 2016 are included in A category of scientific journals. The articles published on TeMA are included in main international scientific database as Scopus (form 2023), Web of Science (form 2015) and the *Directory of Open Access Journals* (DOAJ). TeMA Journal has also received the *Sparc Europe Seal* for Open Access Journals released by *Scholarly Publishing and Academic Resources Coalition* (SPARC Europe). TeMA is published under a Creative Commons Attribution 4.0 License and is blind peer reviewed at least by two referees selected among high-profile scientists. TeMA has been published since 2007 and is indexed in the main bibliographical databases and it is present in the catalogues of hundreds of academic and research libraries worldwide.

EDITOR IN-CHIEF

Rocco Papa, University of Naples Federico II, Italy

EDITORIAL ADVISORY BOARD

Mir Ali, University of Illinois, USA
Luca Bertolini, University of Amsterdam, Netherlands
Luuk Boelens, Ghent University, Belgium
Dino Borri, Politecnico di Bari, Italy
Enrique Calderon, Technical University of Madrid, Spain
Roberto Camagni, Politecnico di Milano, Italy
Pierluigi Coppola, Politecnico di Milano, Italy
Derrick De Kerckhove, University of Toronto, Canada
Mark Deakin, Edinburgh Napier University, Scotland
Carmela Gargiulo, University of Naples Federico II, Italy
Aharon Kellerman, University of Haifa, Israel
Nicos Komninos, Aristotle University of Thessaloniki, Greece
David Matthew Levinson, University of Minnesota, USA
Paolo Malanima, Magna Græcia University of Catanzaro, Italy
Agostino Nuzzolo, Tor Vergata University of Rome, Italy
Rocco Papa, University of Naples Federico II, Italy
Serge Salat, UMCS Institute, France
Mattheos Santamouris, NK University of Athens, Greece
Ali Soltani, Shiraz University, Iran

ASSOCIATE EDITORS

Rosaria Battarra, CNR, Italy
Matteo Caglioni, Université Cote D'azur, France
Alessia Calafiore, University of Edinburgh, UK
Gerardo Carpentieri, University of Naples Federico II, Italy
Luigi dell'Olio, University of Cantabria, Spain
Isidoro Fasolino, University of Salerno, Italy
Romano Fistola, University of Naples Federico II, Italy
Stefano Franco, Politecnico di Bari, Italy
Federica Gaglione, University of Sannio, Italy
Carmen Guida, University of Naples Federico II, Italy
Thomas Hartmann, Utrecht University, Netherlands
Markus Hesse, University of Luxemburg, Luxemburg
Zhanat Idrisheva, D. Serikbayev EKTU, Kazakhstan
Zhadyra Konurbayeva, D. Serikbayev EKTU, Kazakhstan
Seda Kundak, Technical University of Istanbul, Turkey
Rosa Anna La Rocca, University of Naples Federico II, Italy
Houshmand Ebrahimpour Masoumi, TU of Berlin, Germany
Giuseppe Mazzeo, Pegaso Telematic University, Italy
Nicola Morelli, Aalborg University, Denmark
Enrica Papa, University of Westminster, United Kingdom
Yolanda Pena Boquete, AYeconomics Research Centre, Spain
Dorina Pojani, University of Queensland, Australia
Nailya Saifulina, University of Santiago de Compostela, Spain
Athena Yiannakou, Aristotle University of Thessaloniki, Greece
John Zacharias, Peking University, China
Cecilia Zecca, Royal College of Art, UK
Floriana Zucaro, University of Naples Federico II, Italy

EDITORIAL STAFF

Gennaro Angiello, Ph.D. at University of Naples Federico II, Systemica, Bruxelles, Belgium
Annunziata D'Amico, Ph.D. student at University of Naples Federico II, Italy
Valerio Martinelli, Ph.D. student at University of Naples Federico II, Italy
Stella Pennino, Ph.D. student at University of Naples Federico II, Italy
Tonia Stiuso, Research fellowship at University of Naples Federico II, Italy

TeMA Journal of Land Use, Mobility and Environment

NEW CHALLENGES FOR XXI CENTURY CITIES:
Global warming, ageing of population, reduction of energy consumption, immigration flows, optimization of land use, technological innovation

1 (2024)

Contents

REVIEW NOTES

TeMA Journal of Land Use Mobility and Environment

NEW CHALLENGES FOR XXI CENTURY CITIES:
Global warming, ageing of population, reduction of energy consumption, immigration flows, optimization of land use, technological innovation 1

ROCCO PAPA
DICEA - Department of Civil, Building and Environmental Engineering
University of Naples Federico II, Italy
ORCID: https://orcid.org/0000-0003-3355-1418
e-mail: rpapa@unina.it

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 terms, its mission is to contribute to the development of a novel theoretical and methodological framework that, transcending the boundaries separating these research domains, develops innovative solutions for issues now being tackled with methods and techniques rooted in the scientific culture of the last century.
The three issues of the 2024 volume of TeMA Journal propose articles that deal the effects of global warming, the ageing of population, the reduction of energy consumption from fossil fuels, the immigration flows from disadvantaged regions, the technological innovation and the optimization of land use.
In this issue, the section "Focus" contains two contributions. The first article, "Land use changes of coastal wetlands using remote sensing. Study of Muthurajawela & Anawilundawa wetlands, Sri Lanka" by Harsha Dias Dahanayake, DDGL Dahanayaka, Paul Hudson and Deepthi Wickramasinghe (University of Colombo in Sri Lanka and University of York in United Kingdom), delves into the spatiotemporal examination employing Geographical Information System and Remote Sensing techniques to contrast alterations in land usage between an urban locale (Muthurajawela) and a peri-urban area (Anawilundawa) encompassing wetlands and adjacent buffer zones in Sri Lanka. Notably, the configuration of water bodies, dense vegetation, other greenery, human settlements, and open spaces has undergone significant shifts from 2000 to 2021. However, the transformations are notably more pronounced within the urban wetland setting.
The second article of the section, "Gender analysis of urban mobility behaviours in the Tunisian Sahel region" by Mehdi El kébir and Aymen Ghédira (University of Sousse in Tunisia), proposes a focus on gender mobility behaviour in a poorly investigated region of the world. The authors surveyed over 2,000 people in the Tunisian Sahel to understand everyday travel habits. Unlike traditional studies that treat women as a homogenous group, this research focuses on income levels when analyzing women's travel patterns, highlighting significant differences based on gender, exacerbated by financial status. Moreover, this contribution sheds light on an interesting topic for a region of the global south, which is not usually investigated as other parts of the world.
The section "LUME" (Land Use, Mobility and Environment) contains five articles. The first, "Towards the Spanish Local Urban Agenda. The evolution of urban regeneration in Spain (2014-2022)" by Federico Camerin, Lucas Álvarez-Del-Valle, Ana Díez-Bermejo and Ivan Rodríguez-Suárez (Universidad Politécnica de Madrid in Spain), aims to examine the difference in the tools adopted in the Spanish urban policies between the two last EU programming cycles (2014–2020 and 2021–2027). The paper aims to examine the relationship between Integrated European Sustainable Urban Development Strategies and the Spanish Urban Agenda.
The second contribution is "Sustainable development and proximity city. The environmental role of new public spaces", by Antonio Bocca (University Gabriele D'Annunzio in Italy). The article addresses the

potential synergy of the 15-minute city approach to the environmental role of new public spaces. In particular, the paper employs the qualitative review method to examine the literature and obtain extensive information on how the ecological transition is interpreted in the design of public spaces and regenerative processes in the built environment highlight the priority role of public space in the sustainable development of the city. There are two main sections in the article: the first focuses on global challenges and the planning of resilient cities; the second deals with theoretical and application aspects of the concept of proximity about ecological transition (Portland and Barcelona).

The third article, "Spatial attractiveness towards industrial placement: a parametric index based on spatial-economic territorial exposure metrics" di Diego Altafini and Valerio Cutini (University of Pisa in Italy and Cardiff University in United Kingdom), showcases spatial models tailored to address the differences in Spatial Attractiveness based on spatial and economic territorial exposure indexes to unveil the territorial imbalances' spatial logics.

The fourth article of section, "Planning the transition of cities. Innovative research approaches and trajectories" by Francesca Moraci, Carmelina Bevilacqua, and Pasquale Pizzimenti (Università degli Studi Mediterranea in Italy and University of Roma La Sapienza in Italy), focused on the nexus between Ecosystem Services and Key Enabling Technologies as a potential and significant element for the future development of promising research trajectories in urban planning. In light of the ecological, digital, and jus transition envisaged by the EU for reaching the ambitious Green Deal objective by 2050 and its inherent complexity, the transition of cities has become a top priority in academic and policy debates, attracting increasing attention from scholars and policymakers.

The last article of the section, "The cost of shopping: measuring virtual and physical access for obtaining goods" by Jing Chen, Mengying Cui and David Levinson (Nanjing Audit University in China; Chang'an University in China and University of Sydney in Australia), aims to distinguish between physical and virtual shopping accesses and delineate their real-world implications. The authors propose a comprehensive understanding analysis of the disparities in accessibility between digital and brick-and-mortar shopping experiences. Physical and virtual access are studied for the case study of Wuhan City to understand their spatial distribution patterns and to differentiate them for these two commerce forms.

The Review Notes section proposes four insights on the themes of the TeMA Journal. The Urban planning practice section of Review Notes, "New trends in energy transition policies: citizens' involvement in the European energy market", by Valerio Martinelli, examines the role of the European Union in promoting energy transition through citizens' participation. With the Clean European Packages the European Union aims to achieve leadership in renewable energy sources, guaranteeing fair conditions of accessibility to the energy market for citizens and integrating energy and climate policy objectives. The introduction of energy communities makes it possible to realize the objectives defined by the European Directives towards not only environmental but also economic and social sustainability. The second section, "Strategies and instruments for active mobility: comparison of international experiences", by Annunziata D'Amico, aims to present an overview of strategies and tools that promote active mobility, identifying best practices in cities around the world. It highlights that in order to achieve sustainable and low-emission urban mobility, which also encourages active mobility choices, a multi-level approach is needed that involves the collaboration and long-term commitment of governments, local authorities, organisations and citizens. The third contribution, "Global warming or global warning? A review of urban practices for climate change adaptation in Europe", by Stella Pennino, provides an overwiew of the challenges that global warming poses and the risks in terms of climate change that it generates for territories and cities. This note provides an overwiew of the challenges that global warming poses and the risks in terms of climate change that it generates for territories and cities. The challenges that adaptation to climate change commonly faces are outlined, and a brief review of European case studies is carried out. The results of the review are discussed highlighting some key threads of climate adaptation practices and three significant examples of climate change adaptation in urban areas are reported, within a perspective of integration and sharing of know-how on the topic. Finally, the

fourth section, "Exploring approaches and solutions for urban safety: a focus on women", by Tonia Stiuso, reviews agreements and strategies developed internationally to address this issue, including CEDAW, the Istanbul Convention, the European Urban Charter, the Sustainable Development Goals (SDGs), the Urban Agenda and the European Forum for Urban Safety. Various good practices and resources are then presented, including apps, reports, projects, books and studies. Overall, the article provides a comprehensive overview of the challenges and solutions related to women's safety in urban areas.

References

Altafini, D. & Cutini, V. (2024). Spatial attractiveness towards industrial placement: a parametric index based on spatial-economic territorial exposure metrics. *TeMA - Journal of Land Use, Mobility and Environment*, *17* (1), 89-108. http://dx.doi.org/10.6092/1970-9870/10458

Bocca, A. (2024). Sustainable development and proximity city: the environmental role of new public space. *TeMA - Journal of Land Use, Mobility and Environment, 17* (1), 71-87. http://dx.doi.org/10.6092/1970-9870/10414

Camerin, F., Álvarez Del Valle, L., Díez Bermejo, A. & Rodríguez Suárez, I. (2023). Towards the Spanish local urban Agenda. The evolution of urban regeneration in Spain (2014-2022). *TeMA - Journal of Land Use, Mobility and Environment*, *17* (1), 51-70. http://dx.doi.org/10.6092/1970-9870/10338

Chen, J., Cui, M., Levinson, D. (2024). The Cost of Shopping: Measuring Virtual and Physical Access for Obtaining Goods. *TeMA - Journal of Land Use, Mobility and Environment*, *17* (1), 129-145. http://dx.doi.org/10.6092/1970-9870/10688

D'Amico, A. (2024). Strategies and instruments for active mobility: comparison of international experiences. *TeMA - Journal of Land Use, Mobility and Environment*, *17* (1), 155-167. https://doi.org/10.6093/1970-9870/10771

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

El Kébir, M. & Ghédira, A. (2024). Gender analysis of urban mobility behaviors in the Tunisian Sahel region. *TeMA - Journal of Land Use, Mobility and Environment*, *17* (1), 23-49. http://dx.doi.org/10.6092/1970-9870/10415

Martinelli, V. (2024). New trends in energy transition policies: citizens' involvement in the European energy market. *TeMA - Journal of Land Use, Mobility and Environment*, *17* (1), 147-153. https://doi.org/10.6093/1970-9870/10772

Moraci, F., Bevilacqua, C. & Pizzimenti, P. (2024). Planning the Transition of Cities. Innovative research approaches and trajectories. *TeMA - Journal of Land Use, Mobility and Environment*, *17* (1), 109-127. http://dx.doi.org/10.6092/1970-9870/10430

Papa, R. (2023). The city challenges and external agents. Methods, tools and best practices 3 (2023). *TeMA - Journal of Land Use, Mobility and Environment*, *16* (3), 475-477. https://doi.org/10.6093/1970-9870/10566

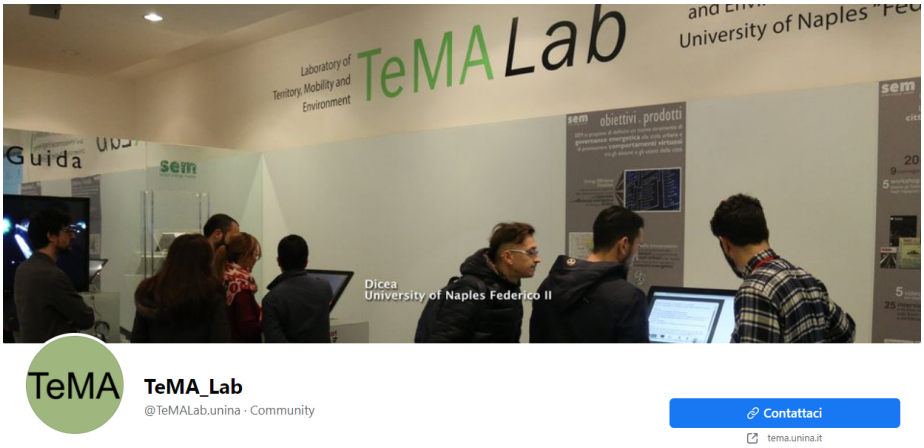
Pennino, S. (2024). Global warming or global warning? A review of urban practices for climate change adaptation in Europe. *TeMA - Journal of Land Use, Mobility and Environment*, *17* (1), 169-177. https://doi.org/10.6093/1970-9870/10784

Stiuso, T. (2024). Exploring approaches and solutions for urban safety: a focus on women. *TeMA - Journal of Land Use, Mobility and Environment*, *17* (1), 179-186. https://doi.org/10.6093/1970-9870/10778

We are online!

TeMA_Lab

Follow us on Facebook



TeMA Lab and our Journal are on Facebook!
TeMA Lab is the Laboratory of Land Use, Mobility and Environment of the Department of Civil, Building and Environmental Engineering, at Università degli Studi di Napoli Federico II. Our field of expertise relates to urban systems, their complexity and the challenges that they will face in near future: adaptation to climate change, ageing population, energy consumptions, development of sustainable mobility and so on. Follow us to be constanly updated!.

www.facebook.com/TeMALab.unina

TeMA Journal of Land Use, Mobility and Environment

TeMA 1 (2024) 7-21
print ISSN 1970-9889, e-ISSN 1970-9870
DOI: 10.6093/1970-9870/10281
Received 11th September 2023, Accepted 5th April 2024, Available online 30th April 2024

Licensed under the Creative Commons Attribution – Non Commercial License 4.0
http://www.serena.unina.it/index.php/tema

Land use changes of coastal wetlands using remote sensing. A case study of Muthurajawela & Anawilundawa wetlands, Sri Lanka

Harsha Dahanayake[a*], DDGL Dahanayaka[b], Paul Hudson[c], Deepthi Wickramasinghe[d]

[a] Department of Zoology and Environment Sciences
University of Colombo, Colombo, Sri Lanka
e-mail: harsha.dahanayake@gmail.com
ORCID: https://orcid.org/0000-0002-8802-3367
* Corresponding author

[b] Department of Zoology
Open University of Sri Lanka, Nawala, Colombo, Sri Lanka
e-mail: ddgldahanayaka@gmail.com
ORCID: https://orcid.org/0000-0001-9052-3873

[c] Depatment of Environment and Geography
University of York, Heslington, York, United Kingdom
e-mail: paul.hudson@york.ac.uk
ORCID: https://orcid.org/0000-0001-7877-7854

[d] Department of Zoology and Environment Sciences
University of Colombo, Colombo, Sri Lanka
e-mail: deepthi@zoology.cmb.ac.lk
ORCID: https://orcid.org/0000-0001-6026-9552

Abstract

Wetlands are confronting significant threats arising from human activities, particularly anthropogenic influences. The alteration of land use and land cover in and around wetlands serves as a clear indicator of the escalating human pressure on these ecosystems. This study employs Geographical Information System (GIS) and Remote Sensing to conduct a spatiotemporal analysis, comparing land use changes in both an urban wetland (Muthurajawela) and a peri-urban wetland (Anawilundawa) and their respective buffer areas in Sri Lanka. The study reveals noteworthy transformations in the extent of water bodies, thick vegetation, other vegetation, settlements, and open areas during the period from 2000 to 2021. The observed changes are particularly profound in the urban wetland. In the Muthurajawela wetland, the core habitat characterized by open water experienced significant conversions into settlements and infrastructure, resulting in an 81% reduction from 2000 to 2010 and a 30% reduction from 2010 to 2021. Similarly, water bodies in the Anawilundawa wetland reduced in size by 12% from 2000 to 2010 and 16% from 2010 to 2021. The results highlight the urban wetland's more substantial transformation from natural areas to anthropogenic areas, necessitating immediate remedial and restoration action. Given this context, it is imperative to delve further into the trajectories, causes, and drivers of land use changes. This deeper investigation is crucial for developing effective wetland management strategies that support sustainability, environmental stability, and the continued functioning of ecosystems.

Keywords

Land use; Land cover; Geographical information system; Wetland; Anawilundawa; Muthurajawela

How to cite item in APA format

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

1. Introduction

Wetlands are among the most valuable, productive, and threatened natural habitats in the world (Barbier, 2013); however, the global loss of wetlands is estimated to be between 64% to 71% over the 20th century (Gardner et al., 2015). Despite this large historical reduction, wetlands still face significant threats mainly due to anthropogenic activities, which continue to exert pressure on these sensitive landscapes.

Coastal wetlands act as an intermediate zone between marine and terrestrial ecosystems, offering a wide array of Ecosystem Services (ES) (Lopes et al., 2022). However, human influence and natural causes contribute to changes in the wetland landscape and the ES delivered by the wetlands (Gayani et al., 2022), and neglecting the full value of the ES provided by the wetlands can further contribute to the degradation of coastal wetlands (Kotagama & Bambaradeniya, 2006; Ustaoglu & Aydinoglu, 2019).

Temporal changes in Land Use Land Cover (LULC) are associated with alterations in the way land is utilized, such as the expansion of urban landscapes, infrastructure development, changes in water bodies, and vegetation cover (Anand & Oniam, 2020). These changes play a significant role in the functionality of coastal wetlands and their buffer areas by altering the hydrology of the area, nutrient cycles, and habitats. Consequently, these changes can further impact biodiversity (Yousaf et al., 2021), ES, and the resilience of the wetlands and their buffer areas. Therefore, understanding the relationship between LULC changes and coastal wetland dynamics is crucial for effective conservation measures in these areas.

It is unsurprising that population growth is a key driving force for land-use land-cover (LULC) changes in coastal areas (Ranagalage et al., 2021). Furthermore, it has been observed that the wetland landscapes most vulnerable to the process of urbanization are wetlands in urban and peri-urban areas (Zucaro & Morosini, 2018), in part due to their proximity to urban areas and the socio-economic opportunity costs the land represents. In this vein, Sri Lanka is not an exception (Athukorala et al., 2021; Hettiarachchi et al., 2014). Sri Lanka is a large island in the Indian Ocean with a coastline of 1340 km and has a significant area of coastal wetlands. Moreover, there is a rapid process of urbanization in coastal areas of Sri Lanka (Senevirathna et al., 2018) that poses a significant threat to Sri Lankan wetlands due to the growth of informal housing, infrastructure development, and poverty creating multiple opportunities to overexploit and degrade wetlands (Vithana et al., 2022). Several studies in Sri Lanka have analyzed the spatial patterns of LULC changes in wetlands; however, there is a gap in detailed investigations on temporal changes in LULC in Anawilundawa and Muthurajawela wetland areas.

The current study seeks to assess the extent to which two prominent urban and peri-urban coastal wetlands in Sri Lanka have transformed into different land uses between 2000 and 2021. This study analyzes and compares the LULC changes in two wetlands using Geographical Information Systems (GIS) and Remote Sensing (RS). The study areas are confined to the Muthurajawela and Anawilundawa wetland and buffer area. The Muthurajawela wetland is a noted nature sanctuary and is in an urban area of the Gampaha district, which is 15 km away from the capital city, Colombo and in close proximity to the main international airport and the main port of Sri Lanka. In contrast, the Anawilundawa wetland, which is a coastal sanctuary, is situated 102 km away from Colombo and is relatively more insulated from development pressures.

2. Study area

The study area is confined to the Anawilundawa wetland, including its 5km buffer zone area (AW) and Muthurajawela wetland, along with its 5 km buffer zone area (MW). To better understand the surroundings of these wetlands, 1 km zones have been established from the wetland boundaries. These zones are identified as zone a, zone b, zone c, zone d, zone e, zone f and zone g, among these the innermost zone being marked as zone a. The Anawilundawa wetland falls within zones a and b, while the Muthurajawela wetland is located within zone a of its corresponding study area (Fig.1).

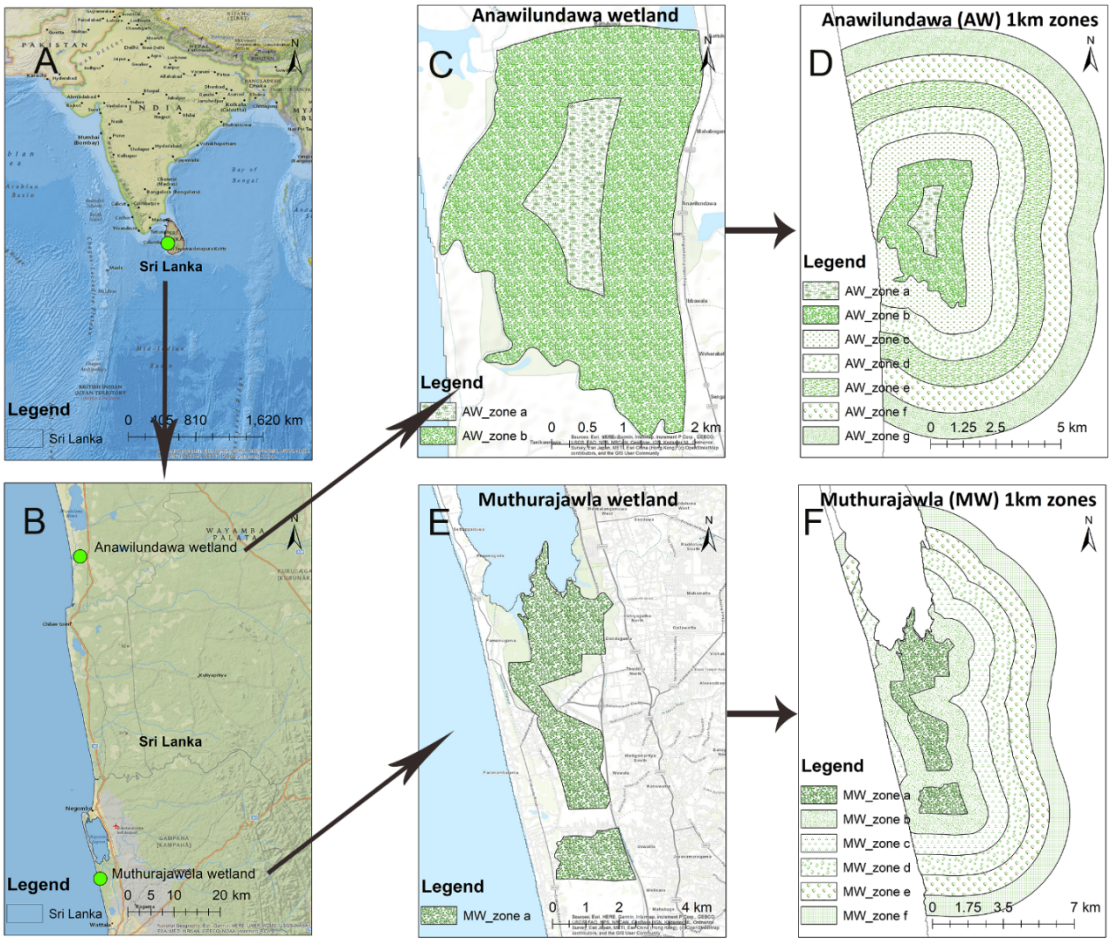


Fig.1 Study area (A) Geographical location of Sri Lanka, (B) Location of Anawilundawa wetland and Muthurajawela wetland, (C) Anawilundawa wetland, (D) Anawilundawa 1km zones, (E) Muthurajawela wetland, (F) Muthurajawela 1km zones

The Muthurajawela wetland is the largest coastal peat bog in Sri Lanka (Dahanayake et al., 2022; Vithana et al., 2022) and it is located (7° 6' 11.10" N, 79° 51' 41.85" E) between the Negombo lagoon to the north, the Kelani River to the south, and spreading inland up to Ragama and Peliyagoda in the Gampaha district. The wetland covers 6,232 ha and forms a costal wetland ecosystem together with the Negombo lagoon. The government of Sri Lanka (GOSL) has declared 1,777 ha of the wetland as a sanctuary (PA1) in July 1996 and governed under the Department of Wildlife Conservation (DWC). In 2006 another protected (PA2) area of 162 ha was designated by a Government Gazettee notification (Central Environmental Authority, 2023). The biodiversity rich wetland receives average annual rainfall around 2,000-2,500mm during the southwest monsoon season (Bambaradeniya et al., 2002). The Muthurajawela marsh receives fresh water from lower Attanagalu Oya and lower Kelani River (Central Environmental Authority and Euroconsult, 1994; IUCN Sri Lanka and Central Environmental Authority, 2006; Greater Colombo Economic Commission and Euroconsult, 1991).

The Anawilundawa wetland, designated as Ramsar site No. 1078 in 2001 and established as a wildlife sanctuary in 1997. This wetland is located (7° 42' 14.30" N, 79° 49' 1.55" E) near the western coast in the Arachchikattuwa Divisional Secretariat Division within the Puttalam District of Sri Lanka. Covering an extensive area of 1,371 hectares, it is under the administration of the Department of Wildlife Conservation (DWC). The wetland experiences a moderately hot and dry climate, with a mean annual temperature of approximately 26°C and an average annual rainfall ranging from 1,000-1,500mm. The primary rainy season occurs during October and November, aligning with the North-East monsoon season (CEA, 2006).

Anawilundawa wetland is characterized by a network of seven shallow ancient cascading tanks: Pinkattiya, Wellawala, Maradansole, Irakka-wela (Ihala Wewa), Anawilundawa tank, Suruwila tank, and Maiyawa tank. Additionally, it encompasses traditional paddy fields and marshland areas, sustaining approximately 412 hectares of traditional paddy fields. The primary water sources for the tank system include surface runoff water from the Rathabala Oya basin and spill water from the Katupotha tank (CEA, 2006).

3. Materials and Methods

3.1 Land use land cover classification and satellite data

The time points of year 2000, 2010 and 2021 were selected for the study, and the Land Use Land Cover classifications were based on satellite data from year 1997 to 2021. The study utilized 30m resolution satellite data from Landsat 5 TM (LS5) and Landsat 8 OLI (LS8), and the images were obtained from United States Geological Survey (USGS) image collection. The Google Earth Engine was used to download the median images and Individual bands were downloaded separately and composite was created for the analysis (Hussain et al., 2022; Liu et al., 2020; Ranagalage et al., 2021).

The satellite images were classified using supervised classification method with the Maximum Likelihood Classifier in Arc Map 10.8. The images were classified into five categories: Water body, thick vegetation, other vegetation, settlements, and open areas and different band combinations used for the image classification is provided in Tab.2.

3.2 The normalized difference vegetation index (NDVI)

NDVI is widely used as an indicator to analyze the vegetation and the biomass of an area using multi spectral satellite images. The NDVI value ranges from -1 to +1, and calculated in Equation (1) Where NIR = Near Infra-Red Band; R = Red Band of the satellite images (Mugendi et al., 2020).

$$NDVI = (NIR-R) / (NIR+R) \quad (1)$$

LULC category	Description	LS5 / Selection	LS8 / Selection
Water body	Areas covered with water	Band 4:3:2	Band 5:4:3
Thick vegetation	Thick green vegetation area	NDVI >= 0.7	NDVI >= 0.7
Other vegetation	Grass lands, wetland soft vegetation, bushes	Band 5:4:3 and 0.1<NDVI<0.7	Band 6:5:4 and 0.1<NDVI<0.7
Settlements	Impervious surfaces including residential, industrial and transport utility	Band 7:5:3	Band 7:6:4
Open area	Areas with open lands, sandy areas	Band 3:2:1	Band 4:3:2

Tab.2 Band combinations used for the image classification

3.3 Assessment of land use land cover changes

After the image classification, LULC maps for the study period were developed. There were 1km zones were created from the wetland boundary, covering 5km of the land area together with inside of the wetland, and the classified image was clipped to each zone and the change detection analysis was performed for year 2000-2010 and 2011-2021.

3.4 Assessment of land use change dynamics

The Land Use Dynamic Degree method was used to evaluate the quantitative changes of rates of the LULC type of the study areas, and two folded approach i.e. Single Land Use Dynamic Degree (SLUDD) and Integrated Land Use Dynamic Degree (ILUDD). SLUDD indicates the rate of changes in the LULC categories for the study period. The ILUDD estimates the overall change of rate of the LULC (all land categories) for the study interval (Degefu et al., 2021; Gong et al., 2017; Quan et al., 2006).

$$SLUDD = (LA_{i,t2} - LA_{it1})/LA_{it1} * \frac{1}{T} * 100\% \quad (1)$$

$$ILUDD = \left(\sum_{i=1}^{n} \Delta LA_{i-j} / \sum_{i}^{n} LA_{it}\right) * \frac{1}{T} * 100\% \quad (2)$$

Where LA_{it2} and LA_{it1} are area of land use type at time *t1* and *t2*, $\Delta LA_{i\text{-}j}$ is the land use type transformation from type i to j (where i≠ j), n is the number of land use types in the study area and T is the study period.
Annual increase (AI) and annual growth rate (AGR)
AI is settlement expansion rate of the same wetland and its zone areas during different time intervals, the AGR measures the comparison of the settlement areas of the different wetlands and its zone areas (Degefu et al., 2021; Meng et al., 2020).

Annual Increase $$AI = (A_{end} - A_{start})\ /d \quad (3)$$

Annual Growth Rate $$AGR = \ 100\% \times \left[(A_{end}/A_{start})^{1/d} - 1\right] \quad (4)$$

Where A_{start} and A_{end} are the settlement land area at the beginning and end of the time intervals respectively, and *d* is the study's time period.

3.5 Accuracy assessment

The accuracy assessment was carried out to determine the accuracy of the LULC categories and there were 300 random points (60 sample points from each LULC class) were created for each study period, equally covering all the LULC categories. The Google Earth Pro time series historical images and topo maps from the Survey Department of Sri Lanka (2023) were used as reference data. Thereafter, confusion matrix was created, overall accuracy, user accuracy, producer accuracy and the Kappa coefficient was computed (Degefu et al., 2021; Samin et al., 2023; Twisa & Buchroithner, 2019).

4. Results

Assessment of spatial distribution of the LULC in the study areas in AW (a-c) and MW (d-f), including the identified 1km zones for the time points of year 2000, 2010 and 2021 are shown in Following Fig.2.

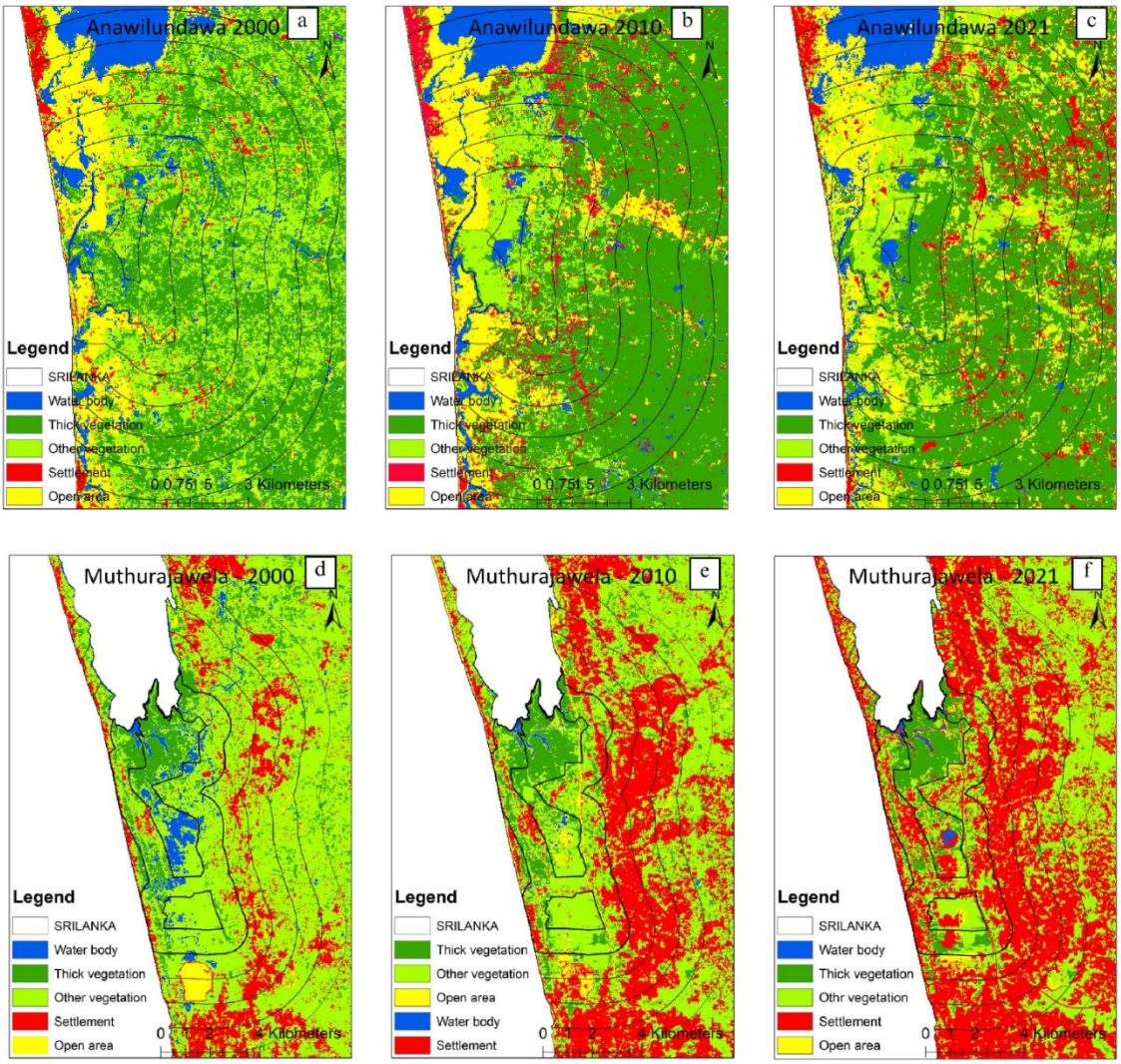


Fig.2 Spatial distribution of the LULC in Anawilundawa and Muthurajawela wetlands: (a) Anawilundawa 2000, (b) Anawilundawa 2010, (c) Anawilundawa 2021, (d) Muthurajawela 2000, (e) Muthurajawela 2010, (f) Muthurajawela 2021 (date of acquisition of the satellite data: 17/12/2022)

4.1 LULC changes in AW and MW

Water Body: Water bodies constitute a key component of wetland landscapes, encompassing rivers, streams, and waterlogged areas.

Anawilundawa (AW): In the AW study area, the total water body coverage was 12 km² in 2000, 11 km² in 2010, and 9 km² in 2021. Notably, the reconstruction of the Daduru Oya irrigation tank in 2014 enhanced regular water supply, deviating from the previous reliance on seasonal rainfall. Despite this improvement, the water bodies continued to diminish, with an annual reduction of 0.1 km² between 2000 and 2010. The decreasing trend suggests a potential acceleration, possibly influenced by reduced community reliance on free-standing water bodies.

Analyzing subzones reveals variations. Zone b experienced the highest water body conversion to other land use/land cover (LULC) categories (7.31%), while zone e showed the lowest (2.55%) from 2000 to 2010. During the second interval (2010 to 2021), zone a witnessed the highest transformation of water bodies to other LULC (7.85%), and zone g exhibited the lowest (2.07%).

Muthurajawela (MW): In the MW study area, water bodies measured 6.9 km² in 2000, reduced to 1.3 km² in 2010, and further to 0.9 km² in 2021, indicating an 87% loss. This substantial reduction diminishes MW's potential as a nature-based solution for urban flooding. Zone a recorded the highest water body conversion

to other LULC categories (19.61%) from 2000 to 2010, while zones d and f showed the lowest (0.88%). In the second interval (2010 to 2021), zone a again exhibited the highest conversion (1.64%), and zone e displayed the lowest (0.12%).

Thick Vegetation: Thick vegetation, characterized by dense foliage with high Normalized Difference Vegetation Index (NDVI) values, faced anthropogenic threats. In the AW, thick vegetation covered 45 km² in 2000, increased to 64 km² in 2010, and decreased to 61 km² in 2021. Zone a in the AW experienced the highest conversion of thick vegetation to other LULC categories (37.09%) from 2000 to 2010, and zone f displayed the highest (20.79%) from 2010 to 2021. In the MW, thick vegetation measured 14 km² in 2000, increased to 15 km² in 2010, and decreased to 11 km² in 2021.

Other Vegetation: AW's total other vegetation extent was 47 km² in 2000, 18 km² in 2010, and 20 km² in 2021. Zone e in the AW experienced the highest transformation of other vegetation to other LULC categories (36.59%) from 2000 to 2010, and zone a displayed the highest (31.04%) from 2010 to 2021. In the MW, other vegetation covered 90 km² in 2000, decreased to 58 km² in 2010, and further to 46 km² in 2021.

Settlements: Settlement areas, including human habitats and infrastructure, expanded in both AW and MW. In the AW study area, settlements covered 4.03 km² in 2000, increased to 10.24 km² in 2010, and 11.17 km² in 2021. Zone e exhibited the highest settlement conversion to other LULC (2.8%) from 2000 to 2010, and zone d displayed the highest (8.7%) from 2010 to 2021. In the MW, settlements measured 21.84 km² in 2000, increased to 52.86 km² in 2010, and further to 73.51 km² in 2021.

Open Area: The total extent of open areas in the AW was 16.90 km² in 2000, increasing to 22.19 km² in 2010, and 23.43 km² in 2021. Zone c experienced the highest transformation of open areas to other LULC (4.41%) from 2000 to 2010, and zone c also showed the highest (12.18%) from 2010 to 2021. In the MW, open areas measured 2.87 km² in 2000, increased to 7.41 km² in 2010, and decreased to 3.84 km² in 2021.

Temporal Dynamics - Single Land Use Dynamic Degree (SLUDD) and Integrated Land Use Dynamic Degree (ILUDD): AW exhibited positive SLUDD values for water bodies, thick vegetation, and other vegetation. In contrast, MW showed negative SLUDD values for water bodies, indicating continuous decrease. ILUDD for both study areas averaged 2% in the first interval (2000 to 2010) and 1.74% in the second interval (2010 to 2021). The highest ILUDD for AW occurred in zone b (2%), and for MW, it was in zone b (2%) in the second interval.

	Zone a		**Zone b**		**Zone c**		**Zone d**		**Zone e**		**Zone f**		**Zone g**	
Anawilundawa	2000-2010	2010-2021	2000-2010	2010-2021	2000-2010	2010-2021	2000-2010	2010-2021	2000-2010	2010-2021	2000-2010	2010-2021	2000-2010	2010-2021
Waterbody	0.324	-0.101	-0.417	-0.217	-0.437	-0.351	-0.142	-0.274	-0.035	-0.300	-0.222	-0.146	-0.487	-0.295
Thick veg	-0.608	0.498	-2.178	2.976	1.361	1.143	2.509	-0.200	5.266	-1.299	5.655	-3.217	7.088	-2.949
Other veg	0.286	-0.503	1.981	-2.562	-3.362	0.441	-4.787	1.451	-6.874	1.309	-7.954	1.646	-8.459	0.782
Settlement	0.012	-0.013	0.377	-0.222	1.293	-0.574	1.020	-0.284	0.991	0.301	1.481	0.711	1.032	1.012
Open area	-0.013	0.119	0.237	0.025	1.145	-0.657	1.400	-0.693	0.652	-0.010	1.039	1.006	0.827	1.450
Muthurajawela														
Waterbody	-2.734	-0.009	-1.726	-0.197	-0.479	-0.075	-0.191	-0.027	-0.271	-0.024	-0.216	-0.054		
Thick veg	1.650	-0.066	0.790	-1.283	-0.165	-0.735	0.012	-0.433	-0.320	-0.530	-0.601	-0.773		
Other veg	-0.071	-1.777	-4.442	-3.368	-7.350	-1.910	-8.151	-1.284	-7.299	-2.052	-4.008	-2.470		
Settlement	0.159	2.516	3.875	5.886	7.266	3.302	8.169	2.392	7.259	2.961	4.291	3.586		
Open area	0.996	-0.664	1.502	-1.037	0.729	-0.582	0.161	-0.648	0.630	-0.356	0.534	-0.289		

Tab.3 Anawilundawa and Muthurajawela LULC Change area, 2000 to 2010 and 2010 to 2021 in km²

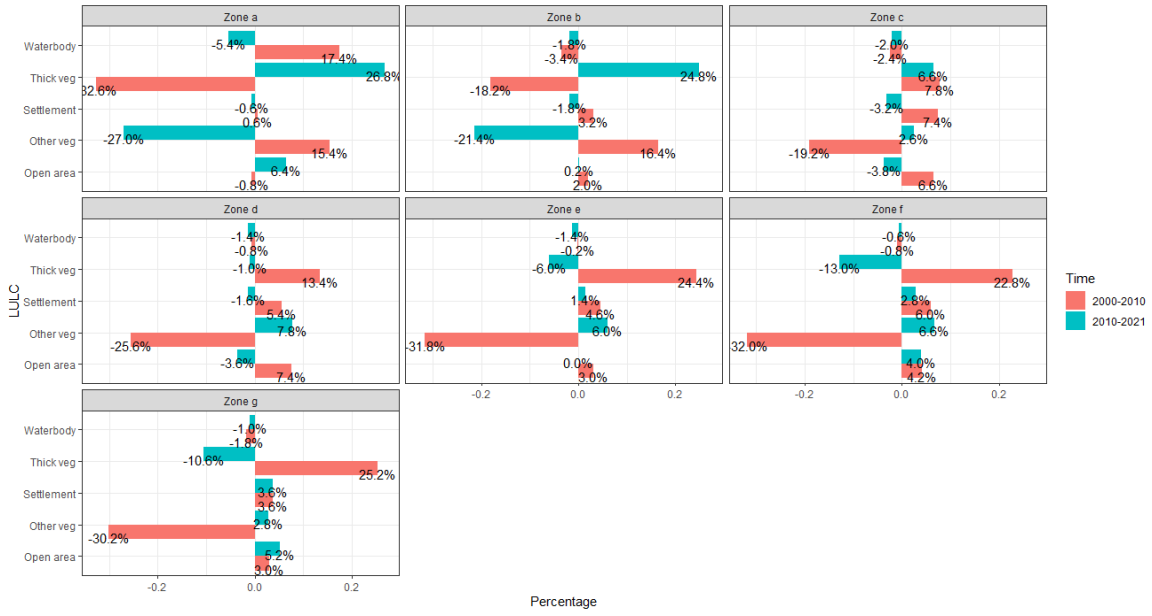
Annual Increase (AI) and Annual Growth Rate (AGR) of Settlements: AW's highest AI occurred in zone f (0.14) from 2000 to 2010, and MW's highest AI was 0.74 in zone d from 2000 to 2021. AW recorded the highest AGR

in zone f (11.437) from 2000 to 2010, and MW's highest AGR was within the wetland (30.86) in the same period. For the second interval, AW's highest AGR was 3.94 in zone g, and MW's highest AGR was 28.32 in zone a.

The detailed analysis provides insights into the changing dynamics of water bodies, vegetation, settlements, and open areas in the Anawilundawa and Muthurajawela wetland areas over two distinct time intervals.

The LULC dynamics change (%) for AW and MW for both study periods is shown in Fig.3. Below and the LULC change from one category to another category for AW and MW for both study periods is shown in Tab.3 and Fig.4.

(a)



(b)

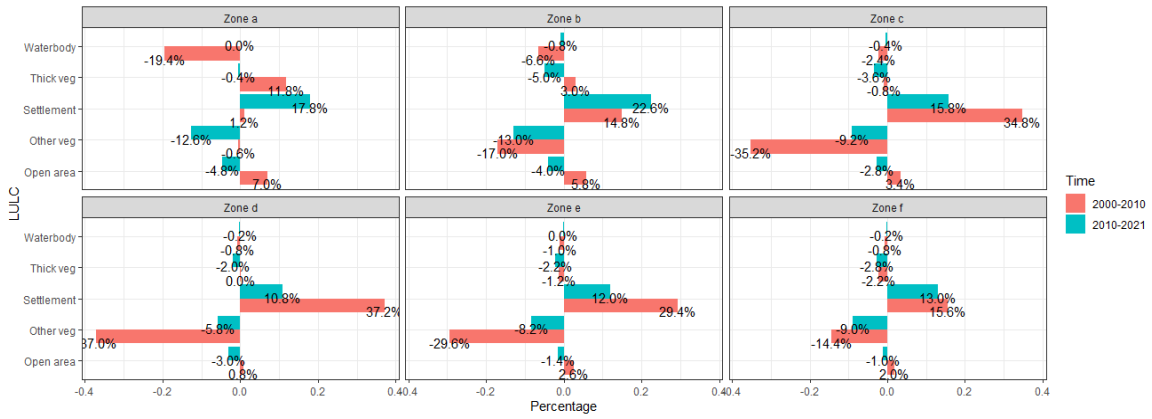


Fig.3 LULC change dynamics for study period, (a) LULC change for the Anawilundawa zone a,b,c,d,e,f and g (% change area) and (b) LULC change for the Muthurajawela zone a,b,c,d,e and f (% change area)

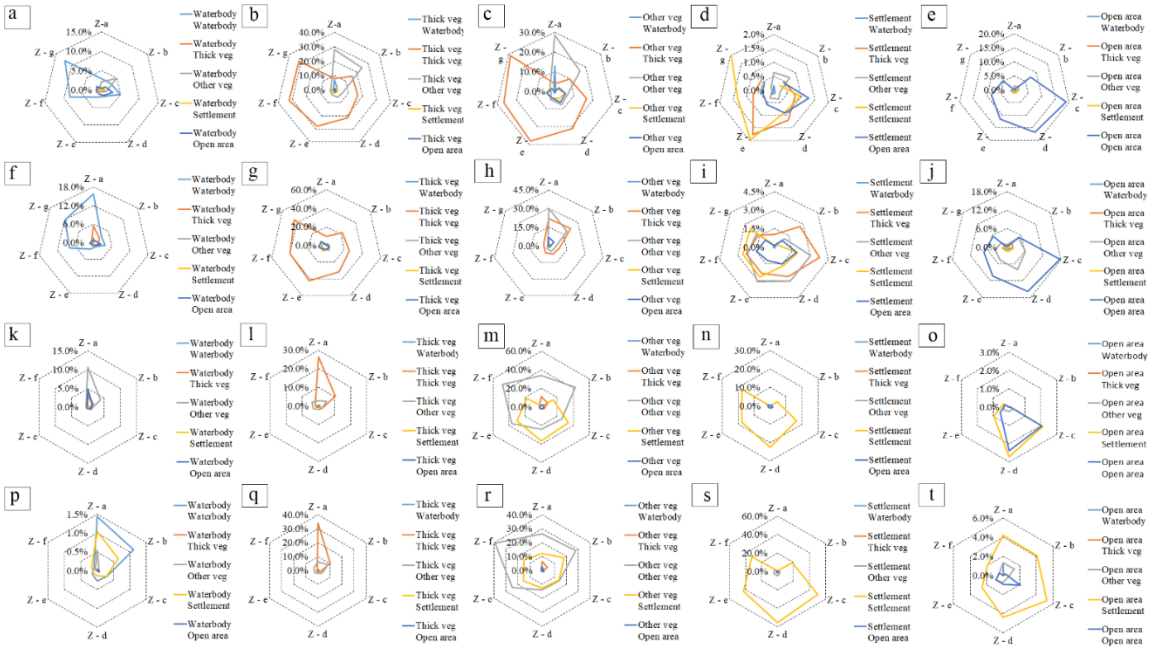


Fig.4 LULC changes from one category to other category, row 1: AW(2000-2010); (a)AW Waterbody to other, (b)AW Thick veg to other, (c)AW Other veg to other, (d)AW settlement to other, (e)AW Open area to other. row 2: AW(2010-2021); (f)AW Waterbody to other, (g)AW Thick veg to other, (h)AW Other veg to other, (i)AW settlement to other, (j)AW Open area to other. row 3: MW(2000-2010); (k)MW Waterbody to other, (l)MW Thick veg to other, (m)MW Other veg to other, (n)MW settlement to other, (o)MW Open area to other. row 4: MW(2010-2021); (p)MW Waterbody to other, (q)MW Thick veg to other, (r)MW Other veg to other, (s)MW settlement to other, (t)MW Open area to other

4.4 Accuracy assessment

Accuracy assessment is used to evaluate the performance of the image classification, and used to identify the errors in the classified image and improve the quality of the classification results. The kappa coefficient values for the each study area and the period remains above 80% and derived as acceptable accuracy for the classified LULC images (refer Tab.4).

Study area	**Anawilundawa wetland (AW)**						**Muthurajawela wetland (MW)**					
Year	2000		2010		2021		2000		2010		2021	
LULC category	UA (%)	PA (%)	UA (%)	PA (%)	UA (%)	PA (%)	UA (%)	PA (%)	UA (%)	PA (%)	UA (%)	PA (%)
Water body	86.7	96.3	85.0	91.1	95.0	91.9	95.0	91.9	93.3	81.2	95.0	98.3
Thick vegetation	85.0	78.5	91.7	78.6	90.0	79.4	86.7	89.7	85.0	81.0	88.3	79.1
Other vegetation	81.7	69.0	85.0	67.1	81.7	73.1	76.7	79.3	91.7	80.9	80.0	70.6
Settlements	81.7	92.5	65.0	97.5	75.0	91.8	90.0	85.7	85.0	94.4	85.0	86.4
Open area	91.7	96.5	93.3	96.6	78.3	87.0	86.7	88.1	73.3	95.7	78.3	97.9
Overall Accuracy	85.3		84.0		84.0		87.0		85.7		85.3	
Kappa	81.7		80.0		80.0		83.8		82.1		81.7	

Tab.4 Accuracy assessment for the Aawilundawa and Muthurajawela study areas. UA: User accuracy, PA: Producer accuracy

5. Discussion

Conducting a cross-scale comparison is invaluable for gaining a comprehensive insight into whether significant transformations have occurred in the two wetlands under consideration and, if so, the nature and extent of the Land Use and Land Cover (LULC) changes across diverse categories. This analytical approach allows for a

nuanced understanding of the alterations in the landscape and ecosystem, offering crucial information for decision-makers, particularly urban and environmental planners in Sri Lanka.

The outcomes of this analysis hold significant implications for the decision-making processes related to the planning and management of both urban and environmental aspects in Sri Lanka. Given the country's rich diversity of wetlands, especially those located in coastal and urban areas, the findings provide a broader context for comprehending the dynamic interplay between human activities and ecological systems. By examining the LULC changes in these wetlands, the study contributes to the knowledge base essential for informed decision-making.

Despite the fact that both wetland sites are subject to partial or full regulation under environmental protection laws, the results of this study serve to illuminate the effectiveness of the existing legal frameworks. This insight is pivotal for evaluating the impact and efficacy of regulatory measures in place, ultimately guiding policymakers and environmental authorities in refining and enhancing the legal tools and conservation strategies employed to safeguard these ecologically vital areas.

5.1 Comparison of two coastal wetlands

Both Anawilundawa and Muthurajawela wetlands have experienced notable Land Use and Land Cover (LULC) changes, with a pronounced reduction in water bodies being the most significant transformation. Anawilundawa witnessed a loss of 12% and 16% of its water bodies during the periods 2000 to 2010 and 2010 to 2021, respectively. In contrast, Muthurajawela faced a substantial decline of 81% and 20% in water bodies during the corresponding intervals. Simultaneously, both study areas saw an expansion of settlements, with Anawilundawa experiencing a growth of 154% and then 9%, while Muthurajawela exhibited a 142% increase in the first time interval followed by a 39% gain in the second time interval.

Noteworthy is the high Annual Growth Rate (AGR) observed for settlements in both study areas during the first time interval. Anawilundawa recorded the highest AGR of 11% in Zone f and the lowest at 5% in Zone a. In contrast, Muthurajawela exhibited an even more substantial expansion of settlements, with the highest recorded AGR reaching 31%, maintaining its prominence even in the second time interval. The settlement conversion rate in Anawilundawa was comparatively lower than in Muthurajawela. The most prominent LULC changes occurred in Zones d, e, f, and g, situated away from the wetland area.

Community consultations revealed that elderly residents in local areas have a strong emotional attachment to the wetland and its ecosystem services from their early days. However, poverty and resource scarcity have compelled communities to exploit the wetland, reflecting a common scenario in developing countries (Ballut-Dajud et al., 2022).

5.2 Impacts of urbanization and other drivers of the LULC changes in the coastal wetland landscapes

The degradation of Asian wetlands poses a significant challenge, influenced by various factors such as unsustainable practices and political interference (Graham et al., 2021), along with the impact of high population and economic development, leading to the transformation of wetland ecosystems (Taylor et al., 2021). Notably, environmental stressors like land reclamation, pollution, and excessive use of biological resources have contributed to the decline of coastal wetlands in China, the United States of America, Argentina, Portugal, and North Africa (Newton et al., 2020; El Mahrad et al., 2020; Lin & Yu, 2018; Zilio et al., 2013). Additionally, several studies have emphasized that the expansion of infrastructure, roads, development projects, industrial facilities, agriculture, and aquaculture activities globally has significantly contributed to the conversion of coastal wetlands into alternative land use categories (Rojas et al., 2019; Sousa et al., 2020).

In Sri Lanka, wetlands face an increasing threat from urbanization (Athapaththu & Wickramasinghe, 2020; Dahanayake et al., 2022). The Gampaha district, where the Muthurajawela Wetland (MW) is situated, holds

the second-largest district population, comprising 11% of the nation's total population, with a growing trend (Department of Census and Statistics, 2012). Community consultations have revealed that political influence and land demand have driven illegal encroachment and unauthorized agricultural land expansion in the MW. In contrast, the Attanagalu Oya Wetland (AW) is located farther from core urban centers, situated in a district with approximately 4% of the national population, exhibiting slower growth and lower population density in 2012 (Department of Census and Statistics, 2012). Compared to the MW, the AW is less urbanized, and the highest Annual Increase (AI) for the AW is recorded in Zone f (0.135) and Zone g (0.092) between 2000 to 2010 and 2010 to 2020. In contrast, many zones in the MW experienced higher AI.

LULC changes in the MW are further exacerbated by regular high floodwaters from the Dandugam Oya and the Hamilton Canal. Unplanned settlements and the development of permanent structures can obstruct the wetland drainage system, leading to prolonged retention (Manawadu and Wijerathna, 2021; Siriwardhana et al., 2020).

5.3 Sustainability, wetlands and societies and policy planning dynamics

Government of Sri Lanka (GOSL) policies related to infrastructure and economic development projects, such as the establishment of an Industrial Zone in the Kerawalapitiya area, the development and operation of the Dikovita Sea Port, Petroleum Oil Terminal Facility, power plants including Kerawalapitya-Yugadanawi (300MW), and two Municipal Solid Waste (MSW) Power Plants (11.5 MW and 10 MW), Katunayake International Airport, metal crushers, asphalt plants, tourist resorts, Katunayake Industrial Zone, and garbage dumping sites within close proximity to the wetland, are anticipated to have adverse effects on the Muthurajawela wetland area. Significantly, past incidents, such as oil leakages from the main distribution pipeline in 2015 near the Muthurajawela wetland area, underscore the environmental risks associated with these projects. Similar incidents of oil leakages impacting coastal wetlands, such as the Deepwater Horizon explosion event in the northern Gulf of Mexico in 2010 and along the Panamanian coast in 1986, led to the imposition of new policies as mitigation measures (Balogun et al., 2020; Mendelssohn et al., 2012).

Furthermore, the conservation of wetlands necessitates the introduction of new policies, tools, and mechanisms. Additionally, attention is required for the implementation of sufficient compensation programs, flexible scheme designs, information-based strategies, and awareness and enforcement measures (Graversgaard et al., 2021; Marambanyika & Beckedahl, 2016). Consequently, effective government policies on wetland conservation, combined with implementation and execution by relevant authorities and local governments, will be crucial for the protection of wetlands in the future (Dinç & Gül, 2021; Pilogallo et al., 2019; Spidalieri 2020).

Community-based stewardship plays a vital role in collaborative efforts to monitor and maintain the health of the Wetland Ecosystem, addressing threats to the wetland. Regular discussions and workshops in conservation areas are essential, campaigning for the values, threats, trends, biodiversity, and overall significance of ecosystems. Additionally, exploring carbon credit markets and biodiversity offset markets for wetlands can provide incentives and tangible economic benefits, encouraging people to protect and enhance ecosystem services, thereby promoting the protection and restoration of wetlands (UNEP, 2022).

6. Conclusion

This study conducts a comprehensive analysis and comparison of land use transformations in two coastal wetlands in Sri Lanka, namely Muthurajawela (an urban wetland) and Anawilundawa (a peri-urban wetland). The findings reveal significant changes in land use and land cover (LULC) patterns, particularly in the extent of water bodies, thick vegetation, other vegetation, settlements, and open areas, spanning a two-decade period. Both study areas experienced a decline in water bodies over the specified timeframe, with Muthurajawela exhibiting the most substantial LULC changes. Notably, Muthurajawela showcased a

pronounced transformation of other LULC categories into settlement areas with houses and infrastructure, while in Anawilundawa, the LULC changes were observed in areas adjacent to water bodies. These results underscore the imperative of prioritizing conservation efforts for urban wetlands, necessitating enhanced management tools such as policies, regulations, and collaborative initiatives with local residents.

References

Anand, V. & Oniam, B. (2020). Future land use land cover prediction with special emphasis on urbanization and wetlands. *Remote Sensing Letters*, 11:3, 225-234. https://doi.org/10.1080/2150704X.2019.1704304

Athapaththu, A. H. L. C. M., Wickramasinghe, D., & Somachandra, M. G. M. C. (2020). Hotspots of land use/land cover change around Bolgoda wetland, Sri Lanka. *Journal of the National Science Foundation of Sri Lanka*, *48*(3), 219-226. http://doi.org/10.4038/jnsfsr.v48i3.9376

Athukorala, D., Estoque, R. C., Murayama, Y., & Matsushita, B. (2021). Impacts of urbanization on the Muthurajawela Marsh and Negombo Lagoon, Sri Lanka: Implications for landscape planning towards a sustainable urban wetland ecosystem. *Remote Sensing*, *13*(2), 316. https://doi.org/10.3390/rs13020316

Ballut-Dajud, G. A., Herazo, L. C.S., Fernández-Lambert, G., Marín-Muñiz, J. L., Méndez, M. C.L., & Betanzo-Torres, E. A. (2022). Factors affecting wetland loss: a review. *Land*, *11*(3), 434. https://doi.org/10.3390/land11030434

Balogun, A. L., Yekeen, S. T., Pradhan, B., & Althuwaynee, O. F. (2020). Spatio-temporal analysis of oil spill impact and recovery pattern of coastal vegetation and wetland using multispectral satellite landsat 8-OLI imagery and machine learning models. *Remote Sensing*, 12(7), 1225. https://doi.org/10.3390/rs12071225

Bambaradeniya, C. N., Ekanayake, S. P., Kekulandala, L. D. C. B., Samarawickrama, V. A. P., Ratnayake, N. D., & Fernando, R. H. S. S. (2002). An assessment of the status of biodiversity in the Muthurajawela wetland sanctuary. *Occasional Papers of IUCN Sri Lanka*, *3*, 48.

Barbier, E. B. (2013). Valuing ecosystem services for coastal wetland protection and restoration: Progress and challenges. *Resources*, 2(3), 213-230. https://doi.org/10.3390/resources2030213

Bin, Q., Jian-Fei, C. H. E. N., Hong-Lie, Q. I. U., Römkens, M. J. M., Xiao-Qi, Y. A. N. G., JIANG, S. F., & Bi-Cheng, L. I. (2006). Spatial-temporal pattern and driving forces of land use changes in Xiamen. *Pedosphere*, 16(4), 477-488.

Central Environmental Authority, Euroconsult. Conservation Master Plan, Muthurajawela Marsh and Negombo Lagoon; Gunaratne offset Ltd., Colombo, Sri Lanka, 1994 (accessed in March 2023).

Central Environment Authority, Sri Lanka (2023), http://www.cea.lk/web/?option=com_content&view=article&layout=edit&id=1155 (accessed on 23 March 2023).

Dahanayake, H., Wickramasinghe, D., & Dahanayaka, D. D. G. L. (2022). Do natural landscapes contribute to reducing Land Surface Temperature (LST)? A case study from Muthurajawela wetland, Sri Lanka. *Journal of Degraded and Mining Lands Management*, *9*(2), 3329-3339.

Degefu, M. A., Argaw, M., Feyisa, G. L., & Degefa, S. (2021). Dynamics of urban landscape nexus spatial dependence of ecosystem services in rapid agglomerate cities of Ethiopia. *Science of The Total Environment*, *798*, 149192. https://doi.org/10.1016/j.scitotenv.2021.149192

Department of Census and Statistics-Sri Lanka. Available online: http://www.statistics.gov.lk/ (accessed on 22 March 2023).

Dinç, G. & Gül, A. (2021). Estimation of the future land cover using Corine Land Cover data. *TeMA - Journal of Land Use, Mobility and Environment*, 14 (2), 177-188. http://dx.doi.org/10.6092/1970-9870/7671

El Mahrad, B., Abalansa, S., Newton, A., Icely, J. D., Snoussi, M., & Kacimi, I. (2020). Social-environmental analysis for the management of coastal lagoons in North Africa. *Frontiers in Environmental Science*, 8, 37.

Gardner, R. C., Barchiesi, S., Beltrame, C., Finlayson, C., Galewski, T., Harrison, I., ... & Walpole, M. (2015). State of the world's wetlands and their services to people: a compilation of recent analyses. Ramsar Briefing Note No. 7. Gland, Switzerland: Ramsar Convention Secretariat, 2015, http://dx.doi.org/10.2139/ssrn.2589447

Gayani, M. S., Wickramasinghe, D. D., Dahanayake, H. D., & Weerasinghe, Y. N. (2022). Transformed Wetlands and Urban Resilience: a Case Study From Bellanwila–Attidiya Wetland Sanctuary, Sri Lanka. *Geography, Environment, Sustainability*, *15*(2), 23-30. https://doi.org/10.24057/2071-9388-2021-028

Gong, J., Li, J., Yang, J., Li, S., & Tang, W. (2017). Land use and land cover change in the Qinghai Lake region of the Tibetan Plateau and its impact on ecosystem services. *International journal of environmental research and public health, 14*(7), 818. https://doi.org/10.3390/ijerph14070818

Graham, V., Geldmann, J., Adams, V. M., Negret, P. J., Sinovas, P., & Chang, H. C. (2021). Southeast Asian protected areas are effective in conserving forest cover and forest carbon stocks compared to unprotected areas. *Scientific Reports*, *11*(1), 1-12. https://doi.org/10.1038/s41598-021-03188-w

Graversgaard, M., Jacobsen, B. H., Hoffmann, C. C., Dalgaard, T., Odgaard, M. V., Kjaergaard, C., ... & Tonderski, K. (2021). Policies for wetlands implementation in Denmark and Sweden–historical lessons and emerging issues. *Land use policy*, 101, 105206. https://doi.org/10.1016/j.landusepol.2020.105206

Greater Colombo Economic Commission, Euroconsult. *Environmental Profile of Muthurajawela and Negombo Lagoon*; Gunaratne offset Ltd.: Colombo, Sri Lanka, 1991.

Hettiarachchi, M., Morrison, T. H., Wickramsinghe, D., Mapa, R., De Alwis, A., & McAlpine, C. A. (2014). The eco-social transformation of urban wetlands: A case study of Colombo, Sri Lanka. *Landscape and Urban Planning*, 132, 55-68. https://doi.org/10.1016/j.landurbplan.2014.08.006

Hussain, S., Lu, L., Mubeen, M., Nasim, W., Karuppannan, S., Fahad, S., ... & Aslam, M. (2022). Spatiotemporal variation in land use land cover in the response to local climate change using multispectral remote sensing data. *Land*, *11*(5), 595. https://doi.org/10.3390/land11050595

IUCN Sri Lanka and Central Environmental Authority (2006). *National Wetland Directory of Sri Lanka,* Colombo, Sri Lanka. ISBN 9558177547.

Kotagama, S. W., & Bambaradeniya, C. N. B. (2006). An overview of the wetlands of Sri Lanka and their conservation significance. *National Wetland Directory of Sri Lanka*, 7-16. (Accessed in March 2023).

Lin, Q., & Yu, S. (2018). Losses of natural coastal wetlands by land conversion and ecological degradation in the urbanizing Chinese coast. *Scientific reports*, 8(1), 15046. https://doi.org/10.1038/s41598-018-33406-x

Liu, C., Li, W., Zhu, G., Zhou, H., Yan, H., & Xue, P. (2020). Land use/land cover changes and their driving factors in the Northeastern Tibetan Plateau based on Geographical Detectors and Google Earth Engine: A case study in Gannan Prefecture. *Remote Sensing*, *12*(19), 3139. https://doi.org/10.3390/rs12193139

Lopes, N. D. R., Li, T., Qian, D., Matomela, N., & Sá, R. M. (2022). Factors influencing coastal land cover change and corresponding impact on habitat quality in the North-western Coastline of Guinea-Bissau (NC-GB). *Ocean & Coastal Management*, 224, 106181. https://doi.org/10.1016/j.ocecoaman.2022.106181

Manawadu, L., & Wijeratne, V. P. I. S. (2021). Anthropogenic drivers and impacts of urban flooding-A case study in Lower Kelani River Basin, Colombo Sri Lanka. *International Journal of Disaster Risk Reduction*, *57*, 102076. DOI: https://doi.org/10.1016/j.ijdrr.2021.102076

Marambanyika, T., & Beckedahl, H. (2016). The missing link between awareness and the implementation of wetland policy and legislation in communal areas of Zimbabwe. *Wetlands Ecology and Management*, 24, 545-563. https://doi.org/10.1007/s11273-016-9486-y

Mendelssohn, I. A., Andersen, G. L., Baltz, D. M., Caffey, R. H., Carman, K. R., Fleeger, J. W., ... & Rozas, L. P. (2012). Oil impacts on coastal wetlands: implications for the Mississippi River Delta ecosystem after the Deepwater Horizon oil spill. *BioScience*, 62(6), 562-574. https://doi.org/10.1525/bio.2012.62.6.7

Meng, L., Sun, Y., & Zhao, S. (2020). Comparing the spatial and temporal dynamics of urban expansion in Guangzhou and Shenzhen from 1975 to 2015: a case study of pioneer cities in China's rapid urbanization. *Land Use Policy*, 97, 104753. https://doi.org/10.1016/j.landusepol.2020.104753

Mugendi, D. M., Mireri, C., Kibwage, J., & Oyoo, D. (2020). Assessment of land use/land covers changes linked to oil and gas exploration. *TeMA - Journal of Land Use, Mobility and Environment*, 13 (2), 169-190. http://dx.doi. org/10.6092/1970-9870/6739

Newton, A., Icely, J., Cristina, S., Perillo, G. M., Turner, R. E., Ashan, D., ... & Kuenzer, C. (2020). Anthropogenic, direct pressures on coastal wetlands. *Frontiers in Ecology and Evolution*, 8, 144. https://doi.org/10.3389/fevo.2020.00144

Pilogallo, A, Saganeiti, L., Scorza, F. & Murgante, B. (2019). Ecosystem services' based impact assessment for low carbon transition processes. *TeMA - Journal of Land Use, Mobility and Environment*, 12(2), 127-138. http://dx.doi.org/ 10.6092/1970-9870/6117

Quan, B., Chen, J., Qiu, H., Römkens, M. J. M., Yang, X., Jiang, S., & Li, B. (2006). Spatial-Temporal pattern and driving forces of land use changes in Xiamen. *Pedosphere*, *16*(4), 477–488. https://doi.org/10.1016/s1002-0160(06)60078-7

Ranagalage, M., Morimoto, T., Simwanda, M., & Murayama, Y. (2021). Spatial analysis of urbanization patterns in four rapidly growing south Asian cities using Sentinel-2 Data. *Remote Sensing*, *13*(8), 1531. https://doi.org/10.3390/rs13081531

Rojas, C., Munizaga, J., Rojas, O., Martínez, C., & Pino, J. (2019). Urban development versus wetland loss in a coastal Latin American city: Lessons for sustainable land use planning. *Land use policy*, 80, 47-56. https://doi.org/10.1016/j.landusepol.2018.09.036

Samin P., Shahnawaz S., Him Lal S. (2023). Suitable Sites for Built-up Area Expansion in Kamalamai Municipality, Sindhuli District, Nepa. *TeMA - Journal of Land Use, Mobility and Environment*, 16 (2), 279-305. http://dx.doi.org/10.6093/1970-9870/9968

Senevirathna, E. M. T. K., Edirisooriya, K. V. D., Uluwaduge, S. P., & Wijerathna, K. B. C. A. (2018). Analysis of causes and effects of coastal erosion and environmental degradation in southern coastal belt of Sri Lanka special reference to unawatuna coastal area. *Procedia Engineering*, 212, 1010-1017. https://doi.org/10.1016/j.proeng.2018.01.130

Siriwardhana, S. T., Gunawardena, A., Mallawatantri, A., & Wickramasinghe, D. D. (2020). Flood Disaster, Wetland Loss and Ecosystem Services: Community Perceptions-A Case Study from Muthurajawela Wetland Complex, Sri Lanka. *Proceedings of International Forestry and Environment Symposium* (Vol. 25). Department of Forestry and Environmental Science, University of Sri Jayewardenepura, Nugegoda, Sri Lanka.

Sousa, C. A., Cunha, M. E., & Ribeiro, L. (2020). Tracking 130 years of coastal wetland reclamation in Ria Formosa, Portugal: Opportunities for conservation and aquaculture. *Land Use Policy*, 94, 104544. https://doi.org/10.1016/j.landusepol.2020.104544

Spidalieri, K. (2020). Where the wetlands are—and where they are going: legal and policy tools for facilitating coastal ecosystem migration in response to sea-level rise. *Wetlands*, 40, 1765-1776. https://doi.org/10.1007/s13157-020-01280-x

Survey Department of Sri Lanka. Available online: https://www.survey.gov.lk/ (accessed on 22 March 2023).

Taylor, N. G., Grillas, P., Al Hreisha, H., Balkız, Ö., Borie, M., Boutron, O., ... & Sutherland, W. J. (2021). The future for Mediterranean wetlands: 50 key issues and 50 important conservation research questions. *Regional environmental change*, 21, 1-17. https://doi.org/10.1007/s10113-020-01743-1

Twisa, S., & Buchroithner, M. F. (2019). Land-use and land-cover (LULC) change detection in Wami River Basin, Tanzania. *Land*, *8*(9), 136. https://doi.org/10.3390/land8090136

Ustaoglu, E. & Aydinoglu, A.C. (2019). Land Suitability Assessment of Green Infrastructure Development: A Case Study of Pendik District (Turkey). *TeMA - Journal of Land Use, Mobility and Environment*, 12(2), 165-178. http://dx.doi.org/10.6092/1970-9870/6118

Vithana, C. L., Ulapane, P. A., Chandrajith, R., Sullivan, L. A., Bundschuh, J., Toppler, N., ... & Senaratne, A. (2022). Assessment of the acidification risk of the acid sulfate soil materials in a tropical coastal peat bog: Muthurajawela Marsh, Sri Lanka. *Catena*, 216, 106396. https://doi.org/10.1016/j.catena.2022.106396

Yousaf, A., Khalid, N., Aqeel, M., Noman, A., Naeem, N., Sarfraz, W., ... & Khalid, A. (2021). Nitrogen dynamics in wetland systems and its impact on biodiversity. *Nitrogen*, 2(2), 196-217. https://doi.org/10.3390/nitrogen2020013

Zilio, M. I., London, S., Perillo, G. M., & Piccolo, M. C. (2013). The social cost of dredging: the Bahia Blanca Estuary case. *Ocean & Coastal Management*, 71, 195-202.

Zucaro, F., Morosini, R. (2018). Sustainable land use and climate adaptation: a review of European local plans. *TeMA - Journal of Land Use, Mobility and Environment*, Issue Volume 11(1), 7-26. http://dx.doi.org/10.6092/1970-9870/5343

Image Sources

Fig.1, Fig.2, Fig.3 and Fig.4: All figures and images are created by the Authors.

Author's profile

Harsha Dahanayake

He is a postgraduate research scholar attached to the Department of Zoology and Environment Sciences, University of Colombo, Sri Lanka, he has extensive professional experience across multiple domains. His career has encompassed roles in Environmental Management, IT and Management reflecting his diverse expertise. Harsha is actively engaged in the research with a particular focus on the fields of Environmental Management, Wetlands, Geographical Information System, Remote Sensing, Ecosystem services, Climate Change and Disaster risk reduction. His active participation in these research areas underscores his commitment to advancing knowledge and addressing pressing environmental challenges.

DDGL Dahanayaka

He is a Senior lecturer attached to the Department of Zoology, The Open University of Sri Lanka, Nawala, Nugegoda, Sri Lanka, He brings extensive experience to his role, with a distinguished career spanning over a two decade as a Scientist specializing in Remote Sensing for Coastal and Inland Water Environment Monitoring. Notably, Dr. Dahanayaka's expertise is well-documented, with his research contributions having been published in esteemed peer-reviewed international journals. In addition, he has actively shared his knowledge through invited presentations delivered in various countries. Dr. Dahanayaka has established valuable research partnerships with esteemed scientists hailing from countries such as Japan, Sri Lanka, the USA, Vietnam, Cambodia, and Indonesia.

Paul Hudson

He is a lecturer in Environmental Economics at the Department of Environment and Geography, University of York, United Kingdom, with expertise in Environmental Economics, Dr. Hudson is actively engaged in research aimed at understanding how society can effectively respond to the complex challenges of Climate Change and Disasters. His work is based on methods to mitigate the adverse effects of these interconnected issues, ultimately fostering a more resilient society. In addition to his research, Dr. Hudson has published a significant number of peer-reviewed journal articles related to his field. His contributions to the academic literature further demonstrate his dedication to advancing knowledge and addressing critical environmental challenges.

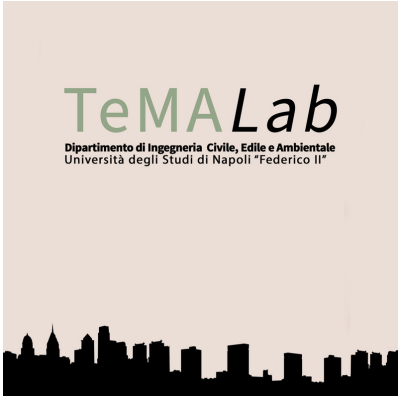
Deepthi Wickramasinghe

She is a Senior Professor attached to the Department of Zoology and Environmental Sciences, Faculty of Science, University of Colombo. She obtained her B.Sc and M.Sc from the University of Colombo. She obtained her doctoral degree in a split programme from the University of Colombo and Dalhousie University, Canada. Professor Wickramasinghe has also served as a Co-director of the Career Guidance Unit, Faculty of Science since 2015. With her guidance, the service-learning program offered by the Career Guidance Unit won the prestigious UNESCO Wenhui Award for Educational Innovation. During her career as an academic and a researcher, she has published extensively in many fields related to biodiversity, ecology and environmental sciences. Her specific research interests include sustainability, wetlands, water, disaster risk reduction, nature-based solutions and gender issues. She has won many awards for her research including several presidential awards and UN award for best water project. She has authored several books and published more than 100 research papers and abstracts. She is serving in many local and international expert bodies and professional networks including global water partnership and the IUCN species survival commission. She loves reading, music, and philanthropical work.

We are online!

TeMA Lab

Follow us on Instagram



TeMA Lab and our Journal are on Instagram!
TeMA Lab is the Laboratory of Land Use, Mobility and Environment of the Department of Civil, Building and Environmental Engineering, at Università degli Studi di Napoli Federico II. Our field of expertise relates to urban systems, their complexity and the challenges that they will face in near future: adaptation to climate change, ageing population, energy consumptions, development of sustainable mobility and so on. Follow us to be constanly updated!.

www.instagram.com/temalab.unina/

TeMA Journal of Land Use, Mobility and Environment

TeMA 1 (2024) 23-49
print ISSN 1970-9889, e-ISSN 1970-9870
DOI: 10.6092/1970-9870/10415
Received 30th October 2023, Accepted 8th April 2024, Available online 30th April 2024

Licensed under the Creative Commons Attribution – Non Commercial License 4.0
http://www.serena.unina.it/index.php/tema

Gender analysis of urban mobility behaviors in the Tunisian Sahel region

Mehdi El Kébir [a,b*], Aymen Ghédira [b]

[a] Higher School of Economic and Commercial Sciences, University of Tunis, Tunis, Tunisia
e-mail: m.elkebir01@gmail.com
ORCID: https://orcid.org/0000-0001-7592-9883
* Corresponding author

[b] Higher Institute of Transport and Logistics University of Sousse, Sousse, Tunisia
e-mail: a.ghedira@gmail.com
ORCID: https://orcid.org/0000-0003-4614-4037

Abstract
The integration of gender into questions of everyday mobility has been the focus of scientific research for several years. Despite the breadth of this topic, few studies on gender mobility are conducted in southern countries. This article attempts to fill this knowledge gap and paint a portrait of women's travel behavior in Tunisia. The study area is the Tunisian Sahel, which was studied as part of a household travel survey conducted in 2019. Based on 2,021 observations, a descriptive analysis of mobility behavior was carried out, providing information about the main travel patterns for both genders in this region. Our analysis deviates from the traditional approach of categorizing women as a unified group, and examining their mobility on an individual basis by considering their income levels. Significant differences were observed between the two genders, which are influenced by the socio-cultural context of Tunisian women and their financial situation. The majority of women are less mobile than men, as more complex journeys are limited to the vicinity of home, and they often rely on public transport. As financial conditions improve for women, travel tends to become easier. Comparing the analytical results of our study with scientific references reveals numerous similarities and differences.

Keywords
Mobility; Gender; Income; Equity; Distance; Time; Costs

How to cite item in APA format
El Kébir, M. & Ghédira, N. (2024). Gender analysis of urban mobility behaviors in the Tunisian Sahel region. *TeMA - Journal of Land Use, Mobility and Environment*, *17* (1), 23-49. http://dx.doi.org/10.6093/1970-9870/10415

1. Introduction

The new structure of modern cities emphasizes the central role of mobility in them. With the vast expansion of urban areas and the spatial disparity of essential activities, mobility becomes a necessity that influences an individual's right to the city and shapes its participation in communal activities (Lucas et al., 2016; Thynell, 2016; Boisjoly & Yengoh, 2017; Kett et al., 2020; Pirra et al., 2021; Joshi & Bailey, 2023). However, given this importance, mobility tends to be very different across different social groups, whether for economic, physical, cultural or even psychological reasons. This idea has consequently led to unequal access to various opportunities in the city (Maksim, 2011; Heinen, 2016; Boisjoly & Yengoh, 2017; Pirra et al., 2021), which is particularly the case for women who continue to face significant challenges in accessing various transportation options that affect their participation in society (Sane, 2022). Therefore, forming a gender perspective on mobility in urban environments without gender neutrality represents a crucial step towards understanding these barriers with the aim of reducing gender differences and inequalities (Bellmann et al., 2020; Gauvin et al., 2020).

The connection between mobility and gender has been the focus of research since the 1970s (Law, 1999), and studies fields have been mainly limited to developed countries (Miralles-Guasch et al., 2016; Lee, 2017; Uteng & Tuner, 2019; Gauvin et al., 2020; Hidayati et al., 2020; Kawgan-Kagan, 2020; Pirra et al., 2021; Rodríguez De La Rosa et al., 2022; Chen et al., 2023; Chidambaram & Scheiner, 2023). Largely due to the unavailability of data, gender mobility has rarely been studied in southern contexts, even though greater mobility differences exist between both genders, where women face many challenges in accessing transportation facilities, coupled with sociocultural constraints that significantly impact their right to the city (Adeel et al., 2017; Nasrin & Bunker, 2021; Howe, 2022; Kacharo et al., 2022; Macedo et al., 2022; Porter et al., 2022; Alizadeh & Sharifi, 2023; Murphy et al., 2023; Parker & Rubin, 2023; Vanderschuren et al., 2023; Nasrin & Chowdhury, 2024). According to this fact, this article seeks to fill this gap by examining the mobility practices of men and women in the Sahel, and being among the first references to analyze the relationship between gender and mobility in Tunisia.

Tunisia is located in North Africa and has been one of the most progressive countries in terms of women's rights since its independence in 1956 (Nillesen et al., 2021; Kashina, 2021). Despite all efforts, Tunisian women still face inequality in both the private and public spheres, especially in the interior and the south, and are even seen as second-class citizens living in the shadow of men as the main breadwinners, according to the conservative consciousness of the Tunisians' social and cultural heritage and deviate from the progressive legal framework (Abbott, 2017; Nillesen et al., 2021; Kashina, 2021; Murphy et al., 2023): a situation that is intensifying after the Arab Spring and the rise of Islamic groups are attempting to impose a sharia-based religious identity on Tunisian society (Hitman, 2018).

In this socio-cultural environment, increasing restrictions on female mobility are evident, underpinned by security issues (particularly harassment) that limit women's travel, their participation in social and economic life, and even their choice of clothing, leading to further family restrictions through permissions and companionship. These restrictions influence women's travel behavior (choice of mode of transport, purpose of the trip, distance travelled, transport costs, etc.) and also lead to the differences in daily mobility between both genders.

Against this background, the aim of our study is to analyze the everyday journeys of women in the Tunisian transport system and to examine the similarities as well as differences in mobility patterns compared to men according to different income categories. Therefore, we seek to answer the following questions: What are the differences in mobility patterns between men and women in Tunisia in terms of mode choice, travel purpose, travel volume, time, distance, and cost? How does the financial situation affect the mobility of Tunisian women? Our research is organized as follows: Section 2 presents a literature review of the main ideas arising

from the articulation between mobility and gender. Section 3 is dedicated to presenting the data collection technique as well as our research area and the variables to be analyzed. The results obtained will be the subject of Section 4. The fifth part concludes with a summary of the main findings and suggestions for further research.

2. Literature review

While the focus is on examining the issues related to gender differences, several studies have focused on analyzing travel behavior based on the differences between men and women (Mahadevia & Advani, 2016; Maciejewska, 2019; Nasrin & Bunker, 2021; Kacharo et al., 2022; Macedo et al., 2022; Porter et al., 2022; Alizadeh & Sharifi, 2023; Murphy et al., 2023; Parker & Rubin, 2023; Nasrin & Chowdhury, 2024). They repeatedly find a visible connection between mobility and gender, with some assuming that this connection reflects the existing inequalities and inequities in our contemporary society. Certainly, mobility is both a necessity and a means of preserving the right to collective life in cities characterized by geographical sprawl and dispersion of activities. However, this meaning does not hide its discriminatory nature, linked to unequal access to transport facilities and, consequently, to urban facilities (Maksim, 2011; Porter et al., 2022; Murphy et al., 2023).

Biological and behavioral differences between men and women, as well as the cultural context they experience, lead to different access to opportunities within the city. This imbalance particularly disadvantages women in a transport system that is primarily geared towards men (Babinard, 2011; Pojani, 2011; Uteng, 2011; Basaric et al., 2016; Heinen, 2016; Cook & Butz, 2018; Nasrin & Bunker, 2021; Rodríguez De La Rosa et al., 2022; Jain & Geetam, 2020; Senikidou et al., 2022; Parker & Rubin, 2023; Pourhashem et al., 2022; Porter et al., 2022; Alizadeh & Sharifi, 2023; Murphy et al., 2023; Nasrin & Chowdhury, 2024). Therefore, we move from an inequality issue to a social justice issue and evaluate women's travel from an equity perspective.

Women's mobility has been studied in the literature in two main categories (Maciejewska, 2019). The first category focuses specifically on women's travel behavior with an emphasis on social justice and environmental sustainability (Delbosc & Currie, 2011; Pojani, 2011; Uteng & Tuner, 2019; Iqbal et al., 2020; Hidayati et al., 2020; Porter et al., 2022; Murphy et al., 2023). The second highlights gender differences in mobility between men and women (Onadja et al., 2013; Zunzunegui et al., 2015; Miralles-Guasch et al., 2016; Basaric et al., 2016; Lee, 2017; McLaren, 2018; Craig & Van Tienoven, 2019; Maciejewska, 2019; Uteng & Turner, 2019; Adom-Asamoah et al., 2020; Bellmann et al., 2020; Gauvin et al., 2020; Hidayati et al., 2020; Nasrin & Bunker, 2021; Jain & Geetam, 2020; Parker & Rubin, 2023; Pourhashem et al., 2022; Nasrin & Chowdhury, 2024).

Our work falls into the second category and aims to analyze the position of women in the Tunisian transport system by comparing their mobility behavior with that of men.

The main findings in the literature suggest that women typically travel shorter distances, often closer to home and for optional reasons (Scheiner, 2010; Frändberg & Vilhelmson, 2011; Nasrin & Bunker, 2021; Pirra et al., 2021; Rodríguez De La Rosa et al., 2022; Parker & Rubin, 2023). Women's trips are chained and involve multiple activities, making them more complex than men's trips (Jain et al., 2011; Brown et al., 2014; Basaric et al., 2016; Miralles-Guasch et al., 2016; Scheiner & Holz-Rau, 2017; Vanderschuren et al., 2019; Bellmann et al., 2020; Gauvin et al., 2020; Dingil et al., 2021; Nasrin & Bunker, 2021; Pirra et al., 2021; Rodríguez De La Rosa et al., 2022; Parker & Rubin, 2023).

Regarding transportation choice, women tend to walk and use public transportation more often (Levy, 2016; Scheiner, 2014; Basaric et al., 2016; Miralles-Guasch et al., 2016; Greed, 2019; Uteng & Turner, 2019; Bellmann et al., 2020; Havet et al., 2021; Nasrin & Bunker, 2021; Pirra et al., 2021; Abdullah et al., 2022; Chidambaram & Scheiner, 2023; Murphy et al., 2023) and have limited access to private car, which are more commonly used by men as they have the primary privilege for car use within a household (Boarnet & Hsu,

2015; Levy, 2016; Mahadevia & Advani, 2016; Miralles-Guasch et al., 2016; Singh, 2019; Dingil, et al., 2021; Havet et al., 2021; Nasrin & Bunker, 2021; Pirra et al., 2021; Chidambaram & Scheiner, 2023). Some explain this by the diversity of natural preferences between the two sexes and by women being less interested in modes and activities that are largely carried out by men (Miralles-Guasch et al., 2016; Nasrin & Bunker, 2021). These differences have their roots in social identity and culture, which is formed either within the family or at school (Sultana & Mateo-Babiano, 2017; Nasrin & Bunker, 2021; Porter et al., 2022; Murphy et al., 2023) and portray men in a position of strength at the expense of women. This fact is supported by the unequal distribution of roles between the two genders in the household or society globally, as well as women's limited access to resources (reflected in their lower income) (Kwan & Kotsev, 2015; Parker & Rubin, 2023; Nasrin & Bunker, 2021). This reality leads to increased responsibilities for women, including travel related to household tasks and accompanying children or even the elderly (Sánchez de Madariaga, 2013; Scheiner & Christian Holz-Rau, 2017; Motte-Baumvol et al., 2017, Havet et al., 2021; Chidambaram & Scheiner, 2023; Pirra et al., 2021; Scheiner & Holz-Rau, 2017; Abdullah et al., 2022; Loukaitou-Sideris & Ceccato, 2020), and they find themselves very constrained in terms of time, which limits the work opportunities that may be available to them (Kim et al., 2012; McQuaid & Chen, 2012; Scheiner & Holz-Rau, 2012; Craig & Powell, 2013; Chidambaram & Scheiner, 2023; Havet et al., 2021; Fan, 2015; Pirra et al., 2021).

These results likely differ from one geographical context to another and consequently from one culture to another (Hanson, 2010; Adeel et al., 2017; Maciejewska, 2019; Hidayati et al., 2020; Xu, 2020; Pirra et al., 2021), directing several works towards analyzing this perception with the aim to fully understand the mobility behavior of both genders. The consideration of sociodemographic characteristics in addition to gender such as age, income or marital status (Onadja et al., 2013; Zunzunegui et al., 2015; Basaric et al., 2016; Adeel et al., 2017; Pirra et al., 2021; Nasrin & Bunker, 2021) proves to be an essential addition to the analysis.

To address this issue, we decided to expand our analysis by including the income aspect to examine its impact on women's urban mobility and identify differences compared to men. This idea has been the subject of various studies in the literature, mainly focused on developing countries (Uteng, 2011; Gera & Hasdell, 2020; Jain & Geetam, 2020; King et al., 2021; Olivieri & Fageda, 2021; Nasrin & Chowdhury, 2024). According to these references, women's mobility characteristics are described by their financial situation, which not only determines their choice of mode of transport but also shapes the extent of their opportunities (Uteng, 2011; Gera & Hasdell, 2020; Jain & Geetam, 2020; King et al., 2021; Nasrin & Chowdhury, 2024). Given limited affordability, women choose walking to meet their mobility needs and are less inclined to own a vehicle or a driver's license (Lecompte & Bocarejo, 2017; Gera & Hasdell, 2020). This situation changes as income increases, as women tend to use more motorized transport (Lecompte & Bocarejo, 2017; Saigal et al., 2021).

The study on gender issues in transport in the context of Tunisia was presented in an exploratory study by the CODATU association (Cooperation for Urban Mobility in Developing Countries) in 2017, focusing on the masculinity of the transport sector and violence against women in public spaces, especially on public transport. A recent study by Porter et al. (2022) in the low-income neighborhoods of Tunis has drawn attention to the safety challenges faced by young women in two different periods (pre- and post-COVID-19). Another recent study was conducted by Murphy et al. (2023) with the aim of studying the daily journeys of women living in socioeconomically marginalized neighborhoods of Grand Tunis. In contrast, limited research on women as transport users or even employees have been published in Tunisia, and some of it has been conducted on a large scale involving the MENA region (Delatte et al., 2018). For example, the World Bank study on the challenges and opportunities of mobility from a gender perspective in MENA countries (World Bank, 2012) focused on women's mobility patterns without including Tunisia in this research. This serves as motivation for us to delve deeper into this topic and provide insights into the position of women in the Tunisian transport system. Despite efforts to support women's rights and promote their place in society, little action has been

taken due to an inherited repressive regime that neglects recognition of women's needs in development strategies and disadvantages them (Kallander, 2021; Murphy et al., 2023). Numerically, this situation was expressed by the fact that according to Global Gender Gap Reports, Tunisia ranked 120th among 156 countries in 2021 (after ranking 90th in 2006) (Murphy et al., 2023). Furthermore, Tunisian women are less present in the labor market than men, with a participation rate of 25.5% (58% in the informal segment) compared to 68% of men (World Bank, 2022; World Economic Forum, 2022). Combined with unequal wages and the unfair cultural roles assigned to them (carrying household responsibilities around 33-50% of their day (The New Arab, 2023)), many Tunisian women still find it difficult to achieve financial freedom. This reality forces low-income females to use the least safe and convenient modes of transportation and to adapt their mobility needs to avoid unsafe stations and neighborhoods, even if it means spending additional time to reach their destination (Murphy et al., 2023). Safety remains one of the biggest challenges for Tunisian women (with or without financial relief) when accessing and using transportation in Tunisia. It influences their choice of transport, the way they reach transport stations, their travel time and even the way they dress (to prevent petty crime) (Murphy et al., 2023).

3. Data and analysis variables

In this section, we highlight the methodology used in our study by presenting the data collection approach, the study area and the analysis variables used.

3.1 Data collection

This study uses data from a survey conducted in 2019 in the Tunisian Sahel region. The questionnaire was carried out as part of a master's research with the aim of defining a real state of daily mobility practices in the Greater Sahel region and highlighting the existing socio-demographic and spatial gaps by providing answers to questions such as: How do the inhabitants of the Sahel region move around? what are their mobility patterns? what modes of transport do they use? how often? for what purpose? for how much cost, time and distance? how do they rate the quality of the transport supply available to them? What variability can be observed between the different socio-demographic categories serving this region? And what are the spatial gaps in mobility and access to social life between the different governorates and even the different delegations that make up the Sahel region?

The survey consists of four parts, which make it possible to provide information both on the socio-demographic characteristics of the respondents, the needs and characteristics of mobility, the total number of trips made daily and the level of participation in social life related to the available transport service. For this research we will use the sections on the characteristics and mobility needs of the inhabitants of the Sahel, as well as the peculiarities of their daily travels. (The survey questionnaire is presented in Appendix A-1)).

The total sample collected for our study consisted of 2,021 respondents selected from a total population of 1,206,763 individuals aged 15 to 60 years and older (INS, 2014), using the stratified probability sampling technique. According to this sampling method, a heterogeneous population is first divided into homogeneous strata based on preselected characteristics and then independent samples are selected from each of these subgroups. In simpler terms, it involves defining distinct and mutually exclusive strata within the target population based on a specific variable such as gender, age, region, household status, income, etc. Independent sampling can then be performed using any sampling method that may vary from one subgroup to another.

The main reason for choosing this method is its efficiency in sample definition. It allows the determination of an appropriate sample size for each subgroup within the target population, ensuring precise and accurate representation.

For this study, stratification was carried out according to spatial context (governorates/delegations), gender and age of the Tunisian Sahel population. This approach allows us to recruit the appropriate number of people to be interviewed within a specific gender, age group and residence in a specific delegation of a specific governorate. Appendix A-2 provides a representation of stratified sampling in Sousse Governorate. The overall sample was evenly distributed between women (51.4%) and men (48.6%). This parity is due to the comparatively higher proportion of women in the Sahel compared to men (51% women versus 49% men). Below we present a statistical distribution of the sociodemographic characteristics of our sample (Tab.1).

		Tunisian Sahel Region (2,021)		**Women (1,038)**		**Men (983)**	
Age	**15-19 years old**	235	11.6%	117	11.3%	118	12%
	20-29 years old	504	25%	258	24.9%	246	25%
	30-39 years old	428	21.1%	225	21.7%	203	20.7%
	4049 years old	337	16.7%	168	16.2%	169	17.2%
	50-59 years old	256	12.6%	130	12.5%	126	12.8%
	60 years and older	261	13%	140	13.5%	121	12.3%
Socio-professional category	**High school student**	236	11.7%	127	12.2%	109	11.1%
	Teaching	33	1.6%	16	1.5%	17	1.7%
	Student	206	10.2%	122	11.8%	84	8.5%
	Private job	898	44.4%	341	32.9%	557	56.7%
	Public job	130	6.4%	60	5.8%	70	7.1%
	Liberal profession	30	1.5%	21	2%	9	0.9%
	Retired	161	8.1%	47	4.5%	114	11.6%
	Unemployed	327	16.1%	304	29.3%	23	2.3%
Marital status	**Single**	812	40.1%	390	37.6%	422	43%
	Divorced	48	2.4%	32	3%	16	1.6%
	Married	1050	52%	514	49.5%	536	54.5%
	Widow(er)	111	5.5%	102	9.9%	9	0.9%
Income	**Low-income (0-1050 dinars)**	1629	80.6%	944	91%	685	69.6%
	Middle-income (1050-2100 dinars)	308	15.2%	85	8.2%	223	22.7%
	High-income (+2100 dinars)	84	4.2%	9	0.8%	75	7.7%
Household size	**Small household (1-4 persons)**	1205	59.6%	604	58%	601	61.1%
	Big household (5-10 persons)	816	40.4%	434	42%	382	38.9%

Tab.1 Sociodemographic characteristics of the study sample

To ensure the legitimacy of our work, we informed the relevant authorities in each of the delegations visited about the purpose of our study.

In order to attract the largest possible number of participants with different profiles, we held meetings on the streets and in public places (as a privileged target group) in urban and rural contexts, e.g. bus stops, train stations, public transport terminals, parking lots, Shopping areas, parks, coffee shops, sports complexes, farmers markets, administrative facilities, schools and universities, etc. Once a person agrees to participate in our survey, the total duration of the questionnaire was estimated at 15 to 20 minutes.

The statistical reference unit of our study is the person surveyed. Seven researchers were involved in conducting this survey: three professional researchers with experience at the National Institute of Statistics (INS) and four master's research students.

The aim was to cover two to three delegations per day (depending on the specifics of the region served). Two teams, each consisting of three to four people, were assigned to a specific study area. Quotas were established based on the age and gender of participants assigned to each interviewer. This approach allowed us to adhere to the predetermined sampling quotas and organize the questionnaire with optimal efficiency. The survey lasted one and a half month from January 29, 2019, not counting Sundays and Mondays, school vacations and public holidays. To maintain the specified sample size, discrepant observations were first identified and excluded. These observations were then collected again during the specified time period. Thus, the pre-determined total number of 2,021 respondents was successfully reached, respecting the specific quotas established for each delegation visited. Given the lack of systematic data on urban mobility in the Tunisian Sahel context (and even at the national level), this database represents a detailed reference for travel patterns and aims to provide an overview of what is actually happening in terms of mobility in the region.

3.2 Study area

The Tunisian Sahel represents 4% of the country's total area and covers 6,659 km^2. Administratively, it includes 40 delegations grouped in three governorates: Sousse (the most populous), Monastir (the main industrial pole) and Mahdia (the most spatially extensive), which are home to more than 15.3% of the country's total population, which makes it the second national metropolis according to the figures of the General Commission for Regional Development (CGDR).

The Tunisian Sahel has a strategic geographical location and serves as an intermediate passage between the southern and northern regions of the country. This is also supported by a well-developed infrastructure, which makes traveling between these two ends increasingly easier. This advantage positions the Sahel as a historical research laboratory for urban mobility studies and travel behavior surveys.

In Appendix A-3 we present the urban setting of our study area[1], illustrating the infrastructure and key public facilities in the region.

As for road transport, the Tunisian Sahel is connected by a network of 1,812,761 km of national, regional and local roads that serve the various delegations in the region. This infrastructure is reinforced by different categories of transport (individual, collective and semi-collective) that serve the region at urban, suburban, regional and rural levels.

In addition, the region serves as a central hub in the Tunisian highway network, with the city of M'saken (a delegation in Sousse Governorate) taking center stage. The A1 motorway stretches 140 km north to Tunis and 98 km south to Sfax.

[1] From the cartographic atlas of the Ministry of Equipment, Housing and Spatial Planning (2019)

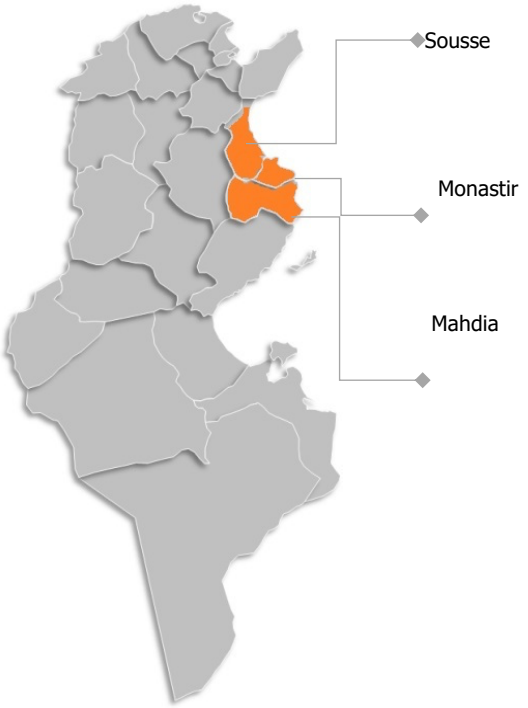
Sahel region (Tunisia map)	Governorates	Demographic characteristics
	Sousse	Total population in 2023 (estimated): 753,370 Area (km^2): 2,669 Population evolution rate (2014-2023): 11.61% Classified road network (2021): 596.81 km Urbanisation rate (2014): 81.1%
	Monastir	Total population in 2023 (estimated): 611,118 Area: 1,024 km^2 Population evolution rate (2014-2023): 11.35% Classified road network (2021): 516.5 km Urbanisation rate (2014): 100%
	Mahdia	Total population in 2023 (estimated): 448,273 Area: 2,966 Km^2 Population evolution rate (2014-2023): 9.12% Classified road network (2021): 569.92 km Urbanisation rate (2014): 45.7%

Fig.1 The Tunisian Sahel region

In addition to the road infrastructure, the greater Sahel area is also crossed by a regional railway line with a length of 72.5 km. Managed by the National Company of Tunisian Railways (SNCFT), this railway (known as the Sahel Metro (the tram)) serves as an important and widely used public transport in the region, connecting Mahdia to Sousse via Monastir. At the national level, all three governorates offer comprehensive rail transport for both passenger and freight transport.

This service is represented by line No. 5, which connects major coastal cities with Tunis, Sfax, Gabès and the southern regions of the country, including Gafsa and Tozeur.

It is worth noting that the Tunisian transport system has several deficiencies, mainly related to the regularity of modes of transport, their spatial availability, security of access, fare irregularities and the behavior of drivers. One of the notable features of Tunisian transport is the very limited presence of informal modes of transport compared to Asia, Africa or even the South American continent. Furthermore, bicycles are relatively rare on the streets of Tunisia, as this mode of transport is ingrained in the culture as a symbol of lower economic status (Poussel, 2018). Depending on the spatial configuration of the delegation (urban or rural), the presence of adequate transport stations is not for everyone, even access to these is characterized by poor infrastructure for the majority of Sahel delegations (particularly in rural areas). These restrictions lead to security problems and open the possibility for petty crimes, which is primarily supported by women (Murphy et al., 2023).

3.3 The analysis variables

We focus on a variety of variables that show the behavioral characteristics of everyday mobility of women and men in the Sahel, its spatial and temporal dimensions, as well as the volume of daily trips and their monetization (Tab.2).

Behavioral features of mobility
Modal choice
Trip purpose
Volume of travel
Daily travel rate
Daily expenses (dinars)
Daily expenses/travel (dinars)
Spatial dimension of mobility
Total daily distance traveled (km)
Distance to transportation (km)
Cost per kilometer (dinars/km)
Temporal dimension of mobility
Access time to transportation (minutes)
Waiting time for the means of transport (minutes)
Time budget (minutes)
Average duration of each trip (minutes)
Hourly cost (dinars/hour)

Tab.2 Analysis variables by category

Here we define a daily trip as the journey between a starting point and a destination. Cost per kilometer is a monetary quantification of kilometers traveled per day and is measured by the ratio between daily expenses and the number of kilometers (distance) traveled across all modes of transport. Regarding the time aspect, the time budget measures the total time a person invests in their trips and considers the time in the vehicle in addition to the access and waiting time. The average duration of each trip is measured by the ratio between the time budget and the average number of daily trips. Finally, hourly costs quantify each hour spent on transportation and are measured by the ratio of daily expenses to time budget multiplied by 60.

4. Results and discussion

In this section we will outline the survey results and attempt to identify gender differences in mobility patterns in the Sahel. Our analysis begins by highlighting these differences by looking at women as a unique category and then examining how income affects their travel behavior.

4.1 Modal choice

Before presenting the results regarding modal choice by gender, we first categorize transportation modes into three groups:

- Individual modes including two-wheel drive, animal, truck, van, walking, private taxi, and private car;
- Public modes covering bus, work-bus, tram, and train;
- Semi-collective modes, a specificity of the Tunisian transport routine, including clandestine, the 'Louage' (connects intercity and inter-governorate), and the collective taxi (8-seater car that connects urban and rural areas in the governorate).

Bus transport is one of the most used modes of transport in the study area, as it is cheaper than the private "yellow" taxi (which is also not 100% spatially available), but its availability appears to be irregular and scarce in many areas of the region and extremely crowded. In the second row there are the shared taxis and the "Louage", which are a semi-collective means of transport in Tunisia and wait at fixed stops until they are full

and then travel on fixed routes. Due to the behavior of the driver, this mode is less safe than others, and train stations are so crowded, especially during rush hour, that they are a place for harassment and robbery.
The tram (which crosses the region from Mahdia to Sousse via Monastir), on the other hand, represents one of the most reliable means of transport due to its low cost, its availability and its ability to reach the intended destination on time. In contrast, the train (which is usually used for used for long distances) is exactly the opposite, as it has the most delays and traffic jams (most of the time passengers can't find a place to sit and can stay standing the whole time).
Transportation problems are not limited to public transport, in fact even private taxis in Tunisia have some deficiencies. In addition to price fraud, taxis refuse to offer door-to-door service either because they plan their trips according to their needs or on the grounds that some areas (low-income neighborhoods) are not safe or poorly accessible (damaged infrastructure, which is particularly worse during heavy rain when it becomes more difficult for cars and even people to move).
For the clandestine mode of transport, this has the same characteristics as the Louage and collective taxi, but with the only one difference: *it is illegal*. Owners of private cars with 7 to 9 seats act as passenger transporters with a variable tariff depending on the importance of the offer. This transport scheme is presented in particular in the Monastir delegations.
Based on this categorization, it can be seen that four out of five daily trips made by men (81.2%) using individual means of transport, compared to only 11% using semi-collective modes of transport. Collective modes make up only 7.9%. For women, private transport accounts for only 61% of trips. The differentiation is balanced by greater use of public transport (13.4%) and semi-public transport, which account for a quarter of their transport choice (Tab.3).

	Total sample		**Low-income**		**Middle-income**		**High-income**	
	Women	**Men**	**Women**	**Men**	**Women**	**Men**	**Women**	**Men**
2-wheel drive	2,5%	**17%**	2.8%	**19.5%**		**12.4%**		**8.5%**
Animal	0,2%	0,2%	0.5%	0.2%				
Bicycle	0,4%	2,6%	0.2%	3.5%		0.9%		
Bus	**10,2%**	**6,2%**	11.1%	8%	2%	2.8%		0.7%
Work bus	1,2%	0,5%	1.3%	0.4%		0.7%		
Truck	0%	0,3%		0.3%		0.6%		
Van	0%	0,5%		0.4%		0.7%		0.7%
Clandestine	0,8%	0,1%	0.8%	0.2%	1%			
'Louage'	**9,2%**	3,7%	9.1%	3.9%	10.3%	3%	**7.1%**	3.3%
Walking	**38,9%**	**33,7%**	**40.1%**	**38.2%**	**28.5%**	**24.7%**	**21.4%**	**19.9%**
Metro	1,8%	1%	1.9%	1.1%	1.3%	0.8%		
Collective cab	**15,6%**	**7,1%**	**16.3%**	7.9%	**9.3%**	5.5%	**7.1%**	4.6%
Individual cab	2,9%	1,3%	2.7%	1.5%	5.6%	0.7%		0.7%
Train	0,1%	0,2%	0.1%	0.1%	0.7%	0.6%		
Private car (as a driver)	**6,8%**	**22,4%**	**3.9%**	**10.4%**	**31.1%**	**45.1%**	**57.1%**	**61.9%**
Private car (as a passenger)	**9,3%**	**3,2%**	**9.2%**	**4.3%**	**10.3%**	**1.1%**	**7.1%**	

Tab.3 Modal distribution by mode character and income category for both sexes

The table above clearly shows how women and men in the Sahel move differently, use different means of transport and face different restrictions in their daily movements. The statistical results highlight the dominance of two modes of transport: walking, which is used more often by women (38.9%) than by men (33.7%), and the private car, with one in four trips for men (of which 87.5% are drivers) and only one in six trips are for women (with around 57.7% as passengers) (Bellmann et al., 2020; Kawgan-Kagan, 2020; Havet

et al., 2021; Nasrin & Bunker, 2021 ; Pirra et al., 2021; Abdullah et al., 2022; Chidambaram & Scheiner, 2023; Murphy et al., 2023). This is due to the fact that women are less likely to have a driving license compared to men (Fig.2).

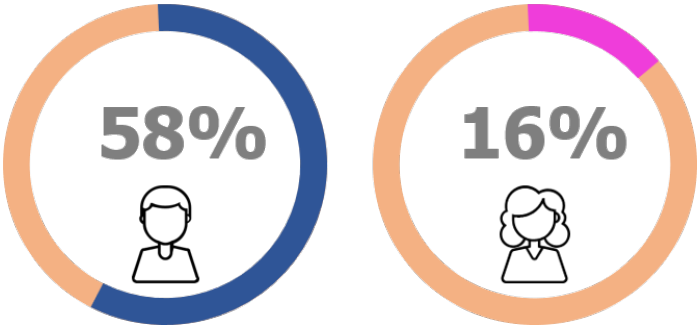


Fig.2 Driver License possession for Men and Women

Women in the study area are often perceived by their families as weak and vulnerable individuals when they travel alone. For this reason, they are mostly accompanied by a male family member, which limits their travel and even their choice of mode of transport (limited access to private vehicle) (Nasrin & Bunker, 2021; Parker & Rubin, 2023; Porter et al., 2022; Murphy et al., 2023).

Despite its modest modal share (2.4%), bicycle use is six times higher among men than among women (0.4%) (Pojani, 2011). For Tunisian women, cycling is considered a culturally inappropriate practice (Porter et al., 2022). These types of restrictions have given women a natural preference for less masculine modes of transport (Miralles-Guasch et al., 2016) and make them highly dependent on public transport.

For women, the shared taxi comes third and covers 15.6% of their trips, followed by the bus (10.2%) and the 'louage' (9.2%). For men, the two-wheeled vehicle is in third place with a share of 17% and justifies the gap between the shares of the individual means of transport, followed by the shared taxi (7.1%) and the bus (6.2%). When using public transport, women face particular problems, particularly harassment and sexual assault, whether through taunting gestures, verbal insults, physical abuse, or a combination of these behaviors. The most stressful experiences tend to occur on very congested public transport, especially when men are in close proximity to women or at night when the availability of transport services is scarce (Nasrin & Bunker, 2021; Pira et al., 2021; Kacharo et al., 2022; Porter et al., 2022; Murphy et al., 2023; Nasrin & Chowdhury, 2024).

According to Gekoski et al. (2017), this phenomenon seems to be related to gender norms that classify some public institutions as male-dominated and limit the place of women in the country's economic and social development.

Contrary to popular belief, the use of the clandestine mode is eight times more common among women (0.8%) than men (0.1%). The low use of this mode of transport is due to its small presence in the Sahel. As already mentioned, this type of transport is used exclusively in the Monastir Governorate (specifically in the Sahline and Werdanine delegations). Compared to other continents such as Asia and Africa, there is relatively little informal transport in the Tunisian transport system (Murphy et al., 2023).

The two findings and the dominance of motorized modes for both men (63.5%) and women (60.4%) are also reflected in the work of Miralles-Guasch et al. (2016), Greed (2019) and Uteng & Turner (2019), which look at northern countries from both urban and rural perspectives.

The observed mode choices for women and men in the Sahel region provide insight into what actually happens in people's daily mobility. Recognizing these patterns is crucial for urban planning to mitigate inequalities between the two genders when navigating urban spaces.

Looking at the financial situation, walking remains the most frequently used mode of transport (also for men) by women in the Tunisian Sahel with a share of 40.1%, followed by shared taxis (16.3%) and private cars (mainly as a passenger (9.2%)) (Lecompte & Bocarejo, 2017; Saigal et al., 2021). For low-income men, mobility is much easier when they use more private means such as two-wheelers (19.5%) and cars, mostly as drivers (10.4%). As income increases, the use of private cars is preferred for both genders (Lecompte & Bocarejo, 2017; Nasrin & Bunker, 2021; Saigal et al., 2021; Nasrin & Chowdhury, 2024). In fact, as affordability increases, women can hold a driver's license and own a private car (Tab.4).

		Low-income		**Middle-income**		**High-income**	
Gender		**Women**	**Men**	**Women**	**Men**	**Women**	**Men**
Driver license possession	**Yes**	12%	46%	53%	83%	56%	85%
	No	88%	54%	47%	17%	44%	15%
Vehicle possession	**Private car**	3%	13%	22%	62%	44%	72%
	Family car	31%	23%	46%	4%	56%	7%
	No	66%	64%	32%	34%		21%

Tab.4 Driver license possession and vehicle ownership by income category for both sexes

As shown in the table above, Sahelian women tend to use their own car and distance themselves from family influence as their financial comfort increases (similar to men, with higher rates than women). While men continue to use private transportation as their income increases, women, on the other hand, still use public transportation. In the middle-income group, women consistently choose shared taxis, although the rate is significantly lower compared to the low-income group (9.3%), and this percentage falls further among those with higher financial comfort (7.1%, similar to the 'louage').

As already mentioned, clandestine mode is used more often by women than men. This is the case of females with low incomes in Monastir (0.8%) and even of women with a significantly better financial situation (middle income) who are looking for economical transport according to the offer available in their area of residence

4.2 Trip purpose

The travel purposes most frequently mentioned by our respondents are 11: work, study, administrative matters (travel for public administrations (city administration, post office, police, etc.)), professional matters (travel related to professional purposes)), accompaniment, shopping, leisure, Health and care, personal (e.g. visits to family/friends, visits to places of worship).

	Total sample		**Low-income**		**Middle-income**		**High-income**	
	Women	**Men**	**Women**	**Men**	**Women**	**Men**	**Women**	**Men**
Work	**26,2%**	**36,2%**	**23.8%**	**32%**	**48.5%**	**42.3%**	**76.9%**	**55.3%**
Study	**19,7%**	**12%**	**21.8%**	**17.2%**	0.6%	0.9%		
Administration	4,7%	1,6%	5%	1.1%	2.3%	3.3%		1.2%
Professional Affairs	0,5%	1%	0.3%	1%		1.3%		
Accompaniment	8,1%	3,2%	7.6%	2%	**12.9%**	6%	**15.4%**	5.3%
Shopping	**17,5%**	**9,1%**	**17.4%**	**8.1%**	**19.3%**	**11.1%**		**10.6%**
Leisure	5,3%	**28,8%**	5.5%	**30.9%**	2.9%	**25%**	**7.7%**	**21.2%**
Health and care	**7%**	1,2%	7.4%	1.5%	2.9%	0.7%		0.6%
Personal	11,1%	7%	**11.2%**	6.2%	10.6%	9.4%		6%

Tab.5 Distribution of trips purpose per income category for both genders

The elementary distribution of the trip purpose (Tab. 5) shows that one of three trips made by men (36.2%) is for work reasons, compared to only one of four trips by women (26.2%). This is consistent with the unemployment rates reported in Tunisia in the current decade, which disproportionately affect women: the unemployment rate for women in 2018 was almost twice that of men (22.7% versus 12.5%) (INS, 2019). Our finding is in line with the results of the empirical literature, which recognizes that the responsibilities carried limit the time spent on accessing the labor market (Loukaitou-Sideris & Ceccato, 2020; Dingil et al., 2021; Nasrin & Bunker, 2021; Pirra et al., 2021; Abdullah et al., 2022; Rodríguez De La Rosa et al., 2022; Parker & Rubin, 2023). Women are likely work in small businesses (bakeries, small factories, kindergartens, etc.) and have little chance of getting high-paying jobs because these are predominantly occupied by men. Despite the low proportion of women in the Tunisian workforce, progress has been made such that their employment rate is above the average of Arab countries (28.1% compared to 21.2% in 2021 (Kashina, 2021).

In second place, we note that about 20% of women's trips are made for educational purposes, while for men the leisure and recreational motive stands out, which accounts for over 28% of their total trips (while for women it represents only 5.3% of their daily trips). Conversely, education is the third most important reason for men with a share of 12%. These results can be explained objectively by the significant difference in the female enrollment rate at the university level (Almost 60% of students are female (Tab.1 in Section 3)) and subjectively by the conservative and sometimes restrictive culture towards women in certain delegations in the Tunisian Sahel, which is mainly characterized by traditional Muslim values and customs that determine the majority of women's student behaviors, especially after the 2011 revolution (when Muslim conservation was strengthened) (Porter et al., 2022; Murphy et al., 2023).

Daily shopping is in third place for 17.5% of women, while for men it is only 9.1%, followed by private trips (11.1%), companionship (8.1%) and health/care rides (7%). Despite the increasing presence of gender equality movements, Tunisian societal norms still dedicate women's lives to the home, raising and accompanying children on their daily journeys, caring for their husbands, and accompanying the elderly (Porter et al., 2022; Murphy et al., 2023).

Looking at income, it seems that for both genders, work trips are the most important activity for using the Tunisian transport system, increasing as the financial situation improves. For low-income women, study motives come second, accounting for 21.8% of all trips, as this category is predominantly students. For men, leisure represents a primary activity, particularly for the low-income group (30.9% of all trips). The same classification of motives for the overall sample also applies to the low-income category. As income increases, there is a proportional shift in travel priorities. In fact, for middle-income women, shopping comes second (19.3%), followed by companionship for 12.9%. The latter is more likely to be observed among women who are financially better off. These results show that women, regardless of their financial status, are still bound by cultural norms that dictate the division of household responsibilities. While men travel mainly for leisure activities (after work), women take on the role of shopping and caregiving (Nasrin & Bunker, 2021; Pirra et al., 2021; Nasrin & Chowdhury, 2024).

4.3 Travel dimensions and rates

When it comes to daily trips (Tab.6), men are significantly more mobile than women, at a rate of about 4.1 trips per day, compared to only 3.2 trips for women. This difference between the two genders remains true even when income is considered. In this context, our results show that the middle-income category has the highest travel rate compared to other income groups for both women (3.4 trips/day) and men (4.2 trips/day). On the other hand, high-income women tend to take the fewest trips, making around 3.1 trips per day.

Men's dominance in daily travel is associated with higher daily expenditures than women's, whether for the total number of trips made (4.9 dinars per day (equivalent to US$1.79)) or for each trip (1.43 dinars/trip/day).

In addition to the total distance traveled: Women travel only a few kilometers, with an average of around 22.11 km/day, while men cover 27.13 km/day. This discrepancy is consistent with other empirical studies (Dingil et al., 2021; Nasrin & Bunker, 2021; Pirra et al., 2021; Abdullah et al., 2022; Rodríguez De La Rosa et al., 2022; Parker & Rubin, 2023), and it becomes more explicit on year basis. In fact, men cover an average of more than 9,900 km per year, covering 1.24 times more distance than women, who limit themselves to an average of 8,070 km. Women's mobility is primarily about family obligations that require the combination of several trips closer to their home. This fact becomes clearer as we move further into the southern part of the region and throughout the country, where authority in the family is vested in men, who are essentially the breadwinners of the workforce (Abbott, 2017, Murphy et al., 2023).

Volume & Distance	**Daily travle rate**	**Daily distance travelled (km)**	**Distance to transportation (km)**	
Total sample	**3.6**	**24.55**	**0.57**	
Women	**3.2**	**22.11**	**0.61**	
Low-income	3.2	21.81	0.61	
Middle-income	3.4	26	0.61	
High-income	3.1	17.2	0.36	
Men	**4.1**	**27.13**	**0.53**	
Low-income	4	20.91	0.57	
Middle-income	4.2	39.73	0.44	
High-income	4.1	46.44	0.48	
Time aspect	**Access time to transportation (minutes)**	**Waiting time for the means of transport (minutes)**	**Time budget (minutes)**	**Average duration of each trip (minutes)**
Total Sample	**9**	**11**	**80**	**26**
Women	**10**	**12**	**82**	**30**
Low-income	10	12	82	30
Middle-income	8	11	78	28
High-income	5	10	57	22
Men	**7**	**10**	**77**	**23**
Low-income	8	10	75	22
Middle-income	5	7	82	24
High-income	6	9	86	29
Cost aspect	**Daily expenses (dinars)**	**Daily expenses/trip (dinars)**	**Cost per kilometer (dinars/km)**	**Hourly cost (dinars/hour)**
Total Sample	**3.61**	**1.15**	**0.52**	**6**
Women	**2.38**	**0.89**	**0.37**	**2.7**
Low-income	2.18	0.84	0.34	2.36
Middle-income	4.2	1.33	0.66	5.51
High-income	7.98	2.38	0.73	7.21
Men	**4.9**	**1.43**	**0.67**	**6.4**
Low-income	3.12	0.85	0.52	4.07
Middle-income	7.98	2.39	0.92	10.04
High-income	12	3.84	1.28	16.27

Tab.6 Mobility indicators for both gender and income category

In terms of financial situation, men's daily distance traveled increases as income increases, moving from 20.91 km/day to 46.44 km/day for the high-income category. A classification that continues to be respected for daily

expenses (even for women). In contrast, improved financial conditions for females result in shorter distances of about 17.2 km per day. Furthermore, it appears that low-income women travel more kilometers than men in the same category (21.81 km/day versus 20.91 km/day) (Nasrin & Bunker, 2021; Nasrin & Chowdhury, 2024).

A person in the Sahel pays an average of 0.52 dinars per kilometer traveled. These unit costs are cheaper for women than for men, whose average cost per kilometer is 29% higher than average, rising to 0.67 dinars. In other words, the cost per kilometer is 81% more expensive for men than for women. A sum that increases with income for both genders, where women with high incomes spending 0.73 dinars per kilometer traveled, compared to 0.34 dinars/km for women with modest financial resources.

The distances to the various means of transport used daily are comparable (0.61 km vs. 0.53). However, the cumulative annual difference puts the woman at a disadvantage of almost 30 km. The built environment in many areas of the Sahel (particularly in low-income neighborhoods) is poorly managed (not all areas have train stations and not all existing train stations have shelters, and they are on main roads far from residential areas: people have to walk an average of 570 meters to use an irregular and unsecured transport service provided over damaged infrastructure) and poses many safety problems for women who prefer to walk further kilometers to a safer neighborhood to use transport, or a Ask a family member with a vehicle to take them there (Porter et al., 2022; Murphy et al., 2023). This reality is particularly evident among low- and even middle-income women, who travel a distance of 0.61 km (corresponding to the overall average observed among women). In developing countries, the transportation system is mainly characterized by deteriorating transportation infrastructure, long distances between home and train stations, and accessibility issues (Dingil et al., 2021; Pirra et al., 2021; Alizadeh & Sharifi 2023). A condition that occurs primarily in low-income neighborhoods (Porter et al., 2022; Murphy et al., 2023). On the other hand, accounting for income in our analysis uncovered a case where men travel a greater distance to access transportation than women. This is an example of the high-income category, where men travel 0.48 km to use transportation while women travel only 0.36 km.

When it comes to time, women invest the most in access to available transport options (access and waiting times) and even in the entire journey (average length of each journey traveled). However, men bear higher hourly costs than women, with more than 6.4 dinars per hour, compared to only 2.7 dinars. On average, women reserve 5 minutes more per day for rides than men. Given the average rate for both genders and at the level of a single trip, this gap is more noticeable and is 7 minutes (26 min vs. 19 min), which is almost 37% of the average trip time for women. The difficulty of women's mobility is most evident from this temporal perspective (as in the case of Abdullah et al., 2022 study). Taking income into account, improved financial conditions make traveling much easier for this population group. According to Tab.6, high-income women spend the least amount of time accessing public transportation at about 5 minutes, while low-income females struggle with twice as much time (10 minutes).

For both genders, low income tends to lead to longer access times to transportation and even longer waiting times for transportation (Gera & Hasdell, 2020). Ironically, it appears that low-income men spend an average of 10 minutes patiently waiting for transportation, which takes the same amount of time for high-income women (underscoring the clear hierarchy between the two genders). Notably, middle-income men experience the lowest time loss in access (5 minutes) and waiting for transport (7 minutes). Despite the aforementioned observation that women generally spend more time in transportation than men (time budget and average duration per trip), income considerations reveal further variation between the two genders. While women's time budget decreases as their income increases, the opposite is the case for men. It appears that low-income women spend about 1 hour and 22 minutes as much on transportation as middle-income men (a duration relatively close to that of high-income men (1 hour and 26 minutes)).

The transposition of this finding to the average duration per trip, present a relatively equal differences between the income groups of the two genders. For this variable, low- and middle-income women spend a longer time on each trip than their male counterparts, 30 and 28 minutes per trip, respectively.
Conversely, well-financed women invest only 22 minutes per trip, which is less than the 29 minutes spent by high-income men. Since men spend the most per hour traveled, these costs increase in proportion to financial comfort for both genders. For low-income women, the cost is 2.36 dinars/hour, for the middle-income group, 5.51 dinars/hour, and for women with significant financial relief, 7.21 dinars/hour. For men in this income category there are also costs of 16.27 dinars per hour traveled.

5. Conclusion

Within the context of no gender-neutral cities, women's travel behavior has been the focus of several research studies, highlighting the differences in mobility patterns between the two genders as a result of the inherent cultural role distribution in which predominantly women assume most of the household duties. A circumstance that is most evident in developing countries, where women encounter inadequate transportation and are constrained by limited financial resources and societal norms (Nasrin & Chowdhury, 2024).
The aim of this research was to analyze women's mobility in the Tunisian Sahel and examine the impact of financial status on their travel habits compared to men. The initial results of the descriptive analysis of variables, addressing multiple dimensions of mobility, revealed notable differences between the two genders. These differences are consistent with those documented in the literature and facilitate the integration of our geographical study into the limited empirical research on the case of Tunisia.
According to the various findings, women in the Sahel appear to spend the most time accessing transport and making their daily journeys, with a greater average distance. On the other hand, men travel more than women, with almost 420,000 trips per day, for almost every mode and travel purpose, incurring much higher transportation costs. Measured by the modal split, women use public and semi-public transport significantly more often than men. The travel motives are predominantly optional for both genders and are in similar proportions. The table presented below provides a summary of the variations in various variables when comparing the values recorded for women with those for men.

	Average variation women vs men
Daily travel rate	-22.0%
Number of daily trips	-17.4%
Daily expenses (dinars)	-51.4%
Daily expenses/travel (dinars)	-37.7%
Daily distance travelled (km)	-18.5%
Distance to transportation (km)	+15.1%
Cost per kilometer (dinars/km)	-44.8%
Access time to transportation (minutes)	+42.8%
Waiting time for the means of transport (minutes)	+20.0%
Time budget (minutes)	+6.5%
Average duration of each trip (minutes)	+30.4%
Hourly cost (dinars/hour)	-57.8%

Tab.7 Summary of the variable's variation between women and men

When it comes to economic status, limited income puts women in the Sahel at a disadvantage. This limitation forces them to walk and use mostly poor transport services, forcing them to endure the misbehavior of drivers

and to confront the security issues they encounter. As financial wealth increases, women tend to have a driver's license and own their own car. Improving financial conditions leads to greater choice of transportation options, easier access to transportation in time and space, greater affordability, and even less time spent on transportation for females in our study area.

These results highlight the position of women in the Tunisian transport sector, which is mainly linked to the socio-cultural context and Tunisian consciousness, and consider them as an essential research target whose mobility patterns must be carefully taken into account when drafting urban policies and public decisions. Expanding our study can integrate a more detailed analysis of the socio-cultural perspectives in which women live by opting even for a finer spatial scale involving country delegations. The analysis of mobility practices in relation to gender, taking into account other socio-demographic characteristics such as age or socio-professional status or other criteria related to the transport system such as security or even public investment, represents an interesting axis that can be carried out in a developing country such as Tunisia.

References

Abbott, P. (2017). Gender Equality and MENA Women's Empowerment in the Aftermath of the 2011 Uprisings. SSRN *Electronic Journal*. https://doi.org/10.2139/ssrn.2902890

Abdullah, A., Ababio-Donkor, A., & Adams, C.A. (2022). Gender Disparities in the Access and Use of Urban Public Transport in Abuja, Nigeria. *Sustainability, 14,* 5219. https://doi.org/10.3390/su14095219

Adeel, M., Yeh, A. G. O., & Zhang, F. (2017). Gender inequality in mobility and mode choice in Pakistan. *Transportation, 44* (6), 1519–1534. https://doi.org/10.1007/s11116-016-9712-8

Adom-Asamoah, G., Amoako, C., & Adarkwa, K. K. (2020). Gender disparities in rural accessibility and mobility in Ghana. *Case Studies on Transport Policy, 8* (1), 49–58. https://doi.org/10.1016/j.cstp.2019.12.006

Alizadeh, H. & Sharifi, A. (2023). Analyzing Urban Travel Behavior Components in Tehran, Iran. *Future Transportation, 3,* 236–253. https:// doi.org/10.3390/futuretransp3010014

Babinard, J. (2011). World Bank gender transport surveys: an Overview. Retrieved from: http://documents.worldbank.org/curated/en/480331468325770198/World-Bank-gender-transpor t-surveys-an-overview

Basaric, V., Vujicic, A., Mitrovic, J.S., Bogdanovic, V., & Saulic, N. (2016). Gender and age differences in the travel behavior – a Novi Sad case study. *Transportation Research Procedia*, 14, 4324–4333. https://doi.org/10.1016/j.trpro.2016.05.354

Bellmann, F., Ypma, L., & Polack, D. (2020). Women move differently - what everyone working in mobility should know. Retrieved from World Economic Forum Web site: https://www.weforum.org/agenda/2020/01/mobility-in-2020-a-female-perspective/

Boarnet, M.G. & Hsu, H.P. (2015). The gender gap in non-work travel: the relative roles of income earning potential and land use. *Journal of Urban Economics*, 86, 111–127. https://doi.org/10.1016/j.jue.2015.01.005

Boisjoly, G. & Yengoh, G.T. (2017). Opening the door to social equity: Local and participatory approaches to transportation planning in Montreal. *European Transport Research Review*, 9, 1–21. https://doi.org/10.1007/s12544-017-0258-4

Brown, D., McGranahan, G., & Dodman, D. (2014). Urban informality and building a more inclusive, resilient and green economic. *IIED, London*. 0.13140/RG.2.2.31381.32483

Chen, X., Hao, Y., Duan, Y., Zhang, Q., & Hu, X. (2023). Gender and Culture Differences in Consumers' Travel Behavior during the COVID-19 Pandemic. *Sustainability, 15,* 1186. https://doi.org/10.3390/su15021186

Chidambaram, B. & Scheiner, J. (2023). The gender dimensions of travel time use in Germany. *European Transport Research Review 15:1*. https://doi.org/10.1186/s12544-023-00574-5

CODATU Research (2017). Mobilité urbaine et genre en Tunisie: Quelle place pour la femme dans le transport en 2017? https://www.codatu.org/actualites/mobilite-urbaine-et-genre-en-tunisie-quelle-place-pour-la-femme-dans-le-transport-en-2017/

Cook, N., & Butz, D. (2018). Gendered mobilities in the making: moving from a pedestrian to vehicular mobility landscape in Shimshal, Pakistan. *Social & Cultural Geography, 19* (5), 606-625. https://doi.org/10.1080/14649365.2017.1294702

Craig, L. & Powell, A. (2013). Non-parental childcare, time pressure and the gendered division of paid work, domestic work and parental childcare. *Community, Work and Family, 16* (1), 100-119. https://doi.org/10.1080/13668803.2012.722013

Craig, L. & van Tienoven, T. P. (2019). Gender, mobility and parental shares of daily travel with and for children: a cross-national time use comparison. *Journal of Transport Geography, 76,* 93–102. https://doi.org/10.1016/j.jtrangeo.2019.03.006

Delatte, A., Baouni, T., Belwal, R., Daou, L., Gourram, D., Iman, R., Zitoun, M.S., & Smadi, A. (2018). Understanding the needs of MENA public transport customers: culture of service and gender responsive recommendations. *TeMA - Journal of Land Use, Mobility and Environment*, *7–30*. https://doi.org/10.6092/1970-9870/5458

Delbosc, A. & Currie, G. (2011). The spatial context of transport disadvantage, social exclusion and well-being. *Journal Transport Geography, 19,* 1130-1137. https://doi.org/10.1016/j.jtrangeo.2011.04.005

Dingil, A.E., Rupi, F., & Esztergar-Kiss, D. (2021). An integrative review of socio-technical factors influencing travel decision-making and urban transport performance. *Sustainability, 13*, 10158. https://doi.org/10.3390/su131810158

Fan, Y. (2015). Household structure and gender differences in travel time: spouse/partner presence, parenthood, and breadwinner status. *Transportation*, *44* (2), 271–291. https://doi.org/10.1007/s11116-015-9637-7

Frändberg, L. & Vilhelmson, B. (2011). More or less travel: personal mobility trends in the Swedish population focusing gender and cohort. *Journal of Transport Geography, 19* (6), 1235–1244. https://doi.org/10.1016/j.jtrangeo.2011.06.004.

Gauvin, L., Tizzoni, M., Piaggesi, S., Young, A., Adler, N., Verhulst, S., Ferres, L., & Cattuto, C. (2020). Gender gaps in urban mobility. *Humanities and Social Sciences Communications 7 (1)*. https://doi.org/10.1057/s41599-020-0500-x

Gera, K. & Hasdell, P. (2020). The context and experience of mobility among urban marginalized women in New Delhi, India. *In Boess, S., Cheung, M. & Cain, R. (eds.), Synergy-DRS International Conference 2020,11-14 August, Held online*. https://doi.org/10.21606/drs.2020.161

Gekoski, A., Gray, J.M., Adler, J.R. & Horvath, M.A.H. (2017). The prevalence and nature of sexual harassment and assault against women and girls on public transport: an international review, *Journal of Criminological Research, Policy and Practice, 3* (1), 3- 16. https://doi.org/10.1108/JCRPP-08-2016-0016

Greed, C. (2019). Are we still not there yet? Moving further along the gender highway. *In C. L. Scholten & T. Joelsson (Eds.), Integrating gender into transport planning: From one-to-many tracks* (pp. 25-42). Palgrave Macmillan. https://doi.org/10.1007/978-3-030-05042-9_2

Hanson, S. (2010). Gender and mobility: new approaches for informing sustainability. *Gender, Place & Culture, 17* (1), 5-23. https://doi.org/10.1080/09663690903498225

Havet, N., Bayart, C., & Bonnel, P. (2021). Why do gender differences in daily mobility behaviours persist among workers? *Transportation Research Part A: Policy and Practice, 145*, 34–48. https://doi.org/10.1016/j.tra.2020.12.016

Heinen, E. (2016). Identity and travel behaviour: A cross-sectional study on commute mode choice and intention to change. *Transportation Research Part F: Traffic Psychology and Behavior*, *43,* 238–253. https://doi.org/10.1016/j.trf.2016.10.016

Hidayati, I., Tan, W., & Yamu, C. (2020). How gender differences and perceptions of safety shape urban mobility in Southeast Asia. *Transportation Research Part F: Traffic Psychology and Behaviour, 73,* 155–173. https://doi.org/10.1016/j.trf.2020.06.014

Hitman, G. (2018). Arab Spring Era: Winds of Change in the Direction of Gender Equality for Tunisian Women: Arab Spring Era. *Digest of Middle East Studies 27, nº 2: 168-84*. https://doi.org/10.1111/dome.12137

Howe, L.B. (2022). The Gender–Poverty–Mobility Nexus and the Post-Pandemic Era in South Africa. *Urban Planning*, 7, issue 3, 35-48. https://doi.org/10.17645/up.v7i3.5463

INS (Institut National de la Statistique) (2014). Recensement Général de la Population et de l'Habitat: Principaux Indicateurs. Retrieved online from https://www.ins.tn/publication/recensement-general-de-la-population-et-de-lhabitat-2014-principaux-indicateurs

INS (Institut National de la Statistique) (2019). Indicateurs de l'emploi et du chômage : Quatrième trimestre 2019. Retrieved from: https://www.ins.tn/publication/indicateurs-de-lemploi-et-du-chomage-quatrieme-trimestre-2019#:~:text=Le%20nombre%20de%20ch%C3%B4meurs%20estim%C3%A9,au%20troisi%C3%A8me%20trimestre%20de%202019

Iqbal, S., Woodcock, A., & Osmond, J. (2020). The effects of gender transport poverty in Karachi. *Journal of Transport Geography*, 84, 102677. https://doi.org/10.1016/j.jtrangeo.2020.102677

Jain, J., Line, T., & Lyons, G. (2011). A troublesome transport challenge? Working round the school run. *Journal Transport Geography*, *19,* 1608–1615. https://doi.org/10.1016/j.jtrangeo.2011.04.007

Jain, D. & Geetam, T. (2020). Gender and Income Based Variability in Travel Choices in Vishakhapatnam, India. *Transportation Research Procedia*, *48,* 2870–2890. https://doi.org/10.1016/j.trpro.2020.08.232

Joshi, S. & Bailey, A., (2023). What happens next? Exploring women's transport motility through the story completion method. *Journal of Transport Geography, 107,* 103547. https://doi.org/10.1016/j.jtrangeo.2023.103547

Kacharo, D. K., Teshome, E., & Woltamo, T. (2022). Safety and security of women and girls in public transport. *Urban Planning and Transport Research, 10* (1), 1-19. https://doi.org/10.1080/21650020.2022.2027268

Kallander, A.A. (2021). Tunisia's Modern Women: Nation Building and State Feminism in the Global 1960s. *Cambridge University Press, Cambridge*. https://doi.org/10.1017/9781108961264

Kashina, A. (2021). Gender Equality In Tunisia: Current Trends. *Journal of Social Sciences Transformations & Transitions*. https://doi.org/10.52459/josstt1140721

Kawgan-Kagan, I. (2020). Are women greener than men? A preference analysis of women and men from major German cities over sustainable urban mobility. *Transportation Research Interdisciplinary Perspectives 8, 100236*. https://doi.org/10.1016/j.trip.2020.100236

Kett, M., Cole, E., & Turner, J. (2020). Disability, mobility and transport in low- and middle-income countries: a thematic review. *Sustainability 12* (2), 589. https://doi.org/10.3390/SU12020589

Kim, C., Sang, S., Chun, Y., & Lee, W. (2012). Exploring urban commuting imbalance by jobs and gender. *Applied Geography, 32* (2), 532–545. https://doi.org/10.1016/j.apgeog.2011.07.001

King, J., King, M., Edwards, N., Carroll, J.A., Watling, H., Anam, M., Bull, M., & Oviedo-Trespalacios, O. (2021). Exploring Women's Experiences of Gender-Based Violence and Other Threats to Safety on Public Transport in Bangladesh. *International Journal for Crime, Justice and Social Democracy, 10* (4), 158–173. 10.5204/ijcjsd.2086

Kwan, M.P. & Kotsev, A. (2015). Gender differences in commute time and accessibility in Sofia, Bulgaria: a study using 3D geovisualisation. *Geographical Journal, 181* (1), 83–96. https://doi.org/10.1111/geoj.12080.

Law, R. (1999). Beyond 'women and transport': towards new geographies of gender and daily mobility. *Progress in Human Geography 23* (4), 567-588. https://doi.org/10.1191/030913299666161864

Lecompte, M. & Bocarejo, J. (2017). Transport Systems and their Impact on Gender Equity. *Transportation Research Procedia, 25,* 4245–4257. https://doi.org/10.1016/j.trpro.2017.05.230

Lee, A. (2017). Gender, everyday mobility, and mass transit in urban Asia. *Mobility in History 8, nº 1*. https://doi.org/10.3167/mih.2017.080110.

Levy, C. (2016). Routes to the just city towards gender equality in transport planning. In: Moser, C.O.N. (Ed.), Gender, Asset Accumulation and Just Cities: Pathways to Transformation. *Routledge, New York, pp. 135–150*.

Loukaitou-Sideris, A., & Ceccato, V. (2020). Sexual violence in transit environments: Aims, scope, and context. *In Transit Crime and Sexual Violence in Cities, 1st ed.; Routledge: Oxfordshire, UK, 3–11*.

Lucas, K., Van Wee, B., & Maat, K. (2016). A method to evaluate equitable accessibility: combining ethical theories and accessibility-based approaches. *Transportation 43* (3), 473–490. https://doi.org/10.1007/s11116-015-9585-2.

Macedo, M., Lotero, L., Cardillo, A., Menezes, R., & Barbosa, H. (2022). Differences in the spatial landscape of urban mobility: Gender and socioeconomic perspectives. *PLoS ONE 17* (3): e0260874. https://doi.org/10.1371 /journal.pone.0260874

Maciejewska, M., Marquet, O., & Miralles-Guasch, C. (2019). Changes in gendered mobility patterns in the context of the Great Recession (2007–2012). *Journal of Transport Geography, 79* (January), 102478. https://doi.org/10.1016 /j.jtrangeo.2019.102478

Mahadevia, D. & Advani, D. (2016). Gender differentials in travel pattern – the case of a mid-sized city, Rajkot, India. *Transportation Research Part D: Transport and Environment 44* (February), 292–302. https://doi.org/10.1016 /j.trd.2016.01.002

Maksim, H. (2011). Potentiels de mobilité et inégalités sociales : La matérialisation des politiques publiques dans quatre agglomérations en Suisse et en France. Thèse pour l'obtention de grade de docteur de l'Ecole Polytechnique Fédérale de Lausanne. Retrieved from https://core.ac.uk/download/pdf/147964152.pdf

McLaren, A. T. (2018). Parent–child mobility practices: Revealing 'cracks' in the automobility system. *Mobilities, 13* (6), 844–860. https://doi.org/10.1080/17450101.2018.1500103

McQuaid, R. & Chen, T. (2012). Commuting times – the role of gender, children and parttime work. *Research in Transportation Economics, 34* (1), 66–73. https://doi.org/10.1016/j.retrec.2011.12.001

Miralles-Guasch, C., Melo, M. M., & Marquet, O. (2016). A gender analysis of everyday mobility in urban and rural territories: From challenges to sustainability. *Gender, Place & Culture, 23* (3), 398-417. https://doi.org/10.1080/0966369X .2015.1013448

Motte-Baumvol, B., Bonin, O., & Belton-Chevallier, L. (2017). Who escort children: mum or dad? Exploring gender differences in escorting mobility among parisian dual-earner couples. *Transportation 44,* 139–157. https://doi.org/10.1007/s11116-015-9630-1

Murphy, E.C., Porter, G., Aouidet, H., Dungey, C., Han, S., Houiji, R., & Zaghoud, H. (2023). No place for a women: Access, exclusion, insecurity and the mobility regime in grand tunis. *Geoforum, 142, article 103753*. https://doi.org/10.1016 /j.geoforum.2023.103753

Nasrin, S. & Bunker, J. (2021). Analyzing significant variables for choosing different modes by female travelers. *Transport Policy 114,* 312-329. https://doi.org/10.1016/j.tranpol.2021.10.017

Nasrin, S. & Chowdhury, S. (2024). Exploring transport mobility issues and adaptive behavior of women in a developing country. *Transportation Research Interdisciplinary Perspectives, 23,* 100991. https://doi.org/10.1016/j.trip.2023.100991

Nillesen, E., Michael G., Micheline G., Ann-Kristin R., & Aline M. (2021). On the Malleability of Gender Attitudes: Evidence from Implicit and Explicit Measures in Tunisia. *World Development 138 (2021): 105263*. https://doi.org/10.1016 /j.worlddev.2020.105263

Olivieri, C., & Fageda, X. (2021). Urban mobility with a focus on gender: The case of a middle-income Latin American city. *Journal of Transport Geography, 91, 102996*. https://doi.org/10.1016/j.jtrangeo.2021.102996

Onadja, Y., Atchessi, N., Soura, B. A., Rossier, C., & Zunzunegui, M. V. (2013). Gender differences in cognitive impairment and mobility disability in old age: A cross-sectional study in Ouagadougou, Burkina Faso. *Archives of Gerontology and Geriatrics, 57* (3), 311–318. https://doi.org/10.1016/j.archger.2013.06.007

Parker, A. & Rubin, M. (2023). Mobility intersections: Gender, family, culture and location in the Gauteng city-region. *Urban Forum 34:463-479*. https://doi.org/10.1007/s12132-022-09479-3

Pirra, M., Kalakou, S., Carboni, A., Costa, M., Diana, M., & Lynce, A.R. (2021). A preliminary analysis on Gender aspects in trabsport systems and mobility services: Presentation of a survey design. *Sustainability, 13,* 2676. https://doi.org/10.3390/su13052676

Pojani, D. (2011). Mobility, Equity and Sustainability Today in Tirana. *TeMA – Journal of Land Use, Mobility and Environment, 4* (2). https://doi.org/10.6092/1970-9870/248

Porter, G., Emma M., Saerom H., Hichem M., Hanen K., Claire D., Sam C., & Kim van der W. (2022). Improving Young Women's Access to Safe Mobility in a Low-Income Area of Tunis: Challenges and Opportunities Pre- and Post-Covid. *Transportation Research Procedia 60: 266-73*. https://doi.org/10.1016/j.trpro.2021.12.035

Pourhashem, G., Malichova, E., Piscova, T., & Tatiana, K. (2022). Gender Difference in Perception of Value of Travel Time and Travel Mode Choice Behavior in Eight European Countries. *Sustainability 14*. https://doi.org/10.3390/%0Asu141610426

Poussel, S. (2018). From 'Hitists' to Cyclists: Towards a Bicycle Revolution in Tunisia. https://www.cmimarseille.org/ blog/"hitists"-cyclists-towar ds-bicycle-revolution-tunisia.

Rodríguez De La Rosa, I., Gielen E., & Palencia Jiménez J.S. (2022). Relationships between Urban Form and Mobility: Gender and Mode of Transport. *In SUPTM 2022: 1st Conference on Future Challenges in Sustainable Urban Planning & Territorial Management. Universidad Politécnica de Cartagena, 2022*. https://doi.org/10.31428/10317/10584

Saigal, T., Vaish, A.K., & Rao, N.V.M. (2021). Gender and Class Distinction in Travel Behavior: Evidence from India. *Ecofeminism and Climate Change, 2* (1), 42–48. https://doi.org/10.1108/EFCC-09-2020-0030

Sánchez de Madariaga, I. (2013). The Mobility of Care. Introducing New Concepts in Urban Transport. In: *Fair Share Cities. The Impact of Gender Planning in Europe*. Ashgate, Aldershot-Nueva York, 49–69.

Sane, S. (2021). Addressing the urban planning gender divide: An analysis of urban transport and female mobility. Retrieved online from: https://repository.upenn.edu/entities/publication/9819f2c6-f3cb-4a74-952a-9e990772ca87

Scheiner, J. (2010). Social inequalities in travel behaviour: trip distances in the context of residential self-selection and lifestyles. *Journal of Transport Geography 18* (6), 679–690. https://doi.org/10.1016/j.jtrangeo.2009.09.002.

Scheiner, J. & Holz-Rau, C. (2012). Gendered travel mode choice: a focus on car deficient households. *Journal of Transport Geography, 24,* 250–261. https://doi.org/10.1016/j.jtrangeo.2012.02.011

Scheiner, J. (2014). Gendered key events in the life course: effects on changes in travel mode choice over time. *Journal of Transport Geography, 37,* 47-60. https://doi.org/10.1016/j.jtrangeo.2014.04.007

Scheiner, J. & Christian Holz-Rau, B. (2017). Women's complex daily lives: a gendered look at trip chaining and activity pattern entropy in Germany. *Transportation 44* (1), 117-138. https://doi.org/10.1007/s11116-015-9627

Senikidou, N., Basbas, S., Georgiadis, G., & Campisi, T. (2022). The Role of Personal Identity Attributes in Transport Mode Choice: The Case Study of Thessaloniki, Greece. *Social Sciences, 11,* 564. https://doi.org/10.3390/socsci11120564

Singh, Y.J. (2019). Is smart mobility also gender-smart? *Journal of Gender Studies, 29,* 1–15. https://doi.org/10.1080/09589236.2019.1650728

Sultana, N., & Mateo-Babiano, I. (2017). Transport Disadvantage and Gender Issues in South Asian Countries: A Systematic Literature Review. *Proceedings of the Eastern Asia Society for Transportation Studies, 11(December)*. Retrieved from https://www.researchgate.net/publication/321978068_Transport_Disadvantage_and_Gender_Issues_in_South_Asian_Countries_A_Systematic_Literature_Review

The New Arab (2023). Unpaid care work behind Tunisia's 'feminisation' of poverty. https://www.newarab.com/features/unpaid-care-work-behind-tunisias-feminisation-poverty.

Thynell, M. (2016). The quest for gender-sensitive and inclusive transport policies in growing Asian cities. *Social Inclusion, 4,* 72–82. https://doi.org/10.17645/si.v4i3.479

Uteng, T. P. (2011). Gender and mobility in the developing world. *World Development Report 2012*.

Uteng, T. P. & Turner, J. (2019). Addressing the linkages between gender and transport in low- and middle-income countries. *Sustainability, 11 (*17), 1-34. https://doi.org/10.3390/su11174555

Vanderschuren, M. J., Phayane, S. R., & Gwynne-Evans, A. J. (2019). Perceptions of gender, mobility, and personal safety: South Africa moving forward. *Transportation research record*, *2673* (11). https://doi.org/10.1177/0361198119854087

Vanderschuren M. J., Allen, H., Krause, Ph., & Lane-Visser, T. (2023). Lessons learnt through gender-based travel data collection and related sexual harassment in Sub-Saharan Africa. *Social Sciences & Humanities Open 7, 100442*. https://doi.org/10.1016/j.ssaho.2023.100442

World Bank (2012). Making transport work for women and men: Challenges and opportunities in the Middle East and North Africa. Lessons from case studies. Retrieved from: https://documents1.worldbank.org/curated/en/220381468278678436/pdf/841710WP0Gende0Box0382094B00PUBLIC0.pdf

World Bank (2022). Tunisia Data. *World Bank Data*, https://data.worldban.org/ indicator/SLUEM.TOTLZS?locations=TN.

World Economic Forum (2022). *Global Gender Gap Report: Insight Report 2022,* https:// www.weforum.org/reports/global-gender-pay-gap-report-2022 (WEF_GGGR_2022.pdf (weforum.org)

Xu, J. L. (2020). Generational trends of gendered mobility: How do they interact with geographical contexts? *Journal of Transport Geography, 82,* 102623. https://doi.org/10.1016/j.jtrangeo.2019.102623.

Zunzunegui, M. V., Alvarado, B. E., Guerra, R., Gómez, J. F., Ylli, A., Guralnik, J. M., Freeman, E. E., Karna, G., Deshpande, N., Garcia, A., Kotecha, J., Philips, S., Curcio, C. L., Freire, A., & Qirjako, G. (2015). The mobility gap between older men and women: The embodiment of gender. *Archives of Gerontology and Geriatrics, 61* (2), 140-148. https://doi.org/10.1016/j.archger.2015.06.005

Appendix

Appendix A-1: The questionnaire

Urban Mobility in the Tunisian Sahel Region

Respondents & Households

1. Gender
○ 1. Male ○ 2. Female

2. Age
○ 1. 15-19
○ 2. 20-29
○ 3. 30-39
○ 4. 40-49
○ 5. 50-59
○ 6. 60 et + (Specify) _____

3. Socio-professional category
○ 1. High school student
○ 2. Vocational training
○ 3. University student
○ 4. Farmer
○ 5. Craftsman
○ 6. Tradesman
○ 7. Liberal professions
○ 8. Company directors
○ 9. Public sector employee
○ 10. Private sector employee
○ 11. Public worker
○ 12. Private worker
○ 13. Retired
○ 14. Unemployed

4. Marital status
○ 1. Married ○ 2. Divorced ○ 3. Widow (er)
○ 4. Single

5. Specify the number of individuals in your household: ☐

6. Do you have a special status among this list?
☐ 1. Pregnant woman ☐ 2. M/F disabled
You can check several boxes.

7. What is your income?
○ 1. No income ○ 2. <=350 DNT ○ 3. 350-750 DNT
○ 4. 750-1050 DNT ○ 5. 1050-1400 DNT ○ 6. 1400-1750 DNT
○ 7. 1750-2100 DNT ○ 8. 2100-2450 DNT ○ 9. 2450-2800 DNT
10. +2800 DNT

8. Could you provide an estimate of your monthly household spending? ☐

9. You live in: ☐

10. What type of accommodation do you live in?
○ 1. Apartment ○ 2. House ○ 3. Studio
○ 4. Other (Specify)

11. Do you own or rent this property?
○ 1. Ownership ○ 2. Renting ○ 3. Other (specify)

12. If renting, please specify the rent in dnt: ☐

Mobility Conditions

13. Do you have a driver's license?
○ 1. Yes ○ 2. No

14. How many licensed drivers are in your household? ☐

15. Do you have a car?
○ 1. No ○ 2. Private car ○ 3. Rented
○ 4. Family car ○ 5. Other (Specify)

16. How many cars do you have in your household? ☐

17. Do you have access to the car when you need it?
○ 1. Yes ○ 2. Rarely ○ 3. Not at all

18. On average, how many trips do you make per day? ☐

Les besoins du transport

19. Which means of transport do you use most frequently?
☐ 1. Private car ☐ 2. 'Louage'
☐ 3. Collective cab ☐ 4. Bus
☐ 5. Individual cab ☐ 6. Train
☐ 7. Metro ☐ 8. Bicycle
☐ 9. Walking ☐ 10. Two wheels
☐ 11. other
You can check several boxes (5 amaximum).

20. How much do you spend on average each day to travel? ☐

21. Why do you choose this means of transport to travel?

- ☐ 1. Lack of alternative
- ☐ 2. Short trip (quick trip)
- ☐ 3. Lower cost
- ☐ 4. Sense of security
- ☐ 5. High reliability
- ☐ 6. Transport of luggage and bulky items
- ☐ 7. Others

You can check several boxes (4 maximum).

22. If money is not a limitation, what mode of transportation would you opt for?

- ○ 1. Private car
- ○ 2. 'Louage'
- ○ 3. Collective cab
- ○ 4. Bus
- ○ 5. Individual cab
- ○ 6. Train
- ○ 7. Metro
- ○ 8. Bicycle
- ○ 9. Walking
- ○ 10. Two wheels
- ○ 11. Others

23. Do you have a bus or metro pass?

- ○ 1. No
- ○ 2. Weekly
- ○ 3. Monthly
- ○ 4. Quarterly
- ○ 5. Half-yearly
- ○ 6. Annual

24. How often do you use prefered transportation per week?

- ○ 1. 1 day
- ○ 2. 2 days
- ○ 3. 3 days
- ○ 4. 4 days
- ○ 5. 5 days
- ○ 6. 6 days
- ○ 7. 7 (everyday)

25. What is the number of cancelled Trips due to lack of transport/week? ☐

Travel Features

26. For what reason/activity do you use transportation?

- ☐ 1. Work
- ☐ 2. Study
- ☐ 3. Training
- ☐ 4. Accompaniment
- ☐ 5. Health & care
- ☐ 6. Leisure
- ☐ 7. Everyday shopping
- ☐ 8. Administration
- ☐ 9. Professional affairs
- ☐ 10. Occasional shopping
- ☐ 11. Visits to worships places
- ☐ 12. Visiting family/friends
- ☐ 13. Others

You can check several boxes (6 maximum).

27. What was the average time in minutes to reach the chosen means of transport? ☐

28. What is the average distance in meters between your home and the nearest suitable transport station? ☐

29. What was the average waiting time in minutes for transportation means? ☐

30. Which of the following are you able to do?

- ○ 1. Walking for 1 km or less
- ○ 2. Cycling for 2 km or less
- ○ 3. Read and communicate in Arabic
- ○ 4. Read and communicate in French
- ○ 5. Speak in everyday language (for people other than Tunisian nationals)

31. Is transport in your area available? (1: not available --> 5: available)

○ 1.1 ○ 2.2 ○ 3.3 ○ 4.4 ○ 5.5

32. Do you find transport in the Sahel region easy to use? (1: not at all-->5: completely)

○ 1.1 ○ 2.2 ○ 3.3 ○ 4.4 ○ 5.5

33. How would you rate the cost of transport in the Sahel region? (1: not at all expensive --> 5: extremely expensive)

○ 1.1 ○ 2.2 ○ 3.3 ○ 4.4 ○ 5.5

34. Is the place where you take public transport well designed? (1: very badly designed --> 5: very well designed)

○ 1.1 ○ 2.2 ○ 3.3 ○ 4.4 ○ 5.5

35. Is the means of transport used safe? (1: not at all --> 5: absolutely)

○ 1.1 ○ 2.2 ○ 3.3 ○ 4.4 ○ 5.5

36. Does the means of transport used arrive on time? (1: not at all --> 5: absolutely)

○ 1.1 ○ 2.2 ○ 3.3 ○ 4.4 ○ 5.5

37. Is there a queue to access your means of transport? (1: not at all --> 5: absolutely)

○ 1.1 ○ 2.2 ○ 3.3 ○ 4.4 ○ 5.5

38. How would you rate the availability of your mean of transport? (1: availability problems --> 5: always available)

○ 1.1 ○ 2.2 ○ 3.3 ○ 4.4 ○ 5.5

39. Does the mean of transport used provide service to your final destination?

○ 1. Yes ○ 2. No

40. Would you find it necessary to make a physical effort to access a mean of transport? (1: not at all--> 5: absoletly)
○ 1.1 ○ 2.2 ○ 3.3 ○ 4.4 ○ 5.5

41. Do you find that transport in Sahel is accessible for all? (1: not at all-->5: absolutely)
○ 1.1 ○ 2.2 ○ 3.3 ○ 4.4 ○ 5.5

42. How easy is it to access information where you take public transport? (1: lack of information--> 5: available and accessible information)
○ 1.1 ○ 2.2 ○ 3.3 ○ 4.4 ○ 5.5

43. How secure is access to transportation in the Sahel region? (1: not at all secure --> 5: absolutely secure)
○ 1.1 ○ 2.2 ○ 3.3 ○ 4.4 ○ 5.5

44. Can you trust the transportation mode to get you to your destination on time? (1: not at all --> 5: absolutely)
○ 1.1 ○ 2.2 ○ 3.3 ○ 4.4 ○ 5.5

45. Are satisfied with public transport frequencies? (1: not at all --> 5: absolutely)
○ 1.1 ○ 2.2 ○ 3.3 ○ 4.4 ○ 5.5

Social Exclusion Indicators

46. What is your average monthly transport budget in dnt? ____

47. Which of the following activities do you take part in?
○ 1. Family visitis
○ 2. Sport
○ 3. Manifestations
○ 4. Politics Events
○ 5. Associations
○ 6. Visits of worship places
○ 7. Volunteer or charity groups
○ 8. Friends meetings
○ 9. Work
○ 10. Training
○ 11. Other (Specify)

48. What factors prevent you from participating in other activities?
○ 1. Lack of money
○ 2. Lack of time due to work
○ 3. Lack of time due to responsabilities (Specify these responsabilities)
○ 4. Can't go out because of responsabilities (Specify these responsabilities)
○ 5. No vehicule
○ 6. Poor quality of public transport
○ 7. No one to go out with (social)
○ 8. Physical access problems
○ 9. Too ill / sick / disabled
○ 10. Too old (must be assisted)
○ 11. Fear of personal attack/ burglary / vandalism
○ 12. Feeling unwelcome (ethnicity)
○ 13. Feeling unwelcome (age)
○ 14. Feeling unwelcome (gender)
○ 15. Feeling unwelcome (disability)
○ 16. Feeling unwelcome

49. Does transport in the Sahel region present a barrier to participation in the following activities? (Moderate limit to participation (ML)/ Severe limit to participation (SL)/ Stops me getting involved (PP)

○ 1. Work place _____	○2. High school/university _____
○ 3. Store _____	○4. Hospital _____
○ 5. Police station _____	○ 6. ATM _____
○ 7. Museum _____	○ 8. Cinema _____
○ 9. Social clubs _____	○ 10. Parcs _____
○ 11. The post office _____	○ 12. Library _____
○ 13. Associations _____	○ 14. Worship place _____

50. Does the increase in fuel price affect how often you use your car?
○ 1. Yes ○ 2. No

51. What prevent you from using public transport (more)?
○ 1. Crime
○ 2. Transport availability
○ 3. Transport prices
○ 4. Difficulties in accessing transport
○ 5. Parking problems (availability or cost)
○ 6. Personnel disability
○ 7. Age
○ 8. No accompanying person
○ 9. Other (Specify)

	What mean of transport do you use? (*)	For what reason/activity do you use this mean of transport? (*)	How do you estimate the journey distance in meters?	What was the average journey time in minutes?	If you use more than one transportation, how long was the transfer time?	WHt was the average diffusion time in minutes?
Trip 1						
Trip 2						
Trip 3						
Trip 4						
Trip 5						
Trip 6						
Trip 7						
Trip 8						
Trip 9						
Trip 10						

1. Private car (as driver)
2. Private car (as passengar)
3. "Louage"
4. Collective cab
5. Bus
6. Individual cab
7. Train
8. Metro
9. Bicycle
10. Walking
11. Two wheels
12. Other (Specify)

1. Home
2. Work
3. Study
4. Training
5. Accompaniment
6. Health and care
7. Leisure
8. Everyday shopping
9. Administration
10. Professional affairs
11. Occasional shopping
12. Visits of worship places
13. Visits of family/friends
14. Other (Specify)

For household members, please specify the number of individuals, their gender and age:

	Gender	Age
individual 1		
individual 2		
individual 3		
individual 4		
individual 5		
individual 6		
individual 7		
individual 8		
individual 9		
individual 10		

Appendix A-2: Starified sampling of the governorate of Sousse

Delegations	Sousse												Total
	15 - 19 years old		20 - 29 years old		30 - 39 years old		40 - 49 years old		50 - 59 years old		>=60 years old		
	Men	Women	Men	Women	Men	Women	Men	Women	Men	Women	Men	Women	
Sousse Medina	3	3	6	6	6	6	3	3	3	2	2	2	43
Sousse Riadh	4	4	9	7	7	7	6	6	3	4	3	3	63
Sousse Jawhara	4	4	10	10	9	10	7	7	6	6	6	6	83
Sousse Sidi Abedelhamid	4	3	6	7	6	6	4	4	3	3	2	3	50
Hammam Sousse	3	3	6	6	6	6	3	3	3	2	2	2	43
Akouda	2	2	5	5	5	5	4	3	3	3	3	3	43
Kalaâ Kebira	3	3	7	7	6	6	5	4	4	4	3	4	54
Sid Bou Ali	2	2	5	6	5	5	4	3	3	3	3	3	43
Hergla	2	2	5	5	4	5	4	3	3	3	3	3	43
Enfidha	2	2	6	6	5	5	4	4	3	3	3	3	46
Bouficha	2	2	5	5	5	5	4	3	3	3	3	3	43
Kondar	2	2	6	5	5	5	4	4	3	3	2	3	43
Sidi El Hèni	2	2	5	5	4	5	4	4	2	3	3	3	43
Msaken	5	5	10	12	9	11	7	8	6	6	5	6	90
Kalaâ Seghira	2	2	5	5	5	5	4	3	3	3	3	3	43
Zaouia Ksiba Thrayet	3	3	6	6	6	6	3	3	2	2	2	2	43
Total	47	45	101	103	90	95	67	66	52	52	47	51	816

Appendix A-3: The urban frame of the Sahel region

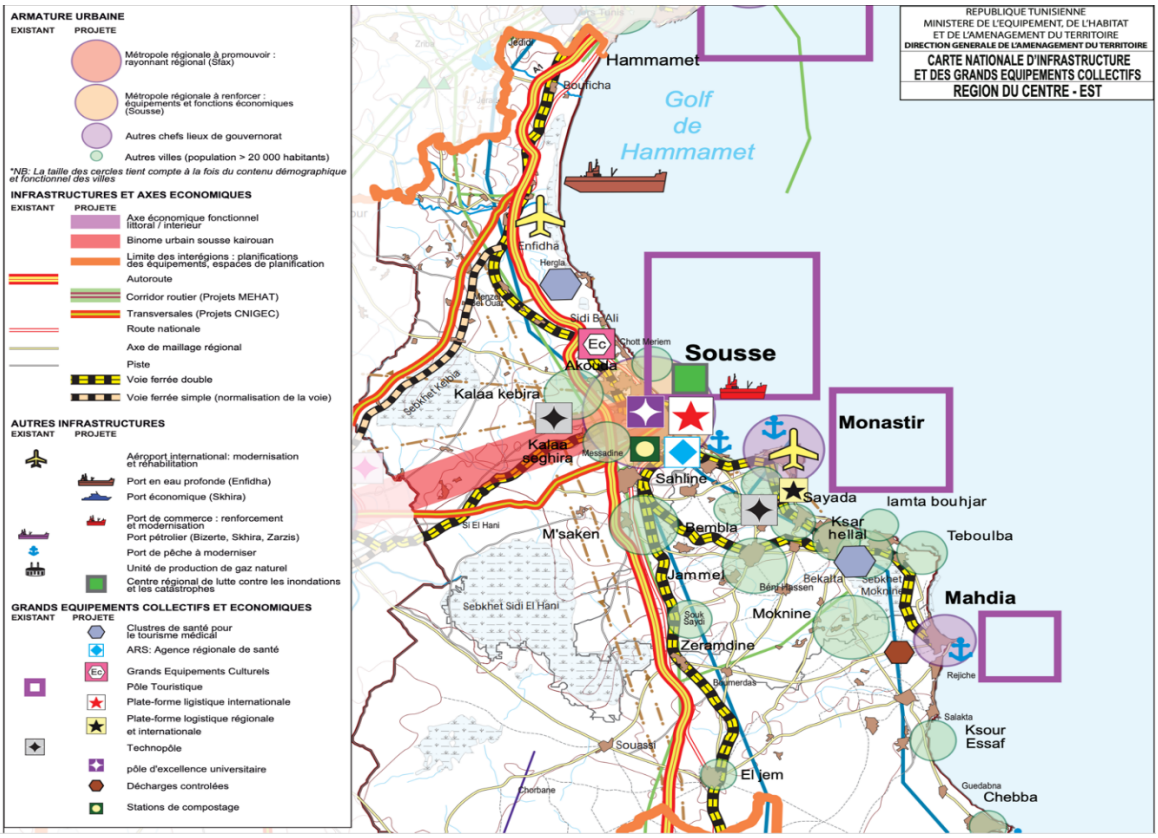


Image Sources

Fig.1: Personal elaboration;

Fig.2: Personal elaboration;

Author's profile

Mehdi El Kébir

Mehdi El Kébir holds two research masters' degrees. The first degree was obtained from the Higher Institute of Transport and Logistics of the University of Sousse and the second degree from the Higher School of Economics and Commercial Sciences of the University of Tunis. El Kébir has a multidisciplinary profile and is currently pursuing a PhD in Transport Studies and Regional Economics. He is interested in the vulnerability issues of mobility behavior and territorial studies. In his role as a temporary university assistant, he teaches tutorials and courses for undergraduate students. During his research career, he published two first papers (with three more in progress) and participated in half a dozen international symposia and indexed scientific conferences.

Aymen Ghédira

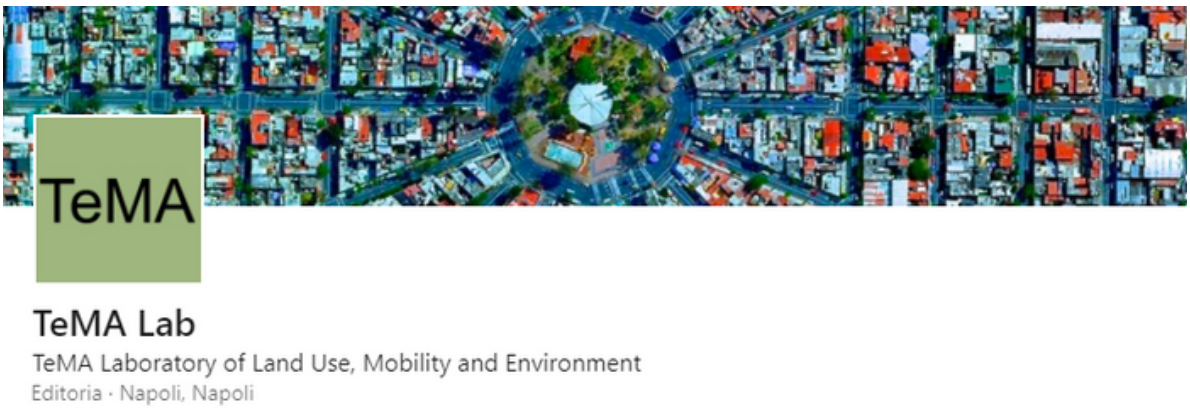
Aymen Ghédira is an urban transport modeler and planner who holds two PhDs from Grenoble Alps University (Territory Sciences) and University of Sousse (Public Management) and is an Associate Professor at the Higher Institute of Transport and Logistics. In addition to teaching urban and regional planning courses, he also teaches courses on sustainable mobility. Since 2010 he has been a visiting professor at the Polytechnic School of the ULB Brussels and gives seminars and training courses in transport management and logistics for international master's students. He is a member, co-founder and

coordinator of many territorial development organizations. He is also spokesman for the Tunisian School of Politics (TSoP), the Decentralization Training and Support Center (CFAD) and the Baladyia Seminar of the Robert Bosch Foundation GIZ. As project manager, Ghédira was, between 2018 and 2021 responsible for the integrated urban development program of Sousse in Tunisia, funded by Swiss State Secretariat for Economic Affairs (SECO), and covering urban planning (1), mobility and transport (2), energy efficiency (3) and GIS (4) areas. In his current position at Ingérop, he leads transport and mobility projects in the French context. A large number of his publications deal with public and political decision-making processes related to urban transport and local and regional development with an interdisciplinary and applied perspective.

We are online!

TeMA Lab

Follow us on LinkedIn



TeMA Lab and our Journal are on LinkedIn!
TeMA Lab is the Laboratory of Land Use, Mobility and Environment of the Department of Civil, Building and Environmental Engineering, at Università degli Studi di Napoli Federico II. Our field of expertise relates to urban systems, their complexity and the challenges that they will face in near future: adaptation to climate change, ageing population, energy consumptions, development of sustainable mobility and so on. Follow us to be constanly updated!.

www.linkedin.com/company/tema-journal/

TeMA Journal of Land Use, Mobility and Environment

TeMA 1 (2024) 51-70
print ISSN 1970-9889, e-ISSN 1970-9870
DOI: 10.6092/1970-9870/10338
Received 16th October 2023, Accepted 16th February 2024, Available online 30th April 2024

Licensed under the Creative Commons Attribution – Non Commercial License 4.0
http://www.serena.unina.it/index.php/tema

Towards the Spanish local urban agenda. The evolution of urban regeneration in Spain (2014-2022)

Federico Camerin[a]*, Lucas Álvarez Del Valle[b], Ana Díez Bermejo[c], Iván Rodríguez Suárez[d]

[a] Departamento de Urbanismo y Representación de la Arquitectura
Universidad de Valladolid, Valladolid, Spain
e-mail: federico.camerin@uva.es
ORCID: https://orcid.org/0000-0002-8659-3761
* Corresponding author

[b] Departamento de Urbanística y Ordenación del Territorio
Universidad Politécnica de Madrid, Madrid, Spain
e-mail: lucas.alvarez@upm.es
ORCID: https://orcid.org/0000-0003-4956-45471

[c] Departamento de Urbanística y Ordenación del Territorio
Universidad Politécnica de Madrid, Madrid, Spain
e-mail: ana.diez@upm.es
ORCID: https://orcid.org/0000-0001-8524-7501

[d] Departamento de Urbanística y Ordenación del Territorio
Universidad Politécnica de Madrid, Madrid, Spain
e-mail: ivan.rsuarez@upm.es
ORCID: https://orcid.org/0000-0002-9139-0280

Abstract
The paper provides an analysis of the difference in the tools adopted in the Spanish urban policies between the two last EU programming cycles (2014–2020 and 2021–2027). After an introduction with references to the policy framework and the literature, a methodological section describes the focus of the research, the source of the data and how this information has been used for the comparative purpose of the work. The following section (Results) provides the comparison of the contents of the policy documents delivered by the Spanish cities involved in the urban agenda, with reference to the type of actions selected, the overlapping of thematic and strategic focus through the two periods, the budget allocated, etc. In the conclusive sections the attempt is to highlights analogies and differences between the two policy periods, pointing out the future investigation needed to provide a more comprehensive outlook on the question addressed in the paper.

Keywords
Urban governance; Urban policies; Integrated sustainable urban development strategies; Spanish urban agenda

How to cite item in APA format
Camerin, F., Álvarez Del Valle, L., Díez Bermejo, A. & Rodríguez Suárez, I. (2023). Towards the Spanish local urban Agenda. The evolution of urban regeneration in Spain (2014-2022). *TeMA - Journal of Land Use, Mobility and Environment*, *17* (1), 51-70. http://dx.doi.org/10.6092/1970-9870/10338

1. Introduction

The policies and practices related to urban regeneration have sparked widespread debate regarding their approach, nature, and conceptual evolution over time (Roberts, 2000; Leary & McCarthy, 2013), as well as its impact and inconsistencies in shaping new urban spaces (Couch et al., 2011; Karadimitriou et al., 2013). Although the implementation of urban regeneration has followed similar patterns in Western countries, there are relevant differences at the national level, particularly in the European context (Zimmermann & Fedeli, 2021). Since the mid-1990s, the European Union (EU) has promoted an integrated vision that includes stakeholders in the decision-making process to establish collaborative and sustainable practices (Van Der Zwet et al., 2017; European Commission, 2020). Although the EU lacks competence in land use planning and urban policy, it holds sway over spatially relevant policies based on the EU Treaty's Article 3 commitment to promote economic, social, and territorial cohesion (Madeiros, 2019). As demonstrated by de Gregorio Hurtado (2017; 2018) and Navarro Yáñez (2020; 2023), European approaches and methods have gradually modified the Spanish framework for urban regeneration policies, which is one of the European countries lacking a well-defined state and regional framework to address urban regeneration (Marshall, 2005; Carpenter, 2013). This framework is periodized into three distinct phases that correspond with the programs implemented by the European Commission (Fig.1).

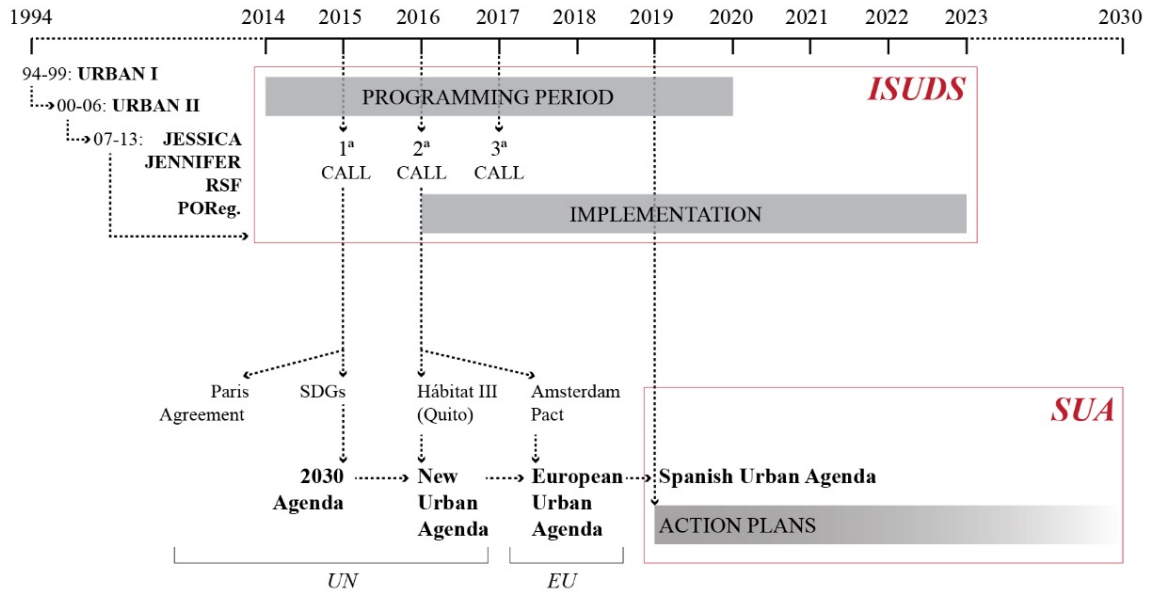


Fig.1 Timeline of Integrated Sustainable Urban Development Strategies (ISUDS) and Spanish Urban Agenda (SUA) and their respective antecedents

During the 1994-2006 programming period, disadvantaged neighborhoods underwent an initial phase of "integral" urban regeneration through the URBAN I and II programs. The approach then shifted to "integral urban development" in the second phase, with the aim of creating new competitive spaces through financial aid that supports sustainable investments in urban regions (Lang & Török, 2017). This includes programs such as JESSICA (Joint European Support for Sustainable Investment in City Areas) axis (Observatorio de la Vivienda Vasco, 2010) under the 2007–2013 URBANA Initiative. Eventually, the third – and current – approach focuses on the "sustainable urban development" of the Integrated Sustainable Urban Development Strategies (ISUDS, *Estrategias de Desarrollo Urbano Sostenible e Integrado* in Spanish). Urban regeneration became a part of the reference framework for broader urban development strategies through three calls for proposals in the 2014–2020 programming period, specifically in 2015, 2016, and 2017. The transition from an area-based approach to addressing urban vulnerability to one that prioritizes enhancing urban competitiveness is noteworthy. This

shift applies to both cities and urban areas, including conurbations and functional areas (Hernández Aja et al., 2021).

Furthermore, international treaties and agreements, such as the 2015 Paris Climate Agreement and the 2030 Agenda for Sustainable Development, which established 17 Sustainable Development Goals (SDGs), have bolstered a more comprehensive approach that encompasses the intricate socioeconomic, environmental, climate, and demographic aspects. Successively, this approach was emphasized by the New Urban Agenda, which arose from the 2016 United Nations Conference on Housing and Sustainable Urban Development "Habitat III" to promote sustainable development and address climate change. The EU subsequently put it into practice through its own Urban Agenda in 2016, underscoring its importance for adoption by the State Members (Caprotti et al., 2017; Olejnik, 2017). Spain is among the countries that launched its policy tool in 2019 (the Spanish Urban Agenda, SUA or AUE) to achieve the SDGs by 2030 through Action Plans (Hernández-Partal, 2023). What is noteworthy about the Spanish urban regeneration policy framework is that the ISUDS constituted the basis for the implementation of the SUA and the launch of urban agendas by Iberian municipalities, which represent the new action framework for urban regeneration (de la Cruz-Mera, 2019a: 682-683).

This paper aims to examine the relationship between ISUDS and SUA, deciphering this new framework. ISUDS is approaching its end (2014-2020 programming period with funding until 2023), while SUA is still in its early stages since it started in 2019. The significance of understanding this connection lies in the fact that the approval of SUA adds value to proposals seeking to be included in the European funding of the 2021–2027 programming period. According to a recent national agreement, funding calls will consider positively the "instruments implemented in recent years, such as the Local Action Plans, which are guided by the Spanish Urban Agenda framework. The actions to be financed must be part of a strategy that promotes the transformation of the local reality in which they are located and sets sustainable development objectives to be achieved by the actions to be financed" (Gobierno de España, 2022: 120).

In the field of urban studies, this analysis holds potential relevance to update the current research for the following reasons. Firstly, it can provide novel insights into the interplay between governance, politics, and spatial planning (Purkarthofer, 2019; De Frantz, 2022) by investigating the relationship between the current implementation of the EU urban policies and the upcoming programming phase on a country-specific basis. Secondly, this inquiry can expand the knowledge of ISUDS. Academics have primarily analyzed the early implementation (de la Cruz-Mera, 2019a) and updates of this instrument in specific municipalities (Álvarez del Valle et al., 2022; Suárez-Rodríguez & Tomé-Fernández, 2023; Rodríguez-Escudero et al., 2023) based on two approaches. On the one hand, as operations for Europeanizing Spanish urban policies (de Gregorio Hurtado, Do Santos Coelho, & Baatti Boulahia, 2021) and, on the other hand, as a local instrument to promote urban regeneration processes and actions at national and regional levels (Rodríguez-Domenech & Cañizares Ruiz, 2023). Thirdly, understanding the relationship between ISUDS and SUA can provide a new comparative perspective to ISUDS, which has already been linked to urban vulnerability (Rodríguez Suárez et al., 2021) and sustainability indicators (Gómez Jiménez, 2017).

Furthermore, it is important to determine the synergies between ISUDS and SUA. The ISUDS are currently in the last phase of their implementation and are difficult to assess due to the lack of progress reports from involved entities and academics. This study can offer valuable insights for academics and stakeholders engaged in SUA implementation and generate novel perspectives for future programming and development of Urban Agendas elsewhere (Pirlone et al., 2017).

The paper includes the following sections. The Methodology (Section 2) explains the rationale and criteria used to compare ISUDS and SUA through 32 case studies and the synergies table proposed by the Spanish Ministry of Transport, Mobility and Urban Agenda (*Ministerio de Transportes, Movilidad y Agenda Urbana* in Spanish, MITMA). The Case Study Analysis (Section 3) explores the primary features of ISUDS and SUA

(Sections 3.1 and 3.2), while the Results (Section 4) compare their content (Section 4.1) and demonstrate their synergies (Section 4.2). The Discussion (Section 5) highlights the most relevant connections between these instruments with particular emphasis on the 32 case studies and their implication in the intertwining between governance, politics, and spatial planning. Finally, the Conclusion (Section 6) underlines the lessons learned, the limitation of this study, and future research lines.

2. Methodology

The starting point of this analysis was the following: the ISUDS is a concrete place-based tool promoted by the Spanish government for the territorial rebalancing of a city, while the SUA has a more holistic approach, translating broader European objectives at the national level and implementing them at the municipal level through Local Action Plans. In particular, the ISUDS requires local authorities to develop a detailed analysis of their territory. This analysis constitutes the preliminary step to defining local actions to implement in a specific sector of the municipality and has also been designated as the preliminary step to approving the Local Urban Agenda. Additionally, a comparison was made between ISDUS' Specific Objectives and SUA's Strategic Objectives as they are analogous. The former are macro objectives, which means that a municipality can take a series of actions but still fails to implement a social program, whereas the latter provides a rulebook and a wide range of action at the urban level.

The methodology consisted of a desk-based review of official documentation related to ISUDS and SUA programs, strategies, monitoring, and evaluation (if available) from 2019 to 2022 and involved three main steps.

An initial stage of this inquiry involved analyzing the contents of the ISUDS and SUA by reviewing official documents released by public authorities (Ministerio de Fomento, 2019; Red de Iniciativas Urbanas, 2015) and considering scientific studies published on both tools (Section 1). This formed the foundational basis for conducting a comparative analysis with the aim of comprehending the new features these instruments have brought to urban regeneration, with a particular emphasis on their similarities and differences (Sections 3.1 and 3.2).

The second step was to establish the connection between the Objectives of both tools based on the synergies table proposed by the MITMA itself (Hernández-Partal & de Santiago-Rodríguez, 2019: 837). This table connects the ISUDS' six Specific Objectives with the SUA's ten Strategic Objectives (Section 4.1). This choice relies on the fact that the synergies table is the official tool provided by MITMA to monitor ISUDS in the SUA, thereby facilitating the transition from ISUDS to SUA.

The third step entailed demonstrating the interplay between ISUDS and SUA by selecting 32 case studies, i.e. Spanish provincial capitals that implemented a municipal ISUDS and encompassed vulnerable statistical areas based on the 2011 Spanish Catalogue of Vulnerable Neighborhoods (*Catálogo de Barrios Vulnerables* in Spanish; Hernández Aja et al., 2021) (Section 4.2). This selection relies on two reasons. Firstly, the Spanish capital cities can be representative of the main ISUDS, which, in turn, have been mainly aimed to functional areas with a minimum population of 20,000. Secondly, the decision to only include capital cities affected by the presence of vulnerability highlights the shift from a sectoral-based approach in the programming period before 2014 and this study was explicitly commissioned by the MITMA to focus on how cities address social vulnerability. This phase relied on consulting the Implementation Plans of each of the 32 ISUDS to describe their main contents (i.e. Action Lines, Specific Objectives, and budget allocation) and classify the Action Lines, all of which was compared with the SUA's Strategic Objectives. Although each Action Line may be related to multiple SUA Strategic Objectives, it was determined that Action Lines would only be assigned to the Strategic Objective with the strongest connection. This decision influenced the evaluation of the cross-cutting nature of the approaches, considering the variations in the quantity and quality of action lines among the 32 case studies, which range from 5 (Murcia) to 24 (Badajoz).

3. Case study

3.1 Description and contents of ISUDS

The "Guidelines for Defining Integrated Sustainable Strategies for Urban Development during the 2014–2020 programming period" (Red de Iniciativas Urbanas, 2015) provide the foundation for designing ISUDS. The guidelines outline the fundamental principles that should inform the ISUDS, the parties responsible for their development, the mechanisms for their administration and assessment, and the steps involved in drafting the "Strategy Document". It is essential to note that the contents of ISUDS is highly regulated and has the following attributes (Alonso Ibáñez, 2017: 11):

- it is a detailed and organized document designed to plan and guide future actions;
- it serves as a strategic plan that involves prolonged consideration of the entire municipality;
- its focus is on establishing priorities by creating a precise selection and a hierarchy of objectives to accomplish;
- it is territorially-oriented as it targets areas with specific urban projects and actions;
- its takes a comprehensive approach, integrating various sectors including physical, environmental, urban, economic, social, and cultural aspects.

The ISUDS outlines its objectives in a strategic document, which comprises:

- an assessment on the current state of municipalities, including their assets, problems, and challenges. Additionally, a SWOT analysis is conducted to identify Specific Objectives (SO) and Action Lines (LA) that align with one of the four Thematic Objectives (TO) established in "Axis 12[1]: Integrated and Sustainable Urban Development" (see Tab.1);
- the details on the participatory processes occurred for establishing the ISUDS's contents, as well as the administrative resources available or planned to be established for its implementation.

Axis 12: Integrated and Sustainable Urban Development

Thematic Objective (TO)	Specific Objective (SO)
TO2. Enhancing access to, and use and quality of, ICT	SO.2.3.3 Strengthening ICT applications for e-government, elearning, e-inclusion, e-culture and e-health
TO4. Supporting the shift towards a low-carbon economy in all sectors	- SO.4.5.1 Promoting low-carbon strategies for all types of territories (especially urban areas), such as sustainable multimodal urban mobility and climate-change-related mitigation and adaptation measures - SO.4.5.3 Supporting energy efficiency, smart energy management and renewable energy use in public infrastructure, including in public buildings, and in the housing sector
TO6. Preserving and protecting the environment and promoting resource efficiency	- SO.6.3.4 Protecting, promoting and developing cultural and natural heritage in urban areas, particularly those affected by tourism, through: a. Rehabilitation of historic centers and other urban areas endowed with cultural heritage; b. Improvements for the conservation, protection and enhancement of cultural heritage. - SO.6.5.2 Taking action to improve the urban environment, revitalize cities, regenerate and decontaminate brownfield sites (including conversion areas), reduce air pollution and promote noise-reduction measures
TO9. Promoting social inclusion and combating poverty	- SO 9.8.2 Providing support for physical, economic and social regeneration of deprived communities in urban and rural areas

Tab.1 Thematic and specific objectives of Axis 12 - Sustainable and integrated urban development

[1] Spain included Axis 12 to be eligible for ERDF funds in response to the European 2020 Strategy, which considers cities important for contributing to achieve sustainable-oriented objectives.

In addition, the ISUDS must:

- adhere to a set of horizontal and cross-cutting principles outlined in the Spanish Partnership Agreement 2014-2020 (Gobierno de España – Ministerio de Hacienda, 2019). These principles include promoting genders equality and non-discrimination actions, sustainable development, accessibility, addressing demographic changes, and managing the impacts of climate change (European Union, 2013);
- implement a system of 22 indicators to evaluate the attainment level of the goals mentioned in the Sustainable Growth Operative Program 2014–2020 (Gobierno de España – Ministerio de Hacienda y Administraciones Públicas, 2013);
- initiate a communication strategy to apply throughout the phases of development, execution, tracking, and assessment.

Out of the 173 approved proposals (Ministerio de Hacienda y Función Pública, 2018), 32 cities were selected based on the application of the double criteria of having vulnerable areas and being a capital city. The territorial distribution of these cities (Fig.2) shows that 15 out of the 17 Autonomous Communities meet the established conditions (Navarra and Madrid does not). Among the Autonomous Communities that are not uniprovincial, Andalusia has the highest represention with its eight provincial capitals, followed by Castilla la Mancha (4 out of 5), the Valencian Community (3 out of 3), and Galicia (3 out of 4). On the contrary, Castile and Leon (2 out of 9), Catalonia (1 out of 4), and Aragon and the Basque Country (1 out of 3) have the lowest representation.

Fig.2 Localization of Spanish capital cities that adopted ISUDS

3.2 Description and contents of SUA

The SUA, like the EDUSI, is designed to be a non-regulatory strategic document that "is committed to a desirable urban model for the future. It seeks to support a new vision of urban planning" (Ministerio de Fomento, 2019: 15). The creation of this tool involved a wide-ranging participatory process with various working groups. Its aim was to provide a platform for the input of diverse public and private stakeholders invested in promoting sustainable development within Spanish urban areas (Ministerio de Fomento, 2019: 276).

This previous work had a significant impact on the SUA's contents of the SUA, which is divided into five sections. The first section evaluates the current state of the Spanish territory and identifies the main issues that affect the viability of the Spanish spatial planning model. The second section proposes an urban model focused on 10 strategic goals (refer to Fig.3) to achieve through specific objectives and corresponding action plans. The third section presents 72 qualitative and quantitative indicators to assist in conducting the SUA, as well as monitoring and revising its contents. The fourth section contains the Action Plan for the General State Administration, which offers detailed recommendations for state competencies. Three sheets are eventually distributed to all levels of public administration, private entities, civil society, and academia interested in developing their own action plan for their urban agenda "within the framework of their needs, capacities and expectations" (Ministerio de Fomento, 2019: 16). These sheets contain a questionnaire to assist in diagnosing assembly and identifying agents and action lines, a SWOT analysis to identify each of the strategic objective, and a tool that provides potential actions for achieving these objectives.

Fig.3 The SUA's Strategic Objectives

4. Results

4.1 Comparison between ISUDS and SUA

Tab.2 shows similarities and distinctions between ISUDS and SUA. Both tools have a strategic and non-normative character, incorporate diagnoses from a comprehensive standpoint, and organize objectives: ISUDS has 4 thematic objectives, while SUA has 10 strategic objectives). Additionally, both instruments provide an execution plan (ISUDS: Implementation Plan, SUA: Action Plan) and a system of indicators for monitoring and evaluating its implementation.

The main differences between the tools are related to their scope of involvement and the scale of intervention. The ISUDS is mainly intended for municipalities or groups of municipalities, whereas the SUA aims to impact all levels of government, including the General State Administration, Autonomous Communities, municipalities, and any other public or private entities that intend to incorporate the tool into their strategic vision. In comparison to the SUA, ISUDS offers a more far-reaching approach, as it involves identifying priorities and objectives based on diagnosis and defining a scope of action to propose more concrete actions. Moreover, ISUDS implements a communication strategy that enhances the dissemination of actions and fosters synergies between the municipality and citizens, which is not addressed in the SUA.

	ISDUS		**SUA**
Information	Integrated Sustainable Urban Development Strategies		Spanish Urban Agenda
Goal	Aimed at municipalities	≠	Aimed at national authorities, Autonomous Communities, Municipalities, and public and private entities
Scope	**Strategic and non-regulatory**	↔	**Strategic and non-regulatory**
	Comprehensive diagnosis	↔	**Diagnosis of the urban reality**
Objectives	**Thematic Objectives (Four of Axis 12: Sustainable and Integrated Urban Development)**	↔	**Rulebook of strategic objectives (SUA Framework)**
	Identification of priorities and objectives	x	
	Delimitation of the scope of action	x	
Type of plan	**Implementation Plan**	↔	**Action Plan**
Evaluation and monitoring	**System of 22 evaluation and monitoring indicators**	↔	**System of 72 evaluation and monitoring indicators**
	Communication Strategy	x	

Tab.2 Comparison of ISUDS' and SUA's contents

4.2 Analysis of the synergies between ISUDS and SUA

This section analyzes potential synergies between the Action Lines (AL) of ISUDS and the ten Strategic Objectives (SO) that structure the SUA. The analysis is organized according to Thematic and Specific Objectives (Tab.4) and utilizes the synergies table developed by MITMA (Tab.3) to identify areas of alignment and coordination between the two entities.

The analysis considers the variation of AL in different ISUDS, which ranges from 6 to 25 with an average of 14 AL per Strategy. The average budget is approximately 18.5 million euros and the expenditure per LA is around 1.5 million euros.

Table 4 displays the 32 Spanish capitals with ISUDS whose strategies refer to at least 5 of the 10 strategic objectives of the SUA, with an average of 7. Two contrasting situations provide a noteworthy piece of information. On the one hand, among the 5 ISUDS with the fewest objectives (5 out of 10), Teruel and Ciudad Real stand out for their lower transversality and higher number of ALs (16 and 10 respectively), while Murcia, Salamanca, and Castellón promoted 5, 6 and 7 ALs.

		ISUDS's Specific Objectives					
		SO 2.3.3 Local eGovern-ment and Smart Cities	**SO 4.5.1** Sustainable urban mobility	**SO 4.5.3** Improve energy efficiency and renewables	**SO 6.3.4** Protection and development of cultural and natural heritage	**SO 6.5.2** Revitalization of the urban environment	**SO 9.8.2** Social inclusion and the fight against poverty
SUA' s Strategic Objectives	**SO1** Rational use of land				•	•	
	SO2 Revitalize existing city		•	•		•	•
	SO3 Climate change effects			•			
	SO4 Sustainable resource management			•		•	
	SO5 Proximity and sustainable mobility		•				
	SO6 Social cohesion and equity						•
	SO7 Urban economy				•		•
	SO8 Access to housing						
	SO9 Digital innovation	•					
	SO10 Intervention and governance tools	•					

Tab.3 Table of synergies between ISUDS' Specific Objectives and SUA's Strategic Objectives

Region	City	ISUDS	Action Lines (AL)	Budget (€)	Average for LA
Murcia	Murcia	It Murcia: Innovación + Tradición	6	17,588,716	2,931,453
Castile and León	Salamanca	Más Tormes (Tormes+)	7	18,900,000	2,700,000
Valencia	Castelló de la Plana	Transforma Castelló	7	20,200,000	2,885,714
Andalusia	Granada	EDUSI Granda "De Tradición a Innovación"	8	18,750,000	2,343,750
Basque Country	Bilbao	EDUSI en el área de Zorrotzaurre	9	29,648,000	3,294,222
Castilla–La Mancha	Cuenca	Estrategia DUSI Cuenca 2022, La ciudad en red	9	18,750,000	2,083,333
Andalusia	Almería	EDUSI - Almería Ciudad Abierta	9	18,750,000	2,083,333
Castilla–La Mancha	Ciudad Real	Ciudad Real 2022, Eco-Integrador	10	18,750,000	1,875,000
La Rioja	Logroño	EDUSI La Villanueva	11	3,615,918	328,720
Andalusia	Cádiz	Cádiz 2020, Un proyecto de ciudad	11	15,874,000	1,443,091
Andalusia	Jaén	EDUSI Jaén Hábitat 2023	11	18,750,000	1,704,545
Andalusia	Córdoba	EDUSI-Córdoba	11	18,750,000	1,704,545
Canary Islands	Santa Cruz de Tenerife	Anaga en el Corazón	11	17,640,000	1,603,636
Andalusia	Málaga	EDUSI Perchel-Lagunillas	12	18,750,000	1,562,500
Castilla–La Mancha	Toledo	EDUSI Toledo	13	8,519,000	655,308
Valencia	Alicante	EDUSI Alicante Área Las Cigarreras	13	22,107,883	1,700,606
Galicia	Lugo	Muramiñae, De la muralla al Miño	13	18,750,000	1,442,308

Region	City	ISUDS	Action Lines (AL)	Budget (€)	Average for LA
Valencia	Valencia	EDUSI de Cabanyal - Canyamelar - Cap de França	13	30,000,450	2,307,727
Castile and León	León	León Norte – Barrios Entrevías	14	28,137,370	2,009,812
Castilla–La Mancha	Albacete	EDUSI de Albacete	15	18,750,000	1,250,000
Cantabria	Santander	Domus Santander	15	8,028,800	535,253
Catalonia	Barcelona	EDUSI-Eix Besòs	15	30,000,000	2,000,000
Andalusia	Sevilla	Estrategia DUSI Norte de Sevilla	16	18,750,000	1,171,875
Andalusia	Huelva	Huelva: Regeneración del Pulmón Verde y Social	17	16,862,250	991,897
Aragon	Teruel	EDUSI Teruel	17	10,000,000	588,235
Extremadura	Cáceres	CreaCeres	17	12,500,000	735,294
Asturias	Oviedo	Conectando Oviedo	18	12,885,150	715,842
Balearic Islands	Palma de Mallorca	Plan Litoral de Ponent	19	25,420,000	1,337,895
Galicia	Pontevedra	Más Modelo Urbano Pontevedra	21	18,750,000	892,857
Canary Islands	Las Palmas de Gran Canaria	El Cono Sur se renueva	22	17,629,993	801,363
Galicia	A Coruña	EidusCoruña, Unha cidade contigo	22	18,750,000	852,273
Extremadura	Badajoz	Ecosistema DUSI Badajoz	25	18,750,000	750,000
	Average		**14**	**18,415,860**	**1,540,075**

Tab.4 List of the case studies with ISUDS

At the opposite extreme, Cordoba, Valencia, and Seville launched respectively 11, 12, and 16 ALs, respectively, related to up to 9 of the 10 strategic goals of the EUA. These data suggest that the transversality of the strategy is not strictly conditioned by the number of ALs if an ISUDS starts with a minimum number of ALs (at least 9 or 10).

The distribution of the ALs of each ISUDS among the strategic goals of the EUA is well-balanced. In only in a few cases, where strategies have a significant number of ALs, is there a greater concentration in one objective. These cases are as follows: Oviedo has 8 out of 17 ALs (47.1%) and Granada has 3 out of 8 ALs (38.0%) related to "SO2 Avoiding dispersion and revitalize existing city"; Caceres has 5 out of 17 ALs (29.4%) related to "SO5 Proximity and sustainable mobility"; Badajoz has 7 out of 24 ALs (29.1%) linked to "SO6 Social cohesion and equity"; and Teruel has 5 out of 16 ALs (31.3%) related to "SO9 Digital innovation".

Figure 4 illustrates the SUA's Strategic Objectives. It is noticeable that the "SO2: Revitalize the existing city" has the largest presence in most of the ISUDS both in terms of ALs (67, 16.4%) and budget (€108,730,290, 18.9%). The SO2 is linked to several ALs in 28 out of the 32 ISUDS. This objective is present in more than one LAs of 21 ISUDS and it is the objective with the greatest presence in 15 ISUDS (it stands out in Oviedo with 8 out of 17 LAs).

The comparison also reveals two main differences. Firstly, there are variations between the objectives with higher scores in terms of the number of ALs. "SO9 Digital Innovation" has the second-highest number of ALs (64 ALs, corresponding to 15.7%), followed by "SO5 Proximity and sustainable mobility" (59, corresponding to 16.0%). Following closely behind is "SO7 Urban economy" (55, corresponding to 13.5%), and "SO6 Social cohesion and equity" (50, corresponding to 12.3%). The second point concerns the differences between objectives that are associated with a larger budget. SO5 ranks third in the number of AL, but it has the highest

budget score (16.0%), followed by "SO1 Rational Use of Land" (15.5%). "SO6 Social cohesion and equity" and "SO9 Digital Innovation" have slightly lower percentages (11.3% each).

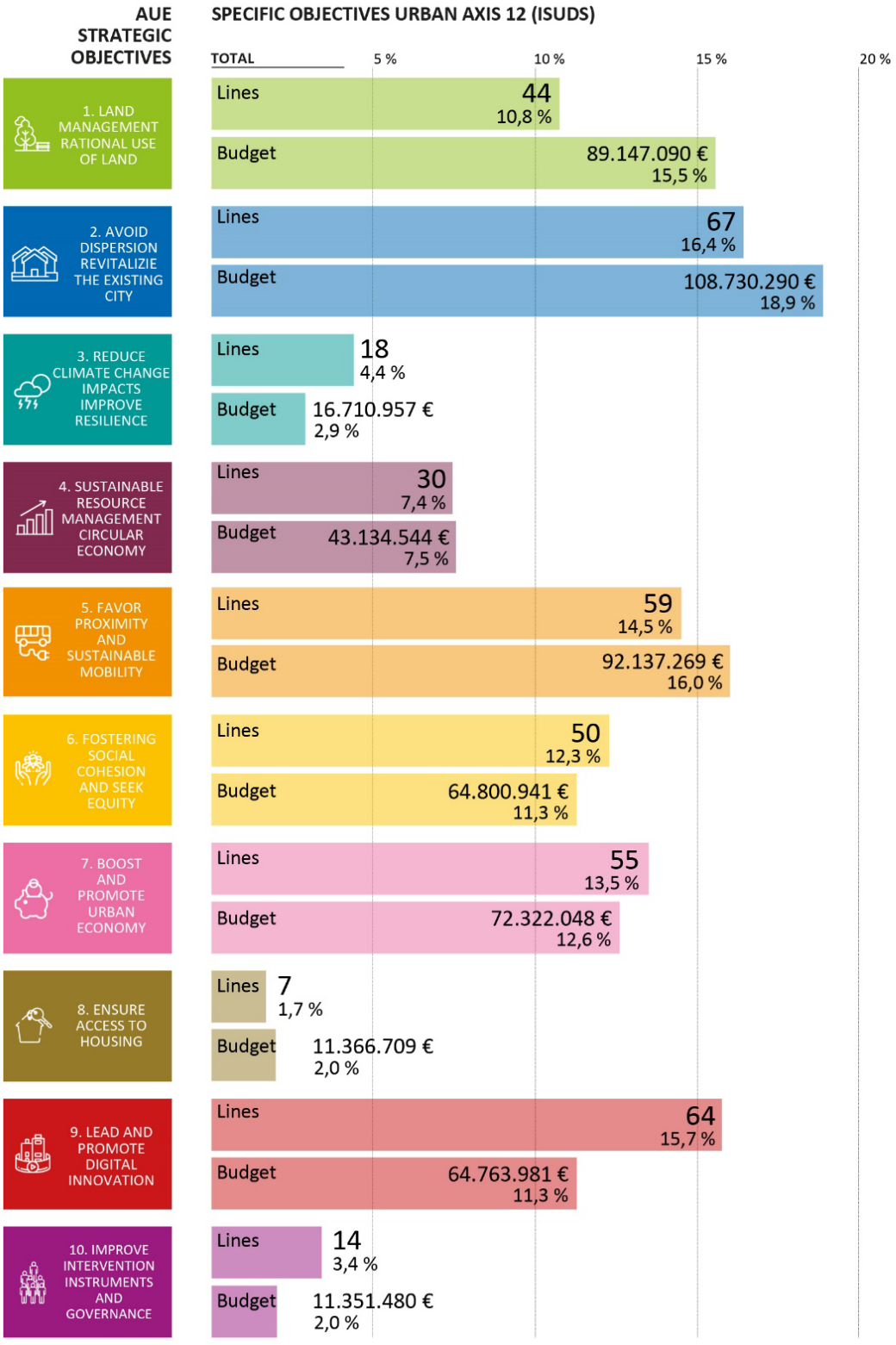


Fig.4 Relationship between the SUA's Strategic Objectives with the ISDUS according to the number of LAs (with data in percent) and budget (with data in percent) of the ISDUS Implementation Plans

Overall, there is a certain diversity in of ALs between the Specific Objectives that focus on physical-spatial and environmental issues and those related to social and economic issues. The relationship between ALs and budget is clear, with the former (SO1, SO2, SO5 and SO4) having a much higher budget, reaching up to 58%

of the total ISUDS budget. Moreover, the Strategic Objectives that have less relevance or connection to the ISUDS (i.e., "SO3 Climate change effects", "SO8 Access to housing", and "SO10 Intervention and governance instruments") exhibit no significant differences between the budget analysis and the number of ALs. SO3 is a broad objective and is therefore closely associated with other Strategic Objectives, making it is more linked to the outcomes of the actions rather than to the Strategic Objectives themselves. This characteristic has led to a significant number of ALs related to SO3 that may be associated with other objectives, such as SO5 or SO2. SO8 is strictly linked to fundable actions within the ISUDS. Consequently, physical rehabilitation of housing and access programs may not be considered eligible for funding in many cases. Eventually, SO10, along with SO9, is related to TO2. The actions aimed at improving access to, use and quality of information and communication technologies have almost no weight. The Thematic Objective's ALs have been focused on innovation aimed at innovation applied to social, economic and environmental dimensions, rather than governance.

5. Discussion

5.1 Correlation between ISUDS and SUA

The analysis of the synergies between ISDUS and SUA reveals that SUA's Strategic Objectives are closely tied to city revitalization, public spaces and facilities, and improvement of urban mobility ("SO1 Rational use of land", "SO2 Revitalize existing city", and "SO5 Proximity and sustainable mobility"), since they received the most funding, accounting for 50.4% of the budget. In contrast, the Strategic Objectives concerning the regeneration of the building stock ("SO3. Effects of climate change", "SO4. Sustainable management of resources", and "SO8 - Access to housing") have received the least amount of funding, totaling only 12.4%. Meanwhile, the ALs related to social and economic recovery ("SO6. Social cohesion and equity" and "SO7. Urban economy") are in an intermediate position with 23.9% of the total budget. Integrating digital innovation accounts for only 11.3% of the total budget, despite its numerous ALs.

The analysis shows that ISDUS is effective in achieving some of the EUA's Strategic Objectives but not as much as in others. While the model used is for integral diagnosis of urban problems, the European funding frameworks prioritize certain themes for direct investment (as seen in the Thematic Objectives of Axis 12 in Table 2), resulting in an imbalance in the fulfillment of the EUA's strategic objectives by ISUDS. This element allows for the municipal initiative to address the less targeted objectives, thereby achieving a balance in the content of the ISUDS, with the possibility for a future Municipal Action Plan to implement the SUA.

This analysis contributes to the understanding of the dynamics of rescaling of local and urban policies and governance which have received considerably less attention than regional levels (Mendez et al., 2021). It demonstrates that the EU's soft policy approach on discourse, knowledge and networking has gradually encouraged strategic planning and the development of thorough strategies based on different time horizons (2030 and 2050). This progress would not have been possible without the specific incipit by ISUDS and SUA and a distinguishing factor between the 2014–2020 and 2021–2027 periods is rescaling. Comprehensive city diagnoses are mandatory for the approval of ISUDS during the 2021–2027 period. The diagnosis is a strategic document that outlines a clear vision of the desired city. In the past, these diagnoses were only required for ISUDS approval. This modification enables municipalities to develop a more comprehensive action plan geared for effective planning, which is a direct result of implementing the SUA as the primary framework for creating local urban policies.

The synergies and discontinuities between the two programming periods depend on the relationship between national and local agendas. This relationship is intimately related to changes taking place in the Spanish context from political, administrative, and socio-economic standpoints. The 2014–2020 period was still suffering from the state-led austerity measures and was marked by a political shift from a right-wing to left-wing central

government in 2019. This change was also reflected in the regional elections. During this phase, urban social movements regained their importance as political actors and drivers of change and the New Municipalist platforms entered City Hall in 18 cities with more than 20,000 residents in 2015. However, they failed to revert the status quo and have been criticized for enabling a "reloaded" urban neoliberalization (Janoschka & Mota, 2021). The year 2020 was marked by the Covid-19 pandemic. In 2021, Spain's recovery and resilience plan aimed to promote a green transition, which has strongly influenced the contents of the 2021–2027 national urban policy. This plan has a stronger focus on urban development than in the past because it is closely linked to urban agendas and sustainable development goals (Pérez de las Heras, 2023). However, it has not been adequately addressed in terms of competitive performance, allocated resources (Sgambati, 2023), or the new frontiers of urban development and sustainability through the lenses of the European program NextGenerationEU (Franco, 2022; Gargiulo & Sgambati, 2023). Moreover, the significance of the SUA in the 2021–2027 programming period has increased in society due to the increasingly apparent consequences of climate change (Ministerio para la Transicción Ecológica y el Reto Demográfico, 2020). Notwithstanding this, even after the 2023 Spanish national elections, local politics, usually tied to right-wing parties, have shown resistance to the implementation of SUA. In some cities that changed from left- to right-wing parties, controversial decisions have been made, such as removing bike lanes (Tena, 2023).

5.2 The SUA in the 32 case studies

This analysis also aimed to determine whether an ISUDS was supported by its own Urban Agenda or Local Action Plan. Due to the SUA being in its early stages at the time of this research (December 2022), the majority of the analyzed cities analyzed had not yet started drafting an Urban Agenda (20 out the 32 cases, 62.5% of the sample). Eight cities (Almería, Málaga, Alicante, Valencia, Salamanca, A Coruña, Pontevedra, and Murcia) had already adopted a Local Urban Agenda, but had not yet approved it, while 4 cities (12.50%), Barcelona, Castelló, Logroño and Seville were in the process of formalizing their Local Urban Agendas. Barcelona was the only city among those without an approved tool that was developing its own Urban Agenda. The other cases were following the guidelines of the Local Action Plans tied to the Spanish Urban Agenda promoted by the MITMA. Cities with most of the work done towards the formalization of the tool have well-established urban strategies, as showed in the cases of Malaga (Marín-Cots, 2019) and A Coruña (Ayuntamiento de A Coruña, 2022) and, in some cases, had already formulated their 2030 strategies by the mid-2010s, as was the case of Seville (Ayuntamiento de Sevilla, 2022) and Murcia (Ayuntamiento de Murcia, 2022). Additionally, Valencia has already been working on "València 2030 Urban Strategy" since 2021 (Ajuntament de Vàlencia, 2023). This project was recognized by the Ministry as one of the pilot projects when the SUA was launched, along with A Coruña. However, Salamanca and Logroño lacked a consolidated urban strategy, resulting in a delayed process for drafting their Action Plans, whose approval occurred respectively in September 2022 and January 2023 (Ayuntamiento de Salamanca, 2022; Ayuntamiento de Logroño, 2023).

This analysis demonstrated that at the Spanish level, the SUA seems to be the Spanish translation of the EU Urban Agenda's intention to exert soft influence on the hard legal and funding instruments, as a confirmation of the international discourse on the implementation of the European Urban Agenda at the broader European level (e.g., Atkinson and Zimmermann, 2016; Potjer et al., 2018; Vinci & Cutaia, 2019). Given the current and future challenges for resilience and sustainability, and the growing debate on degrowth (Schmelzer et al., 2022), the SUA has benefited from the experience of the ISDUS. It may serve as a pilot for the wider implementation of the UN-SDGs. However, as Marín-Cots pointed out (2019: 797-798), there is a real risk that the SUA may not be followed as a model by public and private leaders due to its a non-normative character.

Thematic Objectives (TO)	Action Lines	Projects	Budget
OT 2 Improving access, use and quality of ICT	AL9 Development and improvement of ICT for sustainable mobility	Upgrading and virtualization of the Millennium card	€199,581
		Urban Mobility Portal	€163,000
		ICT equipment for assisted mobility	€596,996
	AL10 Development ICT tools for tourist mobility	On-line ticket reservation and capacity control system	€105,270
		Digital platform for tourist information	€218,337
	AL20 ICT-based energy monitoring of city neighborhoods	ICT-based energy monitoring of city neighborhoods	€432,000
	AL21 Development ICT tools for citizen participation-awareness	Multi-platform citizen app	€160,415
		Environmental Quality Information System	€221,947
		LED Displays for the Environmental Information System	€34,700
TO 4 – Promoting a low-emission economy	AL11 Program for the promotion of walking mobility	Redevelopment of Nuestra Señora del Rosario Street	€669,254
		Pedestrian access to the Pocomaco industrial park from Birloque	€352,557
		Urbanization of Cortaduría Street	€249,350
		Redevelopment of Victoria Fernández Street	€215,063
		Redevelopment of the final section of Ramón Cabanillas Street	€132,430
	AL13 Promoting and expanding school routes	Promoting and expanding school routes	€179,256
	AL14 Program to promote bicycle mobility	Mariscal Pardo de Cela bike lane	€141,665
		Supply and installation of readers, modules, stations and bicycles	€1,792,030
		bike lane between Elviña traffic circle and Pablo Picasso Avenue	€239,380
	AL15 New bus shelter models for urban bus transportation	Interactive bus shelter for urban bus transportation	€240,000
	AL17 Substitution of polluting luminaires, regulation and lighting sunlight	Modernization of lighting in different roads of the city	€320,254
TO 6 – Protecting the environment and resource efficiency	AL1 Naturalizing, humanizing and equipping socially key urban spaces	Restoration of the San Carlos Garden	€310,516
	AL2 Memory of the coastal and fluvial border: recovery of enclaves and watercourses	Improving accessibility and use of the beaches	€145,176
		Bird observatory at O Portiño	€43,345
		Atlantic slow-mobility path	€25,000
	AL3 Restoration of sites of tourist, cultural and environmental interest	Various improvements at the San Amaro Cemetery	€296,611
		Improvement of the third department of the San Amaro Cemetery	€292,300
		Recovery of traditional roads	€159,584
		Creation of the Breogán Forest	€195,682
		Improvement of the second department of the San Amaro Cemetery	€125,423
	AL4 Creation of urban gardens within the city	Urban vegetable gardens in the Adolfo Suarez Park	€293,728
	AL5 Improving industrial park's surroundings	Redevelopment of Severo Ochoa Street	€791,900
TO 9 – Social inclusion and the fight against poverty	AL22 Boosting employability and reducing gender digital divide through ICT tools	Complete renovation of building for municipal civic center in O Birloque (still ongoing in late January 2024)	€797,919
	AL26 Map of the city's fairgrounds and their equipment	Provision of equipment for the realization of fairs and markets	€334,956
	AL27 Refurbishment and commercial activation of urban markets	Renovation of the Adormideras market	€1,507,241
		Redevelopment of the outdoor area of the San Agustín market	€619,520

Thematic Objectives (TO)	Action Lines	Projects	Budget
	AL30 Social and labor inclusion and employability measures for sectors at risk of social exclusion	Refurbishment of the Garcia Sabell association center	€622,669
	AL33 Recovery and management of disused public parks for the young	Renovation of the Plaza José Toubes pavilion to create the new youth space "O Remanso"	€359,140

Tab.5 List of the completed projects planned within ISUDS in A Coruña

The extent to which planning strategies in Spanish urban areas address real issues beyond labels such as 'Urban economy', 'Sustainable mobility', 'Smart city', and others has not been adequately addressed at the national level. However, there is limited research on a single case-study basis that demonstrates how the funding was implemented through the provision of new public equipment or its amelioration and retrofitting. These improvements were devoted to a range of scopes, from social aggregation to sport, and included enhancements to mobility systems such as the installation of efficient lighting, green spaces, and urban furniture. This was demonstrated in the case study of A Coruña. As of late January 2024, 36 projects had been completed and one is currently ongoing (Tab.5).

However, not all projects funded under ISUDS have been successfully implemented. For instance, Obeso Muñiz (2023) demonstrated that Oviedo lost almost half of the European co-financing due to the lack of human resources, the rigidity of the call for proposals, the bureaucratic burden and the complexity of ISUDS management, which can be related to the political change from a left-wing to a right-wing party in the 2019 municipal election.

6. Conclusion

The current approach to sustainable urban development, driven by the EU Urban Agenda in the frame of SDGs, targets not only vulnerable urban sectors but also cities and/or metropolitan areas to enable wider urban development strategies that address multi-scale urban issues. As a result, two new approaches have emerged for channeling and developing urban regeneration actions and processes: the Integrated Sustainable Urban Development Strategies and the Spanish Urban Agenda. This research examines the relationship between SUA and ISUDS and elaborate a proposal for providing an up-to-date overview and monitoring of national urban regeneration policies. ISUDS encouraged a more comprehensive analysis at the municipal level and suggested an intervention area based on the need to address urban disparities, while SUA used the diagnosis developed by ISUDS to establish guidelines for sustainable urban development interventions.

This analysis adds the comparative dimension of these two instruments to the existing literature. It sheds light on the transition from ISUDS to SUA during the 2014–2020 and 2021–2027 programming periods and clarifies the differences from the pre-2014 programming approach. Previously, a precise urban area affected by vulnerability was the target, whereas now the delimitation is entrusted to the municipalities. ISUDS provides a comprehensive diagnosis at the municipal level, focusing on a neighborhood or a group of neighborhoods as the intervention area. In contrast, SUA does not specify any kind of delimitation for the intervention area but instead utilized the diagnostic component of ISUDS to develop a roadmap for sustainable urban development interventions. Therefore, ISUDS can be claimed as the tool originating SUA.

Future research should focus on the following elements. Firstly, in terms of governance, monitoring the results of forums for debate and exchange of good practices – including peer review workshops – performed by networks and observatories to better comprehend the decision-making process and improvements in shared learning and networking (Barreiro, 2017; Lacilla Larrodé et al., 2022). Secondly, regarding urban policies and politics, this paper suggests conducting a comparative analysis within and between the two tools approved on the targeting city, as suggested by recent insights provided at the Spanish regional level (Rodríguez-García &

Navarro Yáñez, 2023). Thirdly, and consequently, detecting the factors that influence the successful and failed implementation (such as proved in section 5.2 for the cases of A Coruña and Oviedo) to understand the missed opportunities and achieved targets for integrated territorial investment and to reduce cities and regional disparities within the European context (Tosics, 2017; Vinci, 2021). Eventually, in terms of spatial planning, it is necessary to determine whether ISUDS and/or SUA have resulted in changes to the municipal general master plans.

Acknowledgments

This work presents the results of the research "*InURBA: Metrópolis fracturadas. Vulnerabilidad, reequilibrio territorial e institucionalización de las estrategias de desarrollo urbano integrado. PID2019-108120RB-C33*", financed by "MICIU. Programa Estatal de I+D+i Orientada a los Retos de la Sociedad. Plan Estatal de Investigación Científica y Técnica y de Innovación 2017-2020. Agencia Estatal de Investigación. Convocatoria 2020." (2) Federico Camerin has participated as co-author within the research project "Urban Regeneration as a new version of Urban Renewal Programmes. Achievements and failures". This project is co-funded by Spanish Ministry of Universities, Recovery, Transformation and Resilience Plan, by the European Union – NextGenerationEU and Universidad de Valladolid.

Authors' contributions

Roles played by contributors according to CRediT taxonomy: Federico Camerin (FC): 25%; Lucas Álvarez del Valle LAV: 25%; Ana Díez Bermejo ADB: 25%; Iván Rodríguez Suárez IRS: 25% to research outputs: Conceptualization: FC; Data curation: IRS; Formal Analysis: LAV; Funding acquisition: ADB; Investigation: LAV; Methodology: ADB; Project administration: ADB; Resources: IRS; Software: IRS; Supervision: FC; Validation: LAV; Visualisation: FC; Writing – original draft: FC & LAV; Writing – review & editing: ADB and IRS.

References

Ajuntament de Vàlencia (2023). *València 2030 Urban Strategy. Documentation*. Retrieved from https://estrategiaurbanavlc 2030.es/documentation/

Alonso Ibáñez, R. (2017). Elementos clave de la financiación comunitaria del desarrollo urbano. La superación de la metodología de las iniciativas URBAN. *WPS Review International on Sustainable Housing and Urban Renewal*, 6(2), 6-12

Álvarez-Del-Valle, L., Camerin, F., Rodríguez-Suárez, I., & Fernández-Ramírez, C. (2022). "EidusCoruña. Unha cidade contigo": Estrategia de Desarrollo Urbano Sostenible Integrado de A Coruña. *Ciudad Y Territorio Estudios Territoriales*, 54(214), 1007-1016. https://doi.org/10.37230/CyTET.2022.214.11

Atkinson, R. & Zimmermann, K. (2016). Cohesion Policy and Cities: An Ambivalent Relationship?. In S. Piattoni & L. Polverari (Eds.). *Handbook on Cohesion Policy in the EU*, 413-426. Cheltenham: Edward Elgar

Ayuntamiento de A Coruña (2022). *A Coruña 2030 Plan para la Agenda Urbana*. Retrieved from https://acoruna2030. files.wordpress.com /2022/09/auac2030_castellano-web_compressed.pdf

Ayuntamiento de Logroño (2023). *Agenda Urbana Logroño Próximo. Plan de Acción*. Retrieved from https://wp.logrono proximo.org/app/uploads/2022/10/AU-LOGRONO_Plan-de-Accion-Nuevo.pdf

Ayuntamiento de Murcia (2022). *Agenda Urbana. Plan de Acción Murcia 2030*. Retrieved from https://www.estrat egiamurcia.es/upload/2022/09/AgendaUrbana_PlandeAccion2030.pdf

Ayuntamiento de Sevilla (2022). *Agenda Urbana de Sevilla 2030*. Retrieved from https://www.sevilla.org/ciudad/ planificacion-estrategica/plan-de-accion-de-la-agenda-urbana-2030

Ayuntamiento de Salamanca (2022). *Plan de Acción Local de la Agenda Urbana de Salamanca*. Retrieved from http://pmvu. aytosalamanca.es/es/docs/AUSA_Plan_accion_local_Mod_06-09-2022.pdf

Barreiro, F. (2017). *Urban development network in Spain (UDN).* Retrieved from https://ec.europa.eu/regional_policy/ sources/policy/themes/urban-development/udn_final_es.pdf

Caprotti, F., Robert Cowley, Ayona Datta, Vanesa Castán Broto, Eleanor Gao, Lucien Georgeson, Clare Herrick, Nancy Odendaal & Simon Joss (2017) The New Urban Agenda: key opportunities and challenges for policy and practice, *Urban Research & Practice*, 10(3), 367-378, https://doi.org/10.1080/17535069.2016.1275618

Carpenter, J. (2013). Sustainable Urban Regeneration Within the European Union: A case of 'Europeanization'? In M. E. Leary & J. McCarthy (Eds.), *The Routledge companion to urban regeneration*, 138-147, Routledge: New York-Oxon

Couch, C., Sykes, O. & Börstinghaus, W. (2011). Thirty years of urban regeneration in Britain, Germany and France: The importance of context and path dependency, *Progress in Planning* 75, 1–52 https://doi.org/10.1016/j.progress.2010.12,001

De Frantz, M. (2022). The Politics of the EU Urban Agenda: Mobilising the 'Right to the City' for European Governance?, *Urban Research & Practice*, *15(5)*, 655-678, https://doi.org/10.1080/17535069.2021.1896029

de Gregorio Hurtado, S. (2017). Is EU urban policy transforming urban regeneration in Spain? Answers from an analysis of the Iniciativa Urbana (2007–2013). *Cities 60*, 402-414. https://doi.org/10.1016/j.cities.2016.10.015

de Gregorio Hurtado, S. (2018). The EU urban policy in the period 2007–13: lessons from the Spanish experience. *Regional Studies, Regional Science, 5(1)*, 212-230. https://doi.org/10.1080/21681376.2018.1480903

de Gregorio Hurtado, S., Do Santos Coelho, V. & Baatti Boulahia, A. (2021). La Europeización de la política urbana en España en el periodo 2014-2020: análisis de las Estrategias de Desarrollo Urbano Sostenible Integrado (EDUSI). *CIUR Cuadernos de Investigación Urbanística*, 134. https://doi.org/10.20868/ciur.2021.134.4579

de la Cruz-Mera, Á. (Ed.) (2019a). *Monográfico 2019. La Agenda Urbana Española. Ciudad y Territorio. Estudios Territoriales Vol. 51 Núm. 202*. Madrid: MITMA

de la Cruz-Mera, Á. (2019). La Agenda Urbana Española. *Ciudad Y Territorio Estudios Territoriales*, 51(202), 675-686

European Commission (2020). *Handbook of Sustainable Urban Development Strategies*. Retrieved from https://publications.jrc.ec.europa.eu/repository/bitstream/JRC118841/handbook_of_sustainable_urban_development_strategies__pdf_2.pdf

European Union (2013). *Regulation (EU) No 1301/2013 of the European Parliament and of the Council of 17 December 2013 on the European Regional Development Fund and on specific provisions concerning the Investment for growth and jobs goal and repealing Regulation (EC) No 1080/2006*. https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=-CELEX:32013R1301&qid=1696176963059

Franco, S. (2022). Towards the achievement of SDGs: Evidence from European cities. *TeMA - Journal of Land Use, Mobility and Environment*, *15(1)*, 163-166. https://doi.org/10.6093/1970-9870/9047

Gargiulo, C., & Sgambati, S. (2023). The investments of NextGenerationEU vs urban competitiveness of Italian metropolitan areas. *TeMA - Journal of Land Use, Mobility and Environment*, *16*(3), 545-564. https://doi.org/10.6093/1970-9870/10271

Gobierno de España – Ministerio de Hacienda y Administraciones Públicas (2013). Programa Operativo de Crecimiento Sostenible 2014-2020. https://www.dgfc.sepg.hacienda.gob.es/sitios/dgfc/es-ES/ipr/fcp1420/c/oacag/Documents/CrecSostenible_20151124_web_acc.pdf

Gobierno de España-Ministerio de Hacienda (2019), *Acuerdo de Asociación de España 2014-2020*, Retrieved from https://www,fondoseuropeos,hacienda,gob,es/sitios/dgfc/esES/ipr/fcp1420/p/pa/Documents/20190215_AA_Espa%c3%b1a_2014_2020_Vdef,pdf

Gobierno de España (2022). *Acuerdo de Asociación de España 2021-2027*. Retrieved from https://www.fondoseuropeos.hacienda.gob.es/sitios/dgfc/esES/ipr/fcp2020/P2127/Documents/20221118_Acuerdo_Asociacion_aprobado.pdf

Gómez Jiménez M.L. (ed.) (2017). *Monográfico sobre las Estrategias de Desarrollo Urbano Sostenible e Integrado (EDUSI). Review International on Sustainable Housing and Urban Renewal 6(2)*. Malaga: Grupo de Investigación Pasos Vivienda Universidad de Málaga

Hernández Aja, A., Álvarez del Valle, L., Diez Bermejo, A., Córdoba Hernández, R., Fernández Ramírez, C., Matesanz Parellada, Á., & Rodríguez Suárez, I. (2021). *Informe sobre los planes y programas asociados a las Estrategias de Desarrollo Urbano Sostenible (EDUSI) y su vinculación con la vulnerabilidad urbana en España en el marco de los nuevos retos urbanos*. Retrieved from https://oa.upm.es/69248/

Hernández-Partal, S. (2023). Los Planes de Acción Local de la Agenda Urbana Española: su papel en el urbanismo del siglo XXI. *Ciudad Y Territorio Estudios Territoriales*, 55(217), 829-858. https://doi.org/10.37230/CyTET.2023.217.14

Hernández-Partal, S. & de Santiago-Rodríguez, E. (2019). Las sinergias entre la Agenda Urbana Española y otras agendas y estrategias. *Ciudad Y Territorio Estudios Territoriales*, *51*(202), 835-846

Janoschka, M. & Mota, F. (2021). New municipalism in action or urban neoliberalisation reloaded? An analysis of governance change, stability and path dependence in Madrid (2015–2019). *Urban Studies*, *58(13)* 2814-2830. https://doi.org/10.1177/0042098020925345

Karadimitriou, N., De Magalhaes, C.S. & Verhage, R. (2013). *Planning, Risk, and Property Development: Urban Regeneration in England, France and the Netherlands*. Abingdon: Routledge

Lang, T., & Török, I. (2017). Metropolitan Region Policies in the European Union: Following National, European or Neoliberal Agendas?. *International Planning Studies, 22(1)*. 1-13. https://doi.org/10.1080/13563475.2017.1310652

Leary E.M. & McCarthy, J. (Eds.) (2013). *The Routledge Companion to Urban Regeneration*. London: Routledge.

Medeiros, E. (Ed.) (2019). *Territorial Cohesion: The Urban Dimension*. Verlag: Springer

Marín-Cots, P. (2019). La Agenda Urbana 2050 de Málaga. *Ciudad Y Territorio Estudios Territoriales*, *51(202)*, 785-798

Marshall, A. (2005). Europeanization at the urban level: Local actors, institutions and the dynamics of multi-level interaction. *Journal of European Public Policy*, 12(4), 668-686. https://doi.org/10.1080/13501760500160292

Mendez, C. van der Zwet, A. & Borkowska-Waszak, S. (2021). Rescaling urban development policy in the EU: the impact of integrated place-based approaches in Cohesion Policy. *Regional Studies*, 55(6), 1154-1165. https://doi.org/10.1080/00343404.2021.1891215

Ministerio de Hacienda y Función Pública (2018*). Evaluación de la selección de las Estrategias de Desarrollo Urbano Sostenible e Integrado (DUSI). Informe final Resumen*. Retrieved from https://www.fondoseuropeos.hacienda.gob.es/sitios/dgfc/es-ES/ipr/fcp1420/e/ep/epeep/Documents/AÑO%202019/Evaluacion_Seleccion_EDUSI_Resumen.pdf

Ministerio de Fomento (Ed.) (2019), *Agenda Urbana Española 2019*, Retrieved from https://www.laspalmasgc.es/export/sites/laspalmasgc/galleries/contenido-edusi/Agenda-Urbana-Espanola.pdf

Ministerio para la Transicción Ecológica y el Reto Demográfico (2020). *National climate change adaptation plan 2021·2030*. Retrieved from https://www.miteco.gob.es/content/dam/miteco/es/cambio-climatico/temas/impactos-vulnerabilidad-y-adaptacion/pnacc-2021-2030-en_tcm30-530300.pdf

Lacilla Larrodé, E., Bergasa Pascual, J. R. & Zulategui Beñarán, J. (Eds.) (2022). *Catálogo de buenas prácticas urbanas en el marco de los objetivos de la en el marco de los objetivos de la Agenda Urbana Española. Estudio y análisis de experiencias urbanas integradas*. Retrieved from https://cdn.mitma.gob.es/portal-web-drupal/AUE/doc/220726_catalogo_a3.pdf

Navarro Yáñez, C. J. (2020). Políticas de regeneración urbana en España en el marco de las iniciativas de la Unión Europea. *Papers: Regió Metropolitana de Barcelona: Territori, estratègies, planejament*, 63, 68-81

Navarro Yáñez, C. J. (2023). Introduction: EU Urban Initiatives as Integrated Multi-level Policy Mixes—Policy Levels, Policy Dimensions and Added Values of Integrated Local Strategies from a Comparative Perspective. In: C.J. Navarro Yáñez, M.J. Rodríguez-García & M.J. Guerrero-Mayo (Eds.). *EU Integrated Urban Initiatives*, 1-30. Cham: Palgrave Macmillan

Obeso Muñiz, Í. (2023). Las estrategias de desarrollo urbano sostenible integrado (EDUSI) en Asturias. *GOT: Revista de Geografia e Ordenamento do Território*, 26, 78-103. https://doi.org/10.17127/got/2023.26.004

Observatorio de la Vivienda Vasco (2010). *Políticas de rehabilitación y regeneración urbana en Europa. Servicio de Estudios, Planificación y Presupuestos*. Retrieved from https://www.euskadi.eus/gobierno-vasco/contenidos/informacion/ovv_a_pc_-eu_001/es_ovv_admi/adjuntos/Pol%C3%ADticas%20de%20Rehabilitaci%C3%B3n%20y%20la%20Regeneracion%20Urbana%20en%20Europa_Informe%20ejecutivo.pdf

Olejnik, A. (2017). Future Perspectives of the Implementation of EU Urban Agenda. *International Studies. Interdisciplinary Political and Cultural Journal*, 19(1), 175-188. https://doi.org/10.1515/ipcj-2017-0011

Pérez de las Heras, B. (2023). The Spanish recovery plan: assessing its contribution to the green transition in the European Union. *Gestión y Análisis de Políticas Públicas*, 33, 6-23. https://doi.org/10.24965/gapp.11207

Pirlone, F., Spadaro, I., & Candia, S. (2017). Metropolitan Governance for Territorial Cohesion. *TeMA - Journal of Land Use, Mobility and Environment*, 10(2), 213-228. https://doi.org/10.6092/1970-9870/4956

Potjer, S., Hajer M., & Pelzer, P. (2018). *Learning to Experiment: Realising the Potential of the Urban Agenda for the EU*. Retrieved from: https://www.docdroid.net/99DbF6c/research-urbanfuturesstudio-web-def-1-pdf

Purkarthofer, E. (2019). Investigating the partnership approach in the EU Urban Agenda from the perspective of soft planning. *European Planning Studies*, 27(1), 86-105. https://doi.org/10.1080/09654313.2018.1527294

Red de Iniciativas Urbanas (2015). *Orientaciones para la definición de Estrategias de Desarrollo Urbano Sostenible Integrado en el Período 2014-2020*. https://www.rediniciativasurbanas.es/recursos_riu/pagina-basica/recursos/20150803_-orientacionesestrategiasintegradas2014202.pdf

Roberts, P. (2000). *The Evolution, Definition and Purpose of Urban Regeneration*. London: Sage

Rodríguez-Domenech, M.Á. & Cañizares Ruiz, M.C. (2023). Urban Planning and Sustainability in the Cities of Castilla-La Mancha (Spain): Current Challenges. *Land*, 12(8), 1540. http://dx.doi.org/10.3390/land12081540

Rodríguez-Escudero, Álvaro D., Díez-Bermejo, A., & Álvarez-Del-Valle, L. (2023). "Motril SI2": Estrategia de Desarrollo Urbano Sostenible e Integrado (EDUSI) de Motril (Granada). *Ciudad Y Territorio Estudios Territoriales*, 55(216), 535-546. https://doi.org/10.37230/CyTET.2023.216.15

Rodríguez-García, M. J. & Navarro Yáñez, C J. (2023). Evaluating the design of integral urban regeneration plans: combining policy evaluability and plan quality approaches to analyse complex urban policies. *Town Planning Review*, 94(3). https://doi.org/10.3828/tpr.2022.19

Rodríguez Suárez, I., Gómez Giménez, J. M., & Hernández Aja, A. (2021). *Catálogos de Barrios Vulnerables de España 1991, 2001 y 2011*. Retrieved from https://edatos.consorciomadrono.es/dataverse/catalogos_barrios_vulnerables

Sgambati, S. (2023). The interventions of the Italian Recovery and Resilience Plan: sustainable development. *TeMA - Journal of Land Use, Mobility and Environment*, *16* (2), 461-468. https://doi.org/10.6093/1970-9870/10038

Suárez-Rodríguez, A., & Tomé-Fernández, S. (2023). La Estrategia de Desarrollo Urbano Sostenible e Integrado (EDUSI) de Avilés (Asturias): análisis y diagnóstico de un instrumento para la ciudad en reconversión. *Ciudad Y Territorio Estudios Territoriales*, 55(216), 349-372. https://doi.org/10.37230/CyTET.2023.216.5

Schmelzer, M. Vansintjan, A. & Vetter, A. (2022). *The Future Is Degrowth. A Guide to a World beyond Capitalism*. London: Verso.

Tena, A. (2023). *Desmantelar carriles bici sale caro: PP, Vox y Foro Asturias se juegan perder hasta 14,5 millones de los fondos europeos*. Retrieved from https://www.publico.es/sociedad/desmantelar-carriles-bici-sale-caro-pp-vox-foro-asturias-juegan-perder-14-5-millones-fondos-europeos.html

Tosics, I. (2017). Integrated Territorial Investments. A Missed Opportunity?. In J. Bachtler, P. Berkowitz, S. Hardy, & T. Muravska (Eds.), *EU Cohesion Policy* (284-296). Routledge: New York-Oxon

Van Der Zwet, A., Bachtler J., Ferry M., McMaster I., & Miller S. (2017). Integrated Territorial and Urban Strategies: How are ESIF Adding Value in 2014–2020?. Retrieved from https://ec.europa.eu/regional_policy/sources/studies/integrated_strategies/integrated_strategies_en.pdf

Vinci I. (2021). Cities and regional disparities in the European Union: evolving geographies and challenges for Cohesion Policy. *Urban Research & Practice*, 4(4), 350-371. https://doi.org/10.1080/17535069.2021.1958252

Vinci, I. & Cutaia, F. (2019). Implementing the Environmental Dimension of the EU's Urban Agenda 2014-2020. *TeMA - Journal of Land Use, Mobility and Environment*, 12(2): 139-146.

Zimmermann, K. & Fedeli, V. (Eds.) (2021). *A Modern Guide to National Urban Policies in Europe*, Chaltehanm: Edward Elgar Publishing.

Image Sources

Fig.1: Authors' elaboration based on Ministerio de Fomento (2019) and Red de Iniciativas Urbanas (2015).

Fig.2: Authors' elaboration (2023).

Fig.3: Authors' elaboration starting from Ministerio de Fomento (2019: 81).

Fig.4: Authors' elaboration according to assignation of values based on the ISDUS Implementation Plan and synergies with the SUA defined by MITMA.

Table Sources

Tab.1: Authors' elaboration (2024) based on the "Guidelines for the definition of EDUSI" (Red de Iniciativas Urbanas, 2015).

Tab.2: Authors' elaboration (2024) based on Ministerio de Fomento (2019) and Red de Iniciativas Urbanas (2015).

Tab.3: Authors' elaboration (2024) based on the "Synergies between the Spanish Urban Agenda and other agendas and strategies" (Hernández-Partal & de Santiago-Rodríguez, 2019).

Tab.4: Source: Authors' elaboration (2024) based on the ISUDS proposed by capital cities.

Tab.5. Source: Authors' elaboration (2024) based on the state of implementation of A Coruña's ISUDS.

Author's profile

Federico Camerin

City planner at the Università Iuav di Venezia (2014), he achieved a double degree of Doctor and Ph.D. awarded by the Universidad de Valladolid (Spain) and Bauhaus-Universität Weimar (Germany) within the European Joint Doctorate "UrbanHist" (2020). He was a post-doc fellow in "Urban Planning" at Iuav (2021) and is currently a post-doc researcher "Margarita Salas" for the Universidad de Valladolid and Universidad Politécnica de Madrid (2022-24). His research and working interests are spatial planning, planning history, urban governance, and urban regeneration.

Lucas Álvarez Del Valle

Architect (2013) and Master in Urban and Territorial Planning (2017) at the Madrid Higher Technical School of Architecture (ETSAM) of the Universidad Politécnica de Madrid (UPM). Since 2018, he is a member of the Research Group Grupo de Investigación en Arquitectura, Urbanismo y Sostenibilidad (GIAU+S) at UPM, where he works on housing, integrated urban

regeneration, vulnerability and public policies for sustainable urban development. Since 2023, he also works at the Instituto Torroja de Ciencias de la Construcción of CSIC on projects related to energy rehabilitation of housing stock, improvement of indoor comfort in buildings and energy poverty.

Ana Díez Bermejo

Architect, Master in Urban and Territorial Planning, and PhD in "Sustainability and Urban Regeneration" at at the Madrid Higher Technical School of Architecture (ETSAM) of the Universidad Politécnica de Madrid, she is member of the GIAU+S Research Group. Her research focuses on the analysis of urban public policies for the rebalancing of territories at all administrative scales and the development of methodologies for their analysis from the point of view of new urban challenges. She is interested in urban studies on the implementation of policies related to urban vulnerability, resilience and sustainability.

Iván Rodríguez Suárez

PhD in Architecture, Master in Urban and Territorial Planning and Specialist in Land and Building Valuation from the Universidad Politécnica de Madrid (UPM), he is Assistant Professor at the Department of Urban and Territorial Planning (DUyOT) of the Madrid Higher Technical School of Architecture (ETSAM) and member of Research Group Grupo de Investigación en Arquitectura, Urbanismo y Sostenibilidad (GIAU+S) at UPM. His research areas focus on urban planning, housing policies, rehabilitation processes and urban vulnerability.

TeMA
Journal of
Land Use, Mobility and Environment

TeMA 1 (2024) 71-87
print ISSN 1970-9889, e-ISSN 1970-9870
DOI: 10.6092/1970-9870/10414
Received 30th October 2023, Accepted 04th March 2024, Available online 30th April 2021

Licensed under the Creative Commons Attribution – Non Commercial License 4.0
http://www.serena.unina.it/index.php/tema

Sustainable development and proximity city: the environmental role of new public spaces

Antonio Bocca[a]*

[a] Dd'A-Department of Architecture Pescara
"G.d'Annunzio" University, Chieti-Pescara, Italy
e-mail: antonio.bocca@unich.it | antoniobocca23@gmail.com
ORCID: https://orcid.org/0000-0002-7384-2394
* Corresponding author

Abstract
Biodiversity, urban regeneration and the climate crisis are inseparable issues and must be addressed simultaneously. The article addresses the potential synergy of the 15-minute city approach to the environmental role of new public spaces. There is a need for a multi-scalar and cross-sectoral approach to open space design that considers environmental resources and components as levers for urban regeneration and socio-economic development. Rethinking the city is part of rethinking the relationship between density, land consumption and sustainability, in which interventions transcend public-private space dichotomies through strategic spatial planning. Proximity can give shape, direction, and meaning to the development of settlement systems. Networks and relationships between spaces and land values must consider environmental dominants as part of spatial design. In this sense, new ecological public spaces can contribute to climate adaptation and increased urban well-being. The paper consists of two main sections: the first focuses on global challenges and the planning of resilient cities; the second deals with theoretical and application aspects of the concept of proximity about ecological transition (Portland and Barcelona).

Keywords
15-minute city, ecological transition, public space

How to cite item in APA format
Bocca, A. (2024). Sustainable development and proximity city: the environmental role of new public space. *TeMA - Journal of Land Use, Mobility and Environment, 17* (1), 71-87. http://dx.doi.org/10.6092/1970-9870/10414

1. Introduction

The 15-minute city is an integrative opportunity to reconfigure the city's open spaces. It is crucial to identify the design relationships that open spaces can establish with issues of adaptability and resilience. Although the city of proximity emphasises community priorities, it also highlights how public spaces are unable to respond to extreme phenomena. It is well known that town planning continues to operate in situations of uncertainty and the term emergency persists in planning. This consideration prompts a review of the approach of urban planning discipline to deal with the unexpected. It is a question of re-functionalising new public spaces not only from a social and economic point of view, but also of recreating a balance from an ecological and environmental point of view. Overall, new public spaces must be vital components of sustainable urban development, promoting environmental conservation, resilience, and community well-being in increasingly urbanised landscapes.

The dispersion of the urban fabric and the rapid expansion of urbanised areas, based on rigid zoning systems and road infrastructure, have incentivised monofunctionality and private car use, along with the loss of the urban effect and degrees of biodiversity. It is no coincidence that car-centric policies, while increasing the speed of travel, have also defined spatial configurations with problematic socio-economic and ecological inequalities (Meschik, 2012; Hickman & Banister, 2014; Eleutério et al., 2023). The concept of the neighbourhood city does not specifically delve into environmental protection issues, focusing mainly on the issues of essential services and mobility (Khavarian-Garmsir, Sharifi & Sadeghi, 2023). The city has an innate complexity in which urban subsystems continuously interact and influence each other[1]. The neighbourhood describes a multidimensional form of relationship between actors whose practices and backgrounds can provide further insights into transitions towards sustainability (Boschma, 2005). This study focuses on the ecological transition and the new environmental role of public space. The manuscript is also consistent with the implementation of the Green Deal at the local level, the challenges of ecological transition and the achievement of the 2030 Agenda goals. The objective of the research is a qualitative assessment of the principles of sustainability and climate change in relation to the city of proximity and the new environmental role of public space. The research used the qualitative review method to examine the literature and obtain extensive information on how the ecological transition is interpreted in the design of public spaces and regenerative processes in the built environment. The analysis focused on the principles of sustainability and climate change in relation to the city of proximity and the new environmental role of public spaces. On the one hand, it is proposed to highlight the priority role of public space in the sustainable development of the city, and on the other hand, the need to adopt a new approach in the design and regeneration of public space.

The article is structured as follows: Section 2 highlights the relationship between the ecological transition and the city of proximity. Section 3 analyses how the principle of interconnection between new public spaces and the flexibility of urban planning instruments and urban regeneration processes. Section 4 analyses the new environmental role of public space in driving urban well-being. Section 5 analyses the case of Portland and Barcelona as an application of the principle of proximity and climate change mitigation, highlighting the strengths and weaknesses of the case studies. Section 6 critically discusses the results obtained.

2. 15-minute city: proximity and environment

The city stands at the intersection of a multitude of social needs and functions. The challenge of innovation fuels thinking about ecosystem issues, mobility, education, employment, and care. These concepts underlie the 15-Minute Approach to the City. The theory, the result of C. Moreno's studies, is applied in experimental

[1] The concept of 'environmental awareness' evaluates how human activities and cities can have a significant impact on the natural environment and the surrounding ecosystem (UN, Department of Economic and Social Affairs, 2017).

form in Paris and the subject of attention in other cities around the world (including: Ottawa, Melbourne, Portland, Nantes, Milan). It is based on rethinking the functioning of the city from a new hierarchy of organizing principles of social life guided by the efficient use of time. The 15-minute city concept aims to create self-sufficient neighbourhoods with the essential functions of living, working, commerce and education by decentralizing urban functions and services.

However, it is necessary to remember that 15-minute city is not new in the urban planning. This approach has its roots in proposals developed during and after the Industrial Revolution. These include E. Howard's Garden City (1965) and C. Perry's Neighbourhood Unity (1923), which focused on planning for human-scale environments. The centrality of the neighbourhood and its mixed nature are also central to the studies of J. Jacobs (1969) and the urban theories of the postmodern approach (Bruno et al., 2023). The

concept of the neighbourhood is a simple one that resonates with many current issues, but today it is rather a matter of reinventing it in light of the ecological and environmental transition.

The 15-minute city concept integrates different dimensions to generate a multi-centred settlement structure. By recomposing and reducing spatial metrics, it shapes the city with new principles of regulation of both time and use. This requires a renewal of existing infrastructures on which to graft services and new public spaces for social and cultural activities. In this vision, both the concepts of chronotopia and topophilia are overcome in favour of a multi-centred settlement structure in which public spaces play a priority environmental role. Ecological and environmental transitions have multi-scalar relationships that are determined with respect to issues of proximity, public space, urban structure and time (Lopito et al., 2022).

The objective is to create a spatial network in which the project coincides with the territory in order to recognise its future effects and impacts. It is no coincidence that open spaces are intended as collective places in which to recognise both the public dimension and the instance for experimentation with new spatial approaches of human-nature hybridisation. The concepts of healthy streets, liveable neighbourhoods are not simply revisited, but are an invitation to reflect on urban modes and habits, going beyond the simple concept of the permeable city of 15 minutes (White, 2023; Abdelfattah et al., 2021). Living neighbourhoods means sharing an urban space, resources of a liveliness that is expressed in a thousand forms: streets, parks, cultural spaces, etc. It is necessary to transform the urban space that is still strongly monofunctional, with a centre and several specialised areas, into a polycentric city supported by the principles: proximity, diversity, density, ubiquity (Moreno, 2023) (Fig.1).

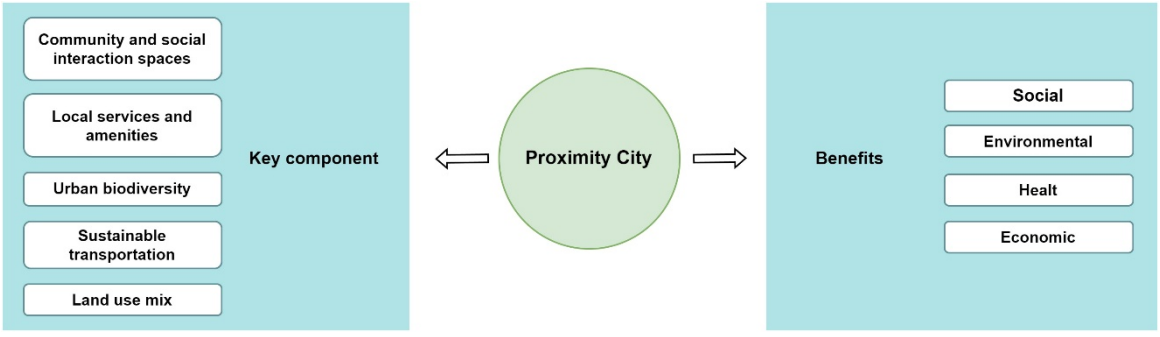


Fig.1 Key component and benefits of proximity city. Source: Author's elaboration

Urban planning is traditionally aimed at achieving spatial development goals and promoting a sustainable urban future, but it has not always had an adequate place in the planning process (Naess, 2001). The application of the 15-minute city to the fractal nature of most settlement systems is what can give shape, direction and meaning to settlement development. Simultaneously, the network structure between spaces and spatial values must necessarily consider environmental dominants as part of spatial design. However, climate effects testify to the degradation of 20th century urban palimpsests, as well as highlighting the need for new spatial meanings. Urban awareness is strategic in a period of transition and change, in which the city is called

upon to modify itself and implement conformity between its different layers (Bocca, 2021). This reinforces the idea that proximity should be one of the criteria for designing the new environmental role of public spaces, in addition to the creation of a functional mix.

The idea of abandoning the definition of open space as a process leads to the definition of a design strategy that defines both ecological characteristics in the sustainable design process and a level of indeterminacy. This logic suggests that the dissolution of cities can be overcome by entrusting new public spaces with the environmental role of variable-geometry hinge and environmental relationship with the territory. The challenge of urban regeneration is surely the ambition of cities to develop a network of interconnected ecological spaces and corridors in which urban environments can recognise human-nature coexistence.

3. The planning frameworks ecological transition

Cities are complex systems and today's challenges require systemic and holistic approaches that consider many distinct factors and feedback loops and simultaneously address sustainability, urbanity, health, and well-being (Nieuwenhuijsen, 2021). Urban regeneration, emptied of the uncertainty of bureaucratic timescales, requires integrated interventions that form the framework on which to set the ecological transition. The contemporary city is oriented towards a design innovation that requires flexible systems compared to those designed for the modern city (Valentino & Lutzoni, 2020; Secchi, 2010). Furthermore, cities are called upon to play a role both as actors in the development of socio-technological systems and as facilitators of places for sustainable innovations (Geels et al., 2011). Planning processes must be qualified as territorial-structures in which environmental dominants are identified as generators of a different order of settlement space and a project is realised around them (Maciocco et al., 2011).

There are numerous policies, programmes, and initiatives aimed at the environmental regeneration of public spaces. Among the most recent initiatives are the EU's Next Generation programme, together with: (i) Green Deal; (ii) Urban Agenda 2030; (iii) European Biodiversity Strategy 2030; (iv) Cohesion Policies; (v) LIFE Programme; (vi) European Structural and Investment Funds (EIS funds). However, urban policies face extreme difficulties in implementing adaptive and transformative sustainability strategies due to old legislation that imposes operational limitations (Gaglione, 2022; Nieuwenhuijsen, 2018).

Some planning practices, even before the pandemic, articulated the hypothesis of building comprehensive visions in which neighbourhoods are the main components of the design of decentralised, yet interconnected urban structures. Furthermore, decentralising urban services to reduce unnecessary travel, expanding cycling and walking routes, redesigning public spaces and developing Greenway, in line with the urban models of Green City, Slow Movement, Walkable City. In this sense, the neighbourhood city can implement an integrated regeneration project if both transformations and spatio-temporal and sequential location are addressed (Marchigiani & Bonfantini, 2022). These approaches appear in line with the main strategic and financial axes represented by the Recovery Found Next Generation and the Green Deal, with the aim of qualifying open spaces as relevant physical elements for sustainable spatial planning (Scheiber & Zucaro, 2023). Although the path set by European directives is to make cities greener, the problem of the impact of green infrastructure and gentrification remains an unresolved issue.

However, urban planning tools are numerous and each of them addresses the main issues differently: while Italian cities can rely on institutional planning and programming tools anchored in the historical tradition (General Regulatory Plan) and others recent (Climate Adaptation Plan, Sustainable Urban Mobility Plan, etc.), cities such as Paris operate in both strategic and operational terms. However, coordination is still lacking and cities explore different strategies, solutions and technologies, depending on the potential of local contexts. Faced with this scenario, the need to accelerate the sustainable urban transition emerges (Gaglione, 2022; Fratini, 2023).

This research shows how the 15-minute concept has encouraged physical determinism, where urban form is improved and social and economic issues cannot be addressed by physical values alone (Khavarian-Garmsir, Sharifi & Sadeghi, 2023). The need to rethink open spaces through the layering of functions and uses collaborates in the creation of a project between the 'extraordinary' events of climate change and the 'ordinary' events of everyday life in the city (Crupi, 2015). It emerges that the 15-minute city has a potential contribution to sustainability, but is not without obstacles to implementation. This underlines how planners need a form of sustainability assessment and measurement integrated into the planning process (Yigitcanlar & Teriman, 2014). Against this backdrop, the issue of climate finance is central to urban regeneration narratives. It is crucial to ensure that urban models can not only meet community needs, but also ensure economic equity for the benefit of local governments (SDG 11) (Allam et al., 2022). This principle bases its effectiveness on a careful review of the effects, positive or negative, that any new project may produce in a given area in relation to planning instruments (Talia, 2022).

Various urban policies can qualify the 15-minute city as a solution to rebalance urban opportunities, counteracting de-densification, urban sprawl and consumption of environmental resources. These visions focus on the negative aspects of urbanisation and the benefits of urban living (Caragliu, 2022). It is clear that the 15-minute city should not be the only attempt to create 'minimal ecological units' (Manzini, 2021), 'minimal resilience units' (Pede et al., 2023), 'minimal layouts' (Crupi, 2015), 'summation of villages' (Shearmur, 2021), but should pursue the promotion of a unified vision of the city. Therefore, holistic and strategic urban planning, mobility and infrastructure development and climate adaptation play a decisive role (Pope et al., 2015). Urban challenges should not be solved through partial or local solutions, but rather should be challenging solutions educated by contemporary issues.

4. Public space and new sustainable perspectives

In the era of ecological transition, reflection on the new role of sustainable public space requires a careful consideration of the socio-spatial and sociotechnical impacts of urban regeneration and redevelopment projects in environmental renaturation and mitigation strategies (Errante, 2023). New public spaces can play a crucial role in sustainability and environmental management according to the themes:

- Green infrastructure to help mitigate the effects of urban heat islands, reduce stormwater run-off and provide habitat for wildlife;
- Carbon sequestration is aimed at offsetting carbon emissions and combating climate change;
- Preservation of biodiversity to promote human-environment interaction and reduce land consumption;
- Promotion of sustainable transport aimed at realising the city of proximity and promoting the use of bicycles;
- Community involvement and awareness-raising to promote environmental awareness;
- Urban resilience and adaptation to improve the ability of urban areas to absorb and manage water, in particular by reducing the risk of infrastructure damage;
- Environmental well-being and connection with nature to improve the perception of public space.

Today, many urban practices of adaptation to climate change find application in urban centralities, where new spatial configurations can be defined in relation to the ecological transition, as well as giving new meaning to public space. Now we talk about squares, boulevards, urban parks, but each of them must also find design solutions to live them as an emergency solution. However, these are not the only spaces on which to experiment with adaptive solutions. Dense spatial figures such as axes, rings, boulevards, even green corridors with a performance function can be found in the literature. Such actions not only innervate the territory with a complex patchwork of ecosystems, but also highlight the fragility of certain natural ecosystems (uncultivated

areas, brownfields, abandoned soils). This leads to the recognition of 'fertile design spaces' on which to set urban and territorial regeneration processes (Pisapia, 2021).
The environment must be read as a lever to establish unprecedented relationships in the urban centrality and establish spatial structures and concepts dense with nature and history (Maciocco & Tagliagambe, 2009). The objective is not only to reverse the process that sees the city driven by consumerist productive approaches, but to build settlement systems capable of developing together with nature, acquiring its prerogatives and capacities (Acierno, 2021) (Fig.2).

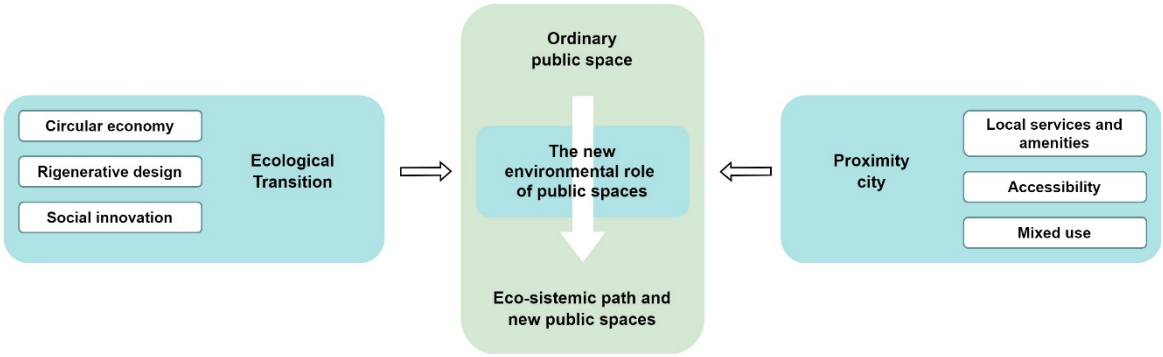


Fig.2 Ecological transition and proximity city: the role of new public spaces. Source: Author's elaboration

These problems are often addressed in their respective fields and therefore bringing together green infrastructure solutions from an urban perspective offers an opportunity to promote a more holistic approach (Pultrone, 2024). This induces a wide range of policies aimed at avoiding gentrification processes, in which the city is an urban ecosystem composed of multiple neighbourhood units that are connected and influence each other (Manzini, 2021). The relationship between dimensions and contexts emerges strongly, both in terms of place characteristics and design choices. In these interventions, the spatial dimension evolves with respect to the past, both in its settlement configurations that identify new empty spaces, and in the presence of contexts differentiated by use (Cialdea & Badami, 2017).
However, it is precisely in empty spaces that experiences can be realised to improve the possible relationships between environmental and human habitats, forms of urbanity and spatial configurations. The aim is to identify a multi-scalar and cross-sectoral approach to the topic of open space design, in order to take environmental resources and components as levers for urban regeneration and socio-economic development. In this sense, traditional solutions and techniques are unable to achieve the new levels of performance required by the current green transition. Therefore, quantifying the input-output ratio of urban functioning can contribute to the development of alternative urban layouts based on the environmental role of public spaces[2].
According to this reading, the new network of public spaces with an environmental role activates: (i) the recognition and protection of eco-system services in the urban environment; (ii) the creation of green infrastructure; (iii) the adoption of nature-based solutions. However, the discourse on sustainable public space does not end with the environmental component alone. The future challenge will be to link the ecological transition with the energy transition in the possibility of spatialising solutions that are mutually consistent and respectful of the spatial context. Only through a holistic approach is it possible to implement the three dimensions (economic, social, environmental) of sustainable development.
The implementation of such a vision makes it possible to understand public space as a resource in the event of emergencies (environmental, climatic and health), as well as allowing flexibility of functions (Carra et al., 2022). Urban green spaces must be studied as a network so that the performance of the system as a whole

[2] The combination of physical transformations and weather conditions can define new spatial configurations. During extraordinary weather events, if public space continues to function, not only does it increase the physical resilience of the place, but also the social resilience of the community.

can be measured and according to a multidisciplinary reading (Tulisi, 2017). However, addressing environmental and biodiversity issues offers a transcale approach in which different scalar and/or complementary levels can be identified. This offers the opportunity to investigate the new environmental role of public spaces in relation to the strategic planning of large areas.

5. Example of multi-scalar urban regeneration

5.1 Portland

The interest in the concept of proximity, although it exploded with Carlos Moreno, can be identified as early as the Portland Plan of 2012. Proximity structures urban planning thinking in the search for models of spatial, social and economic balance (Vitullo, 2022; Giaimo, 2023). The use of comprehensive neighbourhoods in Portland is elaborated on three principles: education; healthy, connected neighbourhoods; and economic prosperity and accessibility. The plan includes 25-year goals and 5-year action plans. Goals are set for the entire city and for specific geographic areas (City of Portland, 2014; 2023).

In particular, the 'healthy and connected neighbourhoods' pillar is based on an urban structure that provides accessibility to services within a 20-minute radius[3]. On a larger scale, however, it connects different habitats through natural areas, greenways and civic corridors[4]. Since the Buildable Lands Inventory Report (2012), the City of Portland has highlighted inadequate infrastructure services and susceptibility to environmental hazards. Building on these considerations, the Comprehensive Plan 2035 presents integrative policies to improve Portland's resilience (e.g. growth in compact centres and corridors, provision of City Greenways and Urban Habitat, employment opportunities, etc.), and the city's urban development plan.

The idea is to create neighbourhoods where people have access to essential services, including grocery stores and other commercial services, public schools, and parks (City of Portland, 2014). The plan is developed as a network of nodes, connected by green paths that allow nature to penetrate the city. This goal is in line with achieving social equity and creating urban forests to increase biodiversity. Neighbourhood centres can induce changes in housing policies through improved bicycle and walking infrastructure and travel. Each center should have a diversity of people and uses to support both environmental sustainability and the 15-minute city (Steuteville, 2023).

Similarly, the goal of the plan was also to intertwine the urban fabric with the city, respecting the Willamette River that divides the city from east to west. Therefore, Portland uses green streets, eco-ways, trees and other green infrastructure to manage stormwater, protect water quality and improve watershed health. Urban waterways, forests, and wetlands manage stormwater naturally and are part of Portland's green infrastructure.

In addition, Portland was among the first cities in the United States to adopt a climate action plan in line with the Paris Agreements. In 2020, by adopting a climate emergency declaration, it reinforced its emissions reduction goal to achieve zero-emissions before 2050[5]. If the Climate action plan (2015) is tasked with getting 80% of the population to live in complete neighbourhoods; the 2035 comprehensive plan acts as a link between local level policies with regional and state agencies. In addition, the Portland Comprehensive Plan is in line

[3] Some structuring elements of the Portland Plan is also found in Melbourne's recent strategy, both in terms of walking distance (20 minutes) and the promotion of interconnected neighbourhood centres.

[4] Civic corridors are defined as roads and public transportation that connect neighbourhoods to each other and to the city centre and provide space for stormwater and other nature-based solutions.

[5] The main goals for 2030 are divided into 9 main pillars: (i) Buildings and energy; (ii) Urban form and transportation; (iii) Consumption and solid waste; (iv) Food and agriculture; (v) Urban forest, natural systems and carbon sequestration; (vi) Climate change preparation; (vii) Community engagement, outreach and education; (viii) Local government operations; (ix) Implementation]

with the Transportation System Plan[6], in which each road is a combination of the transportation function and the surrounding context.

Since individual sites and projects in limited urban environments may vary in terms of challenges and opportunities, the framework also identifies diversion processes that provide flexibility when it is not possible to meet all applicable standards (StreetPDX). This approach involves the mixed use of streets, dividing them into pedestrian zones, pavement/flexible zones, and thoroughfares. This supports the Portland administration's desire to extend the use of roads beyond their transport function, consistent with the role of environmental services. It is therefore not just a matter of identifying places of success, but of bringing out areas where action can be taken to make them more attractive, walkable and ecologically contextual (Tab.1).

Goals	**Spatial planning and urban regeneration**
Economic Prosperity	Physical Planning and spatial reconfigurations - Increase proximity to services and accessibility - Re-invest in Brownfields - Promote land use mix, especially in existing industrial sites
	Community involvement and urban development - Increase sites for businesses and employment opportunities - Promote the Co-design process - Promote employment growth at colleges and hospitals
Human Health	Physical Planning and spatial reconfigurations - Increasing access to complete neighbourhoods - Implementation of city greenways
	Community involvement and urban development - Strengthen consideration of environmental justice - Promoting physical activity in public space
Environmental Health	Physical Planning and spatial reconfigurations - Increase connectivity and multifunctionality of green space through greenway corridors - Preserve and enhance Urban Habitat Corridors - Implement neighbourhood greenways
	Community involvement and urban development - Support nature-friendly infrastructure
Equity	Physical Planning and spatial reconfigurations - Encourage affordable prices in neighbourhoods - Create regulations that acknowledge that one size does not fit all
	Community involvement and urban development - Co-design processes for the production of public space - Provide for on-going affordability - Include under-served and under-represented populations in decisions that affect them - Bottom-up initiatives for the improvement of quality of life
Resilience	Physical Planning and spatial reconfigurations - Promote the development of new housing units in targeted geographic areas so that services and public spaces are within walking distance of residents and reduces carbon emissions - Concentrate growth in centres and corridors to minimise carbon emissions. - Increasing biodiversity through green and blue infrastructure
	Community involvement and urban development - Addressing gentrification through to preserve affordable housing and local businesses.

Tab.1 Evaluation of Portland 2035 Comprehensive Plan

[6] Reference is made to Bicycle Plan 2030, Pedestrian Master Plan, Freight Transportation Master Plan, Neighbourhood Area Plans, etc.

Overall, the plan promotes the self-sufficiency of neighbourhoods by localising basic urban functions, including healthcare, education, childcare, retail, recreation, and fresh food production.
Applying the Portland model implies a rather high degree of localisation of activities that does not currently exist (Pozoukidou & Chatziyiannaki, 2021). While encouraging changes in parking policies and infrastructure improvements, the functional mix to support the 15-minute city is not yet fully identifiable (Fig.3).

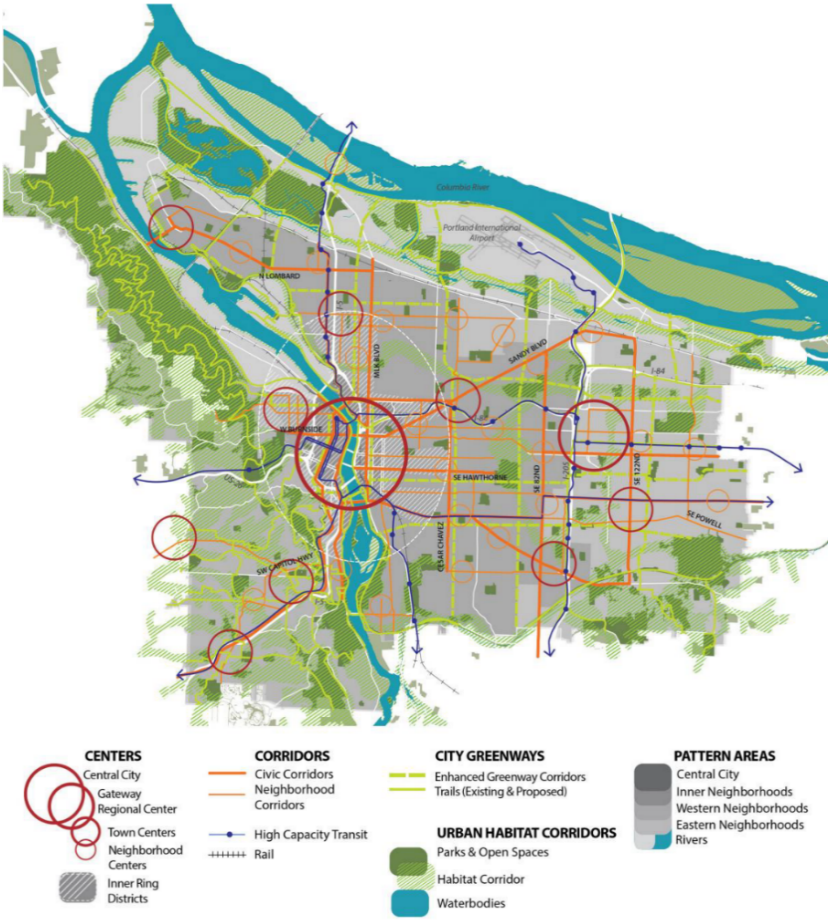


Fig.3 Urban design framework. 2035 Comprehensive plan. Source: City of Portland (May 2023)

5.2 Barcelona

Barcelona's contribution to the 15-minute city concept, in the context of the Super Illes, is organizing by a strong sustainable footprint and integration with the chessboard (eixample) layout (Alberti & Radicchi, 2022). Recent analyses suggest that the city of Barcelona already presents some conditions of a city of proximity, democratic modes of transport (Ortiz et al., 2022), contributing to increasing homogeneous accessibility to essential services. The interest in Barcelona's urban transformation lies in its ability to simultaneously address social, economic, environmental and climate change mitigation issues. In addition to increasing urban proximity, urban transformation aims to improve the quality of public space. In this vision, neighbourhoods are understood as minimal socio-ecological units surrounded by green axes and slow mobility networks for the use of public space.
In Barcelona, while organizing the importance of user-centred mobility, we go beyond the 15-minute city in an attempt to overcome functional zoning through the development of mixed neighbourhoods.
This is achieved by organizing urban spaces in such a way as to reduce distances and increase the walkability of public spaces.

It is evident how urban planning integrates with public mobility planning and acts at different plan levels. Barcelona, in order to strengthen and expand the range of socio-environmental services provided by green infrastructure, has consistently worked in synergy between different urban strategies and planning levels (Ecology, Urbanism, and Mobility Area of the Barcelona City Council, 2020; 2023).

The combination of different urban strategies creates the planning conditions for the Implementation of green infrastructure and healthy arteries on which public relation spaces are built. Ultimately, Barcelon"s strategy can be80mphasizesd as (Mecca, 2023):

- Urban planning with the use of transport and active mobility in the centre and a balanced distribution of services;
- Super-urbanisation with the creation of pedestrian zones, cycle paths and an increase in high vegetation;
- Public transport networks to serve a large catchment area through the implementation of a tariff integration system between different means of public transport, the construction of new metros and the expansion of trams and buses;
- Bike sharing for residents and visitors;
- Parks and green areas for recreation and nature for citizens.

Barcelon"s strategy is to bet on the transcalar role of public space to innovate and omphasizee the potential of an established city model. The proposal of green axes, in addition to mitigating the effects of climate change and increasing connectivity, omphasizess the function of transit and leisure corridors for the community. This approach makes it possible to review the principles of green infrastructure planning for a dense fabric, as in the case of Barcelona.

The proposed green axes, with their increased connectivity, not only allow the migration of certain species and the repopulation of certain areas in heterogeneous landscapes, but also act as transit and recreation corridors for human beings. This creates a network of green spaces that serve the community and biodiversity (Magrinyà et al., 2023).

The Barcelona administration has drafted the Green-Hub Model document. This document describes how the street of the 21st century should be, moving away from the vision that sees it only as a territory for cars. The realisation of these cornerstones translates into a series of fundamental aspects related to uses, mobility, greenery, furniture, and lighting. These principles create a green pole that will encourage people to re-appropriate the streets, with more family life and local commerce and less pollution and noise.

The characteristics of the new street model will be determined by the idea of comfort in relation to the possibility of exploiting established urban networks to recover and generate new places in relation to community needs. This approach can be defined as urban acupuncture and urban naturalisation, combined with the idea of the city of proximity. It involves diversified public space projects in which public facilities and services can be inserted to generate urban centralities. This approach breaks with the idea of urban regeneration in the classical sense to consider it multi-scalar and interdisciplinary.

The case of Barcelona shows the evolution of the urban model towards environmentally networked blocks that not only connect green areas, but also create neighbourhood gardens (particularly in densely populated central areas) and increase the multifunctionality of green infrastructure and active mobility. The interventions implemented and planned in Barcelona are an attempt to combine social and economic functions with the new environmental role of streets and public spaces (e.g. urban drainage, storm water disposal, heat island elimination). In fact, Barcelona takes on the 15-minute city model through the systemic and fractal construction of the city (Mecca, 2023). The idea of the Supermanzana represents the 'transition-revolution' from the current city model to a post-pandemic and de-carbonised one, in which it is evident how the joint intentions of the Administration and the Agència d'Ecologia Urbana attempt to respond effectively to the plurality and diversity of urban demand (Tab.2; Fig.4).

Goals	Spatial planning and urban regeneration
Economic Prosperity	Physical Planning and spatial reconfigurations - Redeveloping the historic centre - Connecting the historic city with contemporary expansion - Decentralise public services - Promoting the mix of land uses
	Community involvement and urban development - Increase business sites and job opportunities - Promoting the co-design process
Human Health	Physical Planning and spatial reconfigurations - Designing public spaces with a high tree cover index - Designing safe spaces through spatial and lighting relationships - Reconfiguring public spaces in relation to the use of greenery
	Community involvement and urban development - Communicating the value of urban nature to inhabitants of cities.
Environmental Health	Physical Planning and spatial reconfigurations - Implement green and public spaces to increase and connect urban green infrastructure. - Integrate green infrastructure with structural elements at the metropolitan level.
	Community involvement and urban development - Activating citizen involvement in the conservation, protection and improvement of greenery and biodiversity in private areas.
Equity	Physical Planning and spatial reconfigurations - Making green and open spaces and public services accessible - Making housing prices affordable - Facilitating the use of public transport by reorganising the public transport service.
	Community involvement and urban development - To spread knowledge of urban nature and the value of its preservation.
Resilience	Physical Planning and spatial reconfigurations - Preserve and improve greenery and biodiversity in heritage green spaces. - Designing public spaces to counter heat islands.
	Community involvement and urban development - Establish synergies with research centers to strengthen knowledge transfer. - Promote an active role of citizens in promoting and preserving urban nature in public areas.

Tab.2 Evaluation of Barcelona

Fig.3 Green hubs planned for the Barcelona Superblock programme. Source: Gerència d'Àrea d'Ecologia Urbana, Consell Municipal de Barcelona.

6. Conclusion

6.1 Discussion

The topics of debate are climate change, proximity, accessibility, but undoubtedly the main theme is urban regeneration. Urban planners have always pursued design success through urban regeneration processes. If until the 1990s urban planning practice had dangerously drifted away from the theme of modelling space (Mascarucci, 1998), today the centrality of the design of urban space at different scales qualifies as a device in which to recognise and bring into coherence the different expectations, the differentiated outcomes of policies, and the operational connection between the different levels of government of the territory. Moreover, diffuse and dispersed urbanisation has led to the loss of landscapes and soils, as well as their related eco-system services. This has increased both consumption and exposure to multiple risks (environmental, social, climatic, etc.).

The sustainable development planning process must think about the needs and opportunities of territories. A dynamic vision should implement multi-level governance based on vertical alignment (international, national, regional and local) and horizontal involvement (public, private and social) towards a collective vision (Battisti, 2023). It is necessary for urbanism to change its perspective to recognise a new disciplinary status in which the civil economy develops with the ecological economy. In this sense, green infrastructure and nature-based solutions are key resources to guide urban transformations towards the ecological transition. Urban green spaces serve as a comprehensive tool for environmental sustainability, regulating urban ecosystem services and microclimatic conditions, protecting biodiversity and providing various socio-ecological benefits to city dwellers (Kumar et al., 2023).

In this sense, the green city sees urban centres as protagonists of change to achieve climate neutrality. The good practices examined show how the concept of sustainable mobility can be the basis for reversing the perspective of the classical city vision. However, in both cases, the main shortcoming concerns equity and the emergence of gentrification effects, in some cases already observed during the experiments and pilot projects. At the same time, what is interesting is the ability to combine strategic thinking and operational results through the definition of guidelines and the initiation of co-creation programmes with the community. The cases of Barcelona and Portland, high and low density respectively, address the issue of ecological transition through the reconstruction of environmental spatial continuity. The two cities examined, although in different contexts, recognise the environmental issue as a priority and become aware of it through the combination of strategic planning and operational actions, as well as the flexibility of urban planning instruments. However, in all likelihood, the actions taken by Barcelona sanction a new modus operandi in the treatment of urban nodes previously dedicated solely to automobile transit. Ultimately, in the absence of precise priorities and a spatialised vision of the urban context as a whole, a city perspective cannot be shaped simply by the paratactic application of a model designed at the scale of neighbourhoods, however locally harmonious it may be (Marchigiani & Bonfantini, 2022).

The desire for urban renaissance must invest urban nodes of autonomous value, on which a search for socio-ecological efficiency of the territory can be set. The unresolved, or partially resolved, problem concerns the interrelationships of the urban dilemma between common goals, strategies, and interests to define urban transformation interventions to activate circular economies and increase the quality of life. Given the interconnected nature of climate change and biodiversity loss, the overall vision of the city cannot disregard the conditions essential to ensure the flow of ecosystem services. This requires going beyond immediate responses to multiple crises and implementing a holistic social-ecological systems approach to urban planning and design based on transdisciplinary integration.

The idea is not only to create different models of urban and territorial functioning, but also to create hybrid places to strengthen the resilience, cohesion and mixing of settlement systems. Public space is not just the

extension of a street, but is what allows public, environmental, socio-cultural and economic needs to coexist. The quality of public spaces, the forms, specialisation and functioning of equipment and economic devices, the atmospheres, and the ways in which they are integrated into the system of urban centralities are at the core of the reflection on the future of the contemporary city (Alonso, 2013). However, quantity and access to green spaces are not enough; it is useful to recognise the quality of green spaces in fostering healthy lifestyles (Koohsari et al., 2023).

Moreover, the fragmentation of planning lines of action of some necessary policies demonstrates a complex and difficult synthesis at the local level to orient not only funding, but also converging objectives towards the right ecological transition. To this end, any urban strategy and policy must promote diversified settlement opportunities, respecting the conditions of environmental compatibility and possible new environmental and climate threats. This underpins spatial and functional flexibility in relation to the permeability of spaces and activities (Baratta, 2022). Therefore, urban centralities, places of living and natural environments identify networked urban spaces that cooperate with each other for a multi-scalar spatial project of sustainability on which the achievement of incremental goals hinge. It is a matter of intersecting ideas, evaluations and lines of work through which to consolidate the statute of the urban project aware of change and barycentric with respect to society's current development trajectories (Russo & Montedoro, 2022).

6.2 Research perspectives

Urban planning must start from new conditions and new visions educated by an awareness of urban complexity. In recent years, planning has been conditioned by a primarily large-scale approach, but urban quality cannot be entrusted exclusively to this level of planning. If we consider the quality of living and environmental issues as a synthesis between personal satisfaction and social justification, between creative processes and spatial performance, urban design can approach a new holistic and comprehensive approach. In this logic, it is possible to operate in the 'taxonomy of sustainable finance' by promoting investments for sustainable projects consistent with the objectives of the Green Deal and the Next Generation EU. This expresses an approach that intervenes in places according to a unified and coherent course of action respecting local conditions as well as interconnected functional systems.

The redesign of mobility infrastructure and public spaces is therefore significant. Quality of life and accessibility are indispensable for the new environmental role of public spaces. Indeed, conscious planning, based on the principle of sustainability and proximity, emphasises how major urban strategies are driven by community priorities. Thus, land use, its definition in the plan and the analyses carried out emphasise what future is envisioned for places and what ecological, climate and conservation covenants and challenges are to be addressed.

Rethinking the city is based on rebalancing the relationship between density, land use and sustainability, in which interventions transcend public-private space dichotomies through strategic spatial planning. It is not just a matter of identifying new ways of making cities, but of updating disciplinary paradigms through the synergy of extra-disciplinary knowledge. Urban planning, rather than supporting a wishful design, must be a process in which socio-economic dynamics, environmental issues and structural requirements are considered from the outset as priority conditions for the identification of sustainable urban projects. The intervention project (now more than ever) must demonstrate from the outset what objectives it intends to pursue and what benefits it can bring to wider contextual situations, in order to be validated as effective with respect to urban regeneration strategies. Urban planning will have to confront the question of 'coherence', not only with implementation tools, but also with spatial issues. According to this reading, the role of the plan becomes 'other' than the mere definition of areas, being enriched by new technical and scientific operations. The need arises to work jointly with standards and projects in which urban planning legislation introduces useful elements to pursue resilience issues for the city and the territory.

References

Abdelfattah, L., Deponte, D. & Fossa, G. (2021). The 15-minute city as a hybrid model for Milan. *TeMA - Journal of Land Use, Mobility and Environment*, 71-86. http://dx.doi.org/10.6092/1970-9870/8653

Acierno, A. (2021). Il pensiero rigenerativo e le Nature-based solutions: oltre il green design. *TRIA. Territory of research on settlements and environment*, 27 (2). https://doi.org/10.6092/2281-4574/8850

Ajuntament Barcelona (2023), Urban greenery and biodiversity, *Urban Planning, Ecological Transition, Urban Services and Housing*. Retrieved from: https://ajuntament.barcelona.cat/ecologiaurbana/en/what-we-do-and-why/green-city-and-biodiversity

Alberti, F., & Radicchi, A. (2022). The Proximity City: a comparative analysis between Paris, Barcelona and Milan. *TECHNE - Journal of Technology for Architecture and Environment*, 23, 69–77. https://doi.org/10.36253/techne-12151

Allam, Z., Bibri, S. E., Chabaud, D. & Moreno, C. (2022). The '15-Minute City' concept can shape a net-zero urban future. *Humanit Soc Sci Commun*, 9 (126). https://doi.org/10.1057/s41599-022-01145-0

Alonso, M. (2013). Qualification de l'espace public, commerce et urbanisme durable: notes sur le cas lausannois. *Revue Géographique de l'Est, Fonctions urbaines et respiration patrimoniale de la ville*, 53 (3-4). https://doi.org/10.4000/rge.5070

Baratta, A. F. L. (2022). Una nuova visione dell'abitare e degli spazi dell'abitare nel PNRR. *TECHNE - Journal of Technology for Architecture and Environment*, no. 24. https://doi.org/10.36253/techne-13435

Barcelona City Council Area of Ecology, Urban Planning and Mobility (2023), *Proximity to green space*, *Atlas de resiliència*. Retrieved from: https://coneixement-eu.bcn.cat/widget/atles-resiliencia/en_index_espais_verds.html

Battisti, F. (2023). SDGs and ESG Criteria in Housing: Defining Local Evaluation Criteria and Indicators for Verifying Project. Sustainability using Florence Metropolitan Area as a Case Study. *Sustainability*, 15(12), 9372, https://doi.org/10.3390/su15129372

BCNecologia, *Charter for the ecosystemic Planning of the Cities and the Metropolis*. Retrieved from: https://charterbcnecologia.wordpress.com/

Bocca, A. (2021). Public space and 15-minute city. A conceptual exploration for the functional reconfiguration of the proximity city. *TeMA - Journal of Land Use, Mobility and Environment*, 14 (3), 395-410. http://dx.doi.org/10.6092/1970-9870/8062

Boschma, R.A. (2005), Proximity and innovation. A critical assessment, *Regional Studies*, 39, 61-74. https://doi.org/10.1080/0034340052000320887

Bruno, D.M., Musante, G. & Decarro, F. (2023), Material for a debate on the 15-minute city: public transportation's effect on urban space and time in two Asia-based alternative proposals, *Journal of Asian Architecture and Building Engineering*. http://dx.doi.org/10.1080/13467581.2023.2287223

Caragliu, A. A. (2022). La città 15 minuti: una moda di gran richiamo mediatico? *ArcipelagoMilan,* 17. 1-8.

Carra, M., Rossetti, S., Tiboni, M. & Vetturi, D. (2022). Urban regeneration effects on walkability scenarios. An application of space-time assessment for the people-and-climate oriented perspective. *TeMA - Journal of Land Use, Mobility and Environment*, 101-114. http://dx.doi.org/10.6092/1970-9870/8644

Cialdea, D., Badami, A. A. (2017). Rigenerare la città multiscalare: trasformare i processi, innovare gli strumenti. In M. Carta, P. La Greca (Eds.), *Cambiamenti dell'urbanistica. Responsabilità e strumenti al servizio del paese*, 261-267, Roma: Donzelli Editore.

City of Portland (2014). *My Portland Plan: What Makes a Neighborhood Complete?* Retrieved from: http://www.portlandonline.com/portlandplan/index.cfm?a=437441&c=50730.

City of Portland (2023). *2035 Comprehensive Plan and Supporting Documents*. Retrieved from: https://www.portland.gov/bps/planning/comp-plan-2035/about-comprehensive-plan/2035-comprehensive-plan-and-supporting#toc-supporting-documents-and-maps

City of Portland, Bureau of Planning and Sustainability (2016). *Citywide Systems Plan*. Retrieved from: https://portland.gov/bps/planning/comp-plan-2035/documents/citywide-systems-plan/download

Crupi, V. (2015). *Spazio Pubblico e Progetto 'climate Proof': Verso Un Cambio Di Paradigma per L'urbanistica?* Trieste: Università degli studi di Trieste.

Eleutério, Y.F.P., Santos, D. M. dos & Silva, L.B.E. (2022). El paradigma de la sostenibilidad urbana: una discusión sobre la Ciudad de 15 minutos y el Desarrollo Orientado al Transporte Sostenible (DOTS), *Revista Latino-Americana De Ambiente Construído & Sustentabilidade*, 3(11). https://doi.org/10.17271/rlass.v3i11.3389

Errante, L. (2023), *Abitare lo spazio pubblico sostenibile. Democrazia, Design Tecnologia*, Aracne, Roma.

Ferrer-Ortiz, C., Marquet, O., Mojica, L., Vich, G. (2022), Barcellona sotto la lente della città in 15 minuti: mappatura del potenziale di accessibilità e prossimità basato sui tempi di percorrenza pedonale. *Smart Cities*, 5, 146-161. https://doi.org/10.3390/smartcities5010010

Fratini, F. (2023). The Eco-Pedagogical Microforest a shared oasis of proximity. A cutting-edge project at the intersection of ecology, urbanism and pedagogy. *TeMA - Journal of Land Use, Mobility and Environment*, 33-54. http://dx.doi.org/10.6092/1970-9870/10055

Gabellini, P. (2001). *Tecniche urbanistiche*, Roma: Carocci.

Gaglione, F. (2022). Accelerating sustainable urban transition: European climate action. *Tema. Journal of Land Use, Mobility and Environment*, 15(1), 149-156. https://doi.org/10.6093/1970-9870/9044

Geels, F, Kemp, R, Dudley, G, Lyons, G (2011). *Automobility in transition? A socio-technical analysis of sustainable transport*. New York: Routledge.

Giaimo, C. (2023), "Prossimo (e complesso)", *Urbanistica Informazioni*, no. 310, 5-6, Roma: INU Edizioni.

Hickman, R., Banister, D. (2014). *Transport, climate change and the city*, London-New York: Routledge, https://doi.org/10.4324/9780203074435

Khavarian-Garmsir A.R., Sharifi A. & Sadeghi A. (2023). The 15-minute city: Urban planning and design efforts toward creating sustainable neighbourhoods. *Cities*, 132. https://doi.org/10.1016/j.cities.2022.104101

Koohsari, M.J., Kaczynsky, A.T., Oka, K. (2023). Residential greenspace and health: quantity or quality? *The Lancet. Planetary Health*. https://doi.org/10.1016/S2542-5196(23)00187-0

Kumar, A., Ekka, P., Upreti, M., Saika, P., Saikia, S. (2023), Urban green space for environmental sustainability and climate resilience. In Nautiyal S., Gupta A.K., Goswami M. & Imran Khan Y.D. (Eds.), *The Palgrave Handbook of socio-ecological resilience in the face of climate change*, Singapore: Palgrave Macmillan. https://doi.org/10.1007/978-981-99-2206-2_23

Lopito, A., Falcone, P. M., Sica, E. (2022). The role of proximity in sustainability transitions: A technological niche evolution analysis, *Research Policy*, 51 (3). https://doi.org/10.1016/j.respol.2021.104464

Maciocco, G, Tagliagambe, S (2009). *People and space. New forms of interaction in city projects*. Verlag, Heidelberg, Berlin, New York: Springer. https://doi.org/10.1007/978-1-4020-9879-6

Maciocco, G., Sanna, G., Serreli, S. (2011). *The urban potential of external territories*. Milano: FrancoAngeli.

Magrinyà, F., Mercadé-Aloy, J., Ruiz-Apilánez, B. (2023). Merging Green and Active Transportation Infrastructure towards an Equitable Accessibility to Green Areas: Barcelona Green Axes, *Land*, 12(4):919. https://doi.org/10.3390/land12040919

Manzini, E. (2021). *Abitare la prossimità. Idee per la città dei 15 minuti*, Milano: Egea

Marchigiani, E., Bonfantini, B. (2022). Urban Transition and the Return of Neighbourhood Planning. Questioning the Proximity Syndrome and the 15-Minute City, *Sustainability*, 14(9):5468. https://doi.org/10.3390/su14095468

Mascarucci, R. (1998). *Immaginare l'incertezza. Le nuove visioni dell'urbanistica debole*, Pescara: Sala Editori

Meschik, M. (2012). Reshaping city traffic towards sustainability Why transport policy should favour the bicycle instead of car traffic, *Procedia-Social and Behavioral Sciences*, 48, 495-504. https://doi.org/10.1016/j.sbspro.2012.06.1028

Moreno C. (2020), *Vie urbaine et proximité a l'heure du Covid-19*, Éditions de l'Observatoire, Paris.

Moreno C. (2023), *La città dei 15 minuti. Per una cultura urbana democratica*, add editore, Milano.

Nieuwenhuijsen, M.J. (2018), New urban models for more sustainable, liveable and healthier cities post covid19; reducing air pollution, noise and heat island effects and increasing green space and physical activity, *Environment International*, 157. https://doi.org/10.1016/j.envint.2021.106850

PBOT. Portland Bureau of Transportation's (2023). *StreetPDX*. Retrieved from: https://pbotapps.portland.gov/streets-pdx/

Pede, E., Scalas, M., Staricco, L. (2023), Towards Neighbourhoods as Minimum Units of Resilience? In G. Brunetta *et al.* (Eds.), *Post Un-Lock. From Territorial Vulnerabilities to Local Resilience, The Urban Book Series*, Switzerland: Springer Nature. 71-80. https://doi.org/10.1007/978-3-031-33894-6_6

Pisapia, L. (2021), The role of environmental infrastructure in the future of the contemporary city, starting with the case of Milan, *TRIA*, 27(2). https://doi.org/10.6092/2281-4574/8820

Pozoukidou, G.; Chatziyiannaki, Z. 15-Minute City: Decomposing the New Urban Planning Eutopia. *Sustainability* 2021, *13*, 928. https://www.mdpi.com/2071-1050/13/2/928

Pultrone, G. (2024). Transform Active Cities facing the ecological transition. Cha(lle)nges, practices and scenarios in the EU Panorama. *Tema. Journal of Land Use, Mobility and Environment*, SI 1, 79-96. http://dx.doi.org/10.6093/1970-9870/10210

Russo, M., Montedoro, L. (2022). *Fare urbanistica oggi*, Roma: Donzelli editore.

Scheiber, S., Zucaro, F. (2023). Urban open and green spaces: is Malta planning and designing them to increase resilience. *Tema. Journal of Land Use, Mobility and Environment,* 16 (2), 331-352. http://dx.doi.org/10.6093/1970-9870/9951

Shearmur, R. (2021). The 15-minute city is not a city. Retrieved from: shearmur.ca/2021/03/01/

Steuteville, R. (2023). The 15-minute neighbourhood gets its 15 minutes of fame, *Public Square. A CNU Journal*. Retrieved from: https://www.cnu.org/publicsquare/2021/01/25/15-minute-neighborhood-gets-its-15-minutes-fame

Talia, M. (2021). Vecchi e nuovi temi dell'urbanistica riformista, *Urbanistica Informazioni*, Retrieved from: http://www.urbanisticainformazioni.it/Vecchi-e-nuovi-temi-dell-urbanistica-riformista.html

UN-United Nation, Department of Economic and Social Affairs (Statistic division) (2017), Framework for the Development of Environment Statistics (FDES, 2013), series M, no. 92. Retrieved from: https://unstats.un.org/unsd/environment /fdes/FDES-2015-supporting-tools/FDES.pdf

Valentino, M., Lutzoni, L. (2020), Among territorial projects and architectural design, *City, Territory and Architecture*, 7 (7). https://doi.org/10.1186/s40410-020-00115-w

Vitullo, P. (2022). Servizi di prossimità, *Urbanistica Informazioni*, no. 302.

Yigitcanlar, T., Teriman, S. (2015). Rethinking sustainable urban development: towards an integrated planning and development process. *Int. J. Environ. Sci. Technol.* 12, 341-352. https://doi.org/10.1007/s13762-013-0491-x.

Image Sources

Fig.1: Key component and benefits of proximity city. Author's elaboration.

Fig.2: Ecological transition and proximity city: the role of new public space. Author's elaboration.

Fig.3: Urban design framework. 2035 Comprehensive plan. Source: City of Portland (May 2023). Retrieved from: https://www.portland.gov/bps/planning/comp-plan-2035
Fig.4: Green hubs planned for the Barcelona Superblock programme. Source: Gerència d'Àrea d'Ecologia Urbana, Consell Municipal de Barcelona, BCN Ajuntament Barcelona. Retrieved from: https://bcnroc.ajuntament.bar celona.cat/ jspui/handle/11703/126250

Author's profile

Antonio Bocca

Antonio Bocca (1992), architect and urban planner, PhD in 'Earth Systems and Built Environments' at the Dd'A-Department of Architecture, "G. d'Annunzio" University Chieti-Pescara. His research concerns urban regeneration and the quality of public space. His contributions are published in books, journals, and proceedings of national and international conferences. He has collaborated in several national research projects, in particular 'Abruzzo2020', 'Medium-Sized Cities and Regional Metropolises', 'Methodological Guidelines for the elaboration of Extraordinary Reconstruction Programs (PSR) and Planning Activities for Reconstruction'. He is a member of INU (National Institute of Urban Planning). He is currently secretary of INU-Abruzzo&Molise and a board member of AssoBiSP (Biennial Public Space Association).

TeMA Journal of Land Use, Mobility and Environment

TeMA 1 (2024) 89-108
print ISSN 1970-9889, e-ISSN 1970-9870
DOI: 10.6092/1970-9870/10458
Received 24th November2023, Accepted 18th March 2024, Available online 30th April 2020

Licensed under the Creative Commons Attribution – Non Commercial License 4.0
http://www.serena.unina.it/index.php/tema

Spatial attractiveness towards industrial placement: a parametric index based on spatial-economic territorial exposure metrics

Diego Altafini [a]*, Valerio Cutini [b]

[a] Welsh School of Architecture
Cardiff University, Cardiff, UK
e-mail: altafinid@cardiff.ac.uk

Dipartimento di Ingegneria dell'Energia, dei Sistemi, del Territorio e delle Costruzioni
Università di Pisa, Pisa, Italy
ORCID: https://orcid.org/0000-0002-6559-2372
* Corresponding author

[b] Dipartimento di Ingegneria dell'Energia, dei Sistemi, del Territorio e delle Costruzioni
Università di Pisa, Pisa, Italy
e-mail: valerio.cutini@ing.unipi.it
ORCID: https://orcid.org/0000-0003-4065-6226

Abstract
The asymmetrical process of industrial development tends to increase regional disparities and result in different patterns of territorial exposure: the amount of support given to activities placed within industrial agglomerates. Spatial Attractiveness towards industrial placement tends to follow such patterns, as places with lower exposure tend to be more attractive, providing more support to productive activities. Spatial models based in economic methods have issues in precising the nature of Spatial Attractiveness disparities, as their interpretation of space as an abstracted parameter, provides insufficient locational precision to demonstrate these patterns and how those are dependent on relations between production, territorial endowments, and industrial agglomerates' internal organization. Novel spatial-economic models ought to consider and incorporate spatial units reflecting the microfoundations of space while providing an accurate spatialization, crucial aspects to create knowledge useful for decision-making. Hence, the paper showcases spatial models tailored to address the differences in Spatial Attractiveness, based in spatial and economic territorial exposure indexes, to unveil the territorial-imbalances' spatial logics. Organized in a GIS-based environment and using Tuscany as a proof-of-concept, the index-models identified factors of sensitivity or support to firms placed within industrial agglomerates providing an overview of spatial attractiveness within the territory, useful for supporting decision-making practices.

Keywords
Territorial disparities; Spatial attractiveness; Territorial exposure; Urban and regional planning; Industry

How to cite item in APA format
Altafini, D. & Cutini, V. (2024). Spatial attractiveness towards industrial placement: a parametric index based on spatial-economic territorial exposure metrics. *TeMA - Journal of Land Use, Mobility and Environment*, *17* (1), 89-109. http://dx.doi.org/10.6092/1970-9870/10458

1. Introduction

Urban-regional spaces have industrial areas as one of their fundamental substructures. It is within these spaces of production that the values destined to sustain and reproduce urban economies, the commercial exchanges, and several other services related to city-life, are created (Lefèbvre, 1974). Upon this assumption, it is logical to associate industrial growth or decline to the development or retrogression of other urban functions, such as residential or retail spaces, in a manner that defines these industrial areas as the real and proper drivers of modern-era urban-regional development (Lefèbrve, 1966; 1974).

From this perspective, the industrial agglomerates location within urban-regional territories possess a recursive role regarding their spatial organization: the industrial activities will locate themselves near or within important market and consumption nodes – the cities – and their development will have an influence on the successive industrial agglomeration, conducing to their further growth; plus this expansion will also influence the public policies of investment in infrastructure, resulting in circular and reiterative relationships of growth between cities and industry. Even though desired from a developmental standpoint, these iterations in urban-regional growth also tend to increase the territorial disparities. The asymmetrical regional development patterns may lead to a condition of underuse or straight forward abandonment of potentially productive spaces, that can result in urban-regional environments' exposition to grave socio-economic pressures, such as unemployment and populational decline (Smith, 2008).

While this interdependence between spatial location and development was quite discussed since the Regional Economics introduction as a rationale in the late 19th century, economists' analytical efforts in that matter have been rather restricted to identifying of what is where – and why? at macro-territorial scales; in comparative evaluations of the microeconomic factors regarding costs, production and growth (Weber, 1909; Christaller, 1933; Alonso, 1964; Mills, 1987; Duranton et al., 2015). In that aspect, regional economics maintained a rather unchanging approach – to both theory and space – throughout the 1900-1970 period, firmly based on mainstream economics and its neoclassical theory principles.

The predominance of such overviews, and the historical detachment among economic-based and territorial-geographic-based studies, were in the background of a heated debate regarding the flaws and limitations of the neoclassical synthesis approach (Sraffa, 1925; 1926; 1960; Samuelson, 1947; 1966; Solow, 1956; Lucas, 1976; Pasinetti, 2000). These issues were deemed structural for economics, challenging its very foundations in the period between crisis (1970-1990), enclosing the science in itself, and resulting in limited methodological developments for its marginal fields founded in neoclassical principles, such as regional economics. Hence, few spatial-economic analyses incorporated methods that can describe spaces with sufficient detail, or how the disparities in territorial endowments can affect economic activities placement. In economics, space is more than often defined and interpreted as an abstracted background – or a region that is homogeneous in its innermost territorial characteristics yet, that is assumed to have different economic characteristics from other regions (Altafini & Cutini, 2021; Altafini, 2022).

This abstracted spatial representation of territories can be identified as one of the causes for the discontinuities in spatial-economic models' progress and the production of spatial knowledge in spatial economics and its related fields; present even when the most recent approaches from New Economic Geography are considered (Krugman et al., 1999; Duranton et al., 2015; Altafini, 2022). Paul Krugman (1991) states that this seems to arise from the apparent "neglect" of these branches by mainstream economics – a conclusion which concurs with the hypothesis of a *crisis* in economic thought, following the initial *neoclassical synthesis* consensus. In other hand, Jacques-François Thisse (1998), argue that the economists regarded space – in reality, the territorial characteristics within a region – as intractable in their economic models, given a limitation on spatial-economic methodologies. In that regard, comparative models with limited territorial detail – such as locational quotients (shift-share models) – are still revered, being used on most regional analysis; those, however, tend to ignore the actual territorial setting in which economic activities exist, not because these are considered

unimportant, but simply because they are unable to consider it (Thisse, 1998; Altafini, 2022). This issue, associated to economics' reluctance in the adoption of novel instruments and computational methods that interpret space at a greater level of detail – as those developed for Geography, Architecture and Urban and Regional Planning, has left fundamentally unexplored several spatial-economic relations among production systems, the importance of spatial configuration of infrastructural networks, and the organization of economic activities and industrial agglomerates at local scales.

Awareness of these limitations and issues on the current regional economics – and even in Contemporary takes on Economic Geography (Boschma, 2005; 2015), which partakes in the same problems – ought to conduce to novel models capable to assess the complex spatial behaviours and the territorial disparities within industrial agglomerates placed on urban-regional settings. It is necessary then to consider the infrastructural dimensions of space, a transformation that also depends on how economics understand space and create and interpret spatial knowledge. This achieves an unprecedented relevance, as surpassing the analysis limitations of Urban and Regional Economics' spatial models is fundamental to further planning, plus to the successful outcome of post-crisis economic recovery policies.

Based on these issues and foreseeing the future concerns regarding urban-regional analysis, this paper – and the thesis from it derives: Spatial-economic models to evaluate industrial agglomerations: novel instruments for urban-regional analysis (Altafini, 2022); proposes to develop novel spatial-economic methods and models that are more adapted to evaluate the logics of industrial agglomerations, highlighting the motives behind the territorial disparities. Therefore, it is crucial to establish the parameters – or the "spatial microfoundations" – that differentiate the territories and the productive spaces. Based on this premise, this paper discusses the concept of Spatial Attractiveness, and the supporting concept of Territorial Exposure.

Territorial Exposure defines the amount of support given towards the economic activities' placement within the territory, where insufficient support characterizes a degree of exposure to the everchanging economic cycles (Altafini & Cutini, 2021; Altafini, 2022). Exposure can be of spatial nature: given by the organization of territories, the endowments in them (built structures and road-circulation networks); and of economic nature, where the presence of capital and labour contributes to the total amount of support. In other hand, Spatial Attractiveness is interpreted as the sum of positive and negative conditions of Territorial Exposure that will result in the combined support from space and economics – a high overall Exposure will be then equivalent to a low overall Attractiveness. The paper then describes the steps for the construction and an application of the Spatial Attractiveness Index (SAi) a parametric, unweighted general linear model that comprises the partial indices of Spatial and Economic Territorial Exposure Indexes (sTEi and eTEi). The sTEi represents the amount of spatial-derived territorial exposure, associated to the infrastructural support – cohesiveness, agglomeration, and road-network centrality – provided by a territory to the placed economic activities. The eTEi represents, instead, the amount of economic-derived territorial exposure, derived from the distribution of capital and labour in the territory. Those partial indices are also unweighted. The Spatial Attractiveness Index (SAi) then denotes the amount of attractiveness that a territory has towards the placement of industrial activities, given the overall presence or absence of support from the structural-territorial and spatial-economic standpoints.

Formally, the Spatial Attractiveness Index can be defined as:

$$SA_i = sTE_i + eTE_i \quad (1)$$

The paper is structured in four sections: this first introductive part; the section two, that describes and explains the datasets and methods used for the indexes' construction; the section three, that consists of the proof-of-concept, with the application of the SA_i for Tuscany, and the section four, that make the conclusive remarks about the objectives, as well as point out to further research.

2. Datasets and Methods

The datasets used for constructing the Spatial Attractiveness Index (SAi) as well as both Territorial Exposure Indexes (sTEi & eTEi), were organized into a GIS suite (QGIS, 2022), which rendered them suitable for spatial modelling. The section 2.1 describes the used datasets, their pre-processing and extraction methods, as well as the geoprocessing steps. The section 2.2, instead, consists in an overview of the parameters used in the indexes' construction, as well as a brief explanation of the indexes' scoring methods.

2.1 Datasets organization

Part of a multi-domain model, the Spatial Attractiveness Index (SAi) combines a series of spatial and economic parameters defined in the partial indexes that represent Territorial Exposure patterns. Hence, the data used to construct the SAi index can be divided into two groups: spatial-based datasets and economic-based datasets (Altafini, 2022), each with their own particularities.

The spatial datasets comprehend information about Tuscany's territorial endowments – or the characteristics in terms of the morphology and organization of its built structures. Fundamentally, those datasets spatialize Tuscany's industrial assets' distribution and the extension of its road-circulation infrastructure, both used as parameters to construct the Spatial Territorial Exposure Index (sTEi) (Altafini, 2022).

Industrial assets are extracted from Tuscany Region's Built-Structures dataset (Edificato 2k, 10k 1988-2013) (Regione Toscana, 2019a), that outlies the location of all structures set throughout the territory and represent them as volumetric units (polygons) categorized in accordance with their main function. This dataset spans across multiple scales, being assembled from different technical charts (scales 2k and 10k) and is periodic, thus collected over a time-period comprised between 1988 and 2013. For this analysis purpose, only volumetric units categorized under "Industrial" (Industriale) or "Technological Plant" (Impianto Tecnologico) and that are listed as "active" in the post 2013 period are considered as industrial assets. The data was exported from the main dataset and organized in the GIS-suite (Altafini, 2022). The spatial information about the industrial assets is used into the construction of spatial units (Macroareas) – which territorialize the industrial presence within the territory and is used to address aspects related to territorial size and the dynamics of industrial placement and agglomeration. Plus, it serves as basis to enact spatial correlations and incorporate the economic variables (Fig.1).

The road-circulation network dataset employed in the Configurational and Network Analysis derives from the Tuscany Region's Road Graph (Grafo Stradario della Toscana) (Regione Toscana, 2019b), a Road-Centre Line (RCL) graph map that represents the entire regional road-infrastructure. Road-elements were generalized through QGIS integrated Douglas-Peucker algorithm (QGIS, 2022; Altafini & Cutini, 2020) to diminish the total number of vertices and reduce the extensive network modelling time-lapses for Space Syntax' Angular Analysis (Turner, 2001; Altafini, 2022) and for Markov-based network analyses (Altafini et al., 2022; Altafini, 2022).

Angular Analyses can address different kinds of network properties and highlight the urban-regional centralities hierarchies through the configurational measures of Normalized Angular Integration – NAIN (mathematical closeness centrality) and Normalized Angular Choice – NACH (mathematical betweenness centrality) (Hillier et al., 2012) (Tab.1). Those metrics can estimate the movement dynamics within the road system by attributing a value to each road-element and can visualize the local and global patterns of connectivity, accessibility, and proximity within the industrial areas, important for promoting the inter-industrial interactions (Boschma, 2005; Altafini, 2022). Associated to the Space Syntax classic metrics, two novel network measures were developed, based on Markov-Chain principles, to highlight network properties related to the structure of road-elements' importance as connectors within the road-infrastructure: the Normalized Page-Rank Centrality – NPRC and the Normalized Kemeny-based Centrality – NKBC. Based on the properties of strong and weak-ties, (Granovetter, 1973; Altafini, 2022) these metrics visualize the global patterns of road-element importance (NPRC) and overall system redundancy (NKBC) within the network, important aspects regarding Territorial Exposure as the

interruption of these elements can lead to a general collapse in terms of accessibility-to-and-within the industrial spaces (Tab.1).

Metric	Formula (Normalized)	Concept	References
Normalized Angular Integration (NAIN)	$NAIN = \frac{Node\ Count^{1.2}}{Total\ Depth}$	Measure the farness between elements in a network; in space syntax, denotes the relative accessibility or movement potential of a road-element, as it informs how close – in topological terms – a road-element is in relation to the others.	Bavelas, 1950; Sabidussi, 1966; Hillier, 2007; Hillier et al, 2012; Altafini, 2022
Normalized Angular Choice (NACH)	$NACH = \frac{\log(Angular\ Choice + 1)}{\log(Total\ Depth + 3)}$	Measures the number of times a certain network element is traversed when moving through the shortest paths from all origin-destination pairs of elements within the network. In *space syntax*, it denotes the hierarchy of *preferential routes* throughout the system.	Freeman, 1977; 1978 Freeman et al.,1979; Hillier, 2007; Hillier et.al, 2012; Altafini, 2022
Normalized Page-Rank Centrality (NPRC)	$PRC_{ij} = \mu_i P_{ij} + \mu_j P_{ij}$ $NPRC = \frac{(PRC * NC) - \wedge(PRC * NC)}{\vee(PRC * NC) - \wedge(PRC * NC)}$	Measures the most important elements within the network, given their own score and the connected elements scores. It denotes the most *strong-tied* road-elements in the network.	Page et al. 1999; Altafini et al., 2022; Altafini et al, 2023
Normalized Kemeny-based Centrality (NKBC)	$KBC_{ij} = k\hat{P} - k(P)$ $NKBC = \frac{KBC' - \wedge KBC'}{\vee KBC' - \wedge KBC'}$	Measures the overall network redundancy, scoring higher the road-elements that establish the weak-ties or bridges between groups of road-elements. NKBC scores the road-elements based on their redundancy, it indicates which elements that, if removed from the network, can lead to a more probable system collapse in terms of connectivity.	Kemeny, Snell, 1960; Altafini et.al. 2022; Altafini et al, 2023

Tab.1 Overview of the configurational and Markov-based network analysis methods

Economic datasets, on the other hand, contain information used to describe the territorial distribution of capital and labour within Tuscany, thus, to construct the Economic Territorial Exposure Index (eTEi). These datasets, while not spatial, can be spatialized through their association to the spatial units used in their data collection – the ISTAT census zones (ISTAT, 2016; Altafini, 2022).

Labour-related variables are obtained from the Italian Industrial and Services Census (Censimenti ISTAT dell'industria e servizi), for the periods of 2001 and 2011 (ISTAT, 2001; 2011; 2016) datasets, and used to address the territorial distribution and density of Local Units (Firms), Number of Employees; plus, the Average Firm-Sizes, this last established from the ratio between Local Units and Employees for each census zone (Altafini & Cutini, 2021b; Altafini, 2022). These datasets are organized in a GIS-based environment (QGIS, 2022) (Fig.1) and, since the data tables (.csv) and their spatial data counterparts (.xls) are placed in different files, a spatial join needs to be performed to assemble the table datum to its respective spatial position, only then permitting variables' manipulation and spatialization. Local Units, Employees and Average Firm-Size variables are used as parameters for the construction of the eTEi attributed to each census zone. The spatialization is further restricted to the Macroareas, to represent only the areas with industrial presence (Fig.1).

The datasets from the Osservatorio del Mercato Immobiliario (OMI) (Agenzia delle Entrate, 2018) are used as a proxy variable to describe the amount of Installed Capital within a certain territory. This variable considers the average real-estate values – in this case, real-estate assets with a productive function – surveyed within a delimited spatial unit and aggregated for the 2002-2020 period. Methodological procedures to construct the OMI values have been described in detail on Altafini et.al. (2021); Altafini & Cutini (2022) and Altafini (2022) and result in the €/m^2 ranges described in section 2.2 (Table 6, p.9), from Very Low to Very High (Fig.1). The OMI values are used as parameters in the eTEi, with their data attributed to each census zone. Likewise, as in the eTEi's Labour component, OMI data is spatially restricted to each Macroarea to represent only the areas with industrial presence within Tuscany.

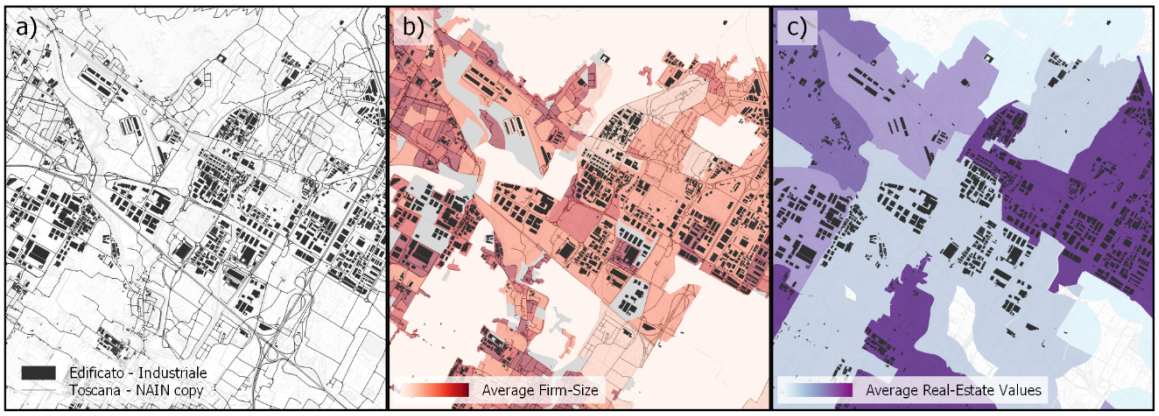


Fig.1 Datasets Spatialization (a) Industrial assets and Road-Circulation Networks; (b) Average Firm-Sizes spatialized into Census Zones and (c) OMI Average Real-Estate values spatialized into a Macroarea restricted representation

Tuscany is an interesting case study, as a representative of the Third Italy (Bagnasco, 1977), which combines larger, medium, and small industrial areas, often scattered throughout the territory. Moreover, it has important road-circulation network differences in terms of density, thus, distinct patterns of infrastructure distribution.

2.2 The Spatial Attractiveness Index structure – sTEi & eTEi methodology

The Spatial Attractiveness Index (SAi) is a General Linear Model (GLM) derived from the unweighted sum of the value ranges established in the Spatial Territorial Exposure Index (sTEi) and Economic Territorial Exposure Index (eTEi). For each TEi, the value ranges are defined from the standardized – unweighted – sum of the modelled parameters that indicate Territorial Exposure (Altafini, 2022). The choice behind using unweighted indices was to provide an unbiased representation of Territorial Exposure, as defined solely by their territorial characteristics without giving a parameter more importance than the reminder.

The sTEi denotes the amount of territorial support that comes from the spatial distribution and organization of the built-structures and road-infrastructure within the territory. This index is derived from the attribution of scores for the following spatial parameters, derived from morphological, configurational, and network structure analysis: The Macroarea Size (Si) and Agglomeration (Ai), which are morphological properties given by the patterns of industrial assets, industrial spaces and macroareas territorial distribution; the NAIN (Ii) and NACH (Ci), configurational properties that indicate the spatial proximity correlations between the macroareas and the highest valued centralities of relative accessibility and preferential routes; and the NPRC (Pi), and NKBC (Ki), Markov-based network properties that indicate the spatial proximity correlation between macroareas and the important road-elements (strong-tied and weak-tied) in the network structure.

Henceforth, the sTEi is defined as (see Tab.2 for value ranges and Tab.3 and 4 for numerical breakdown):

$$sTE_i = S_i + A_i + I_i + C_i + P_i + K_i \quad (2)$$

The numerical ranges for this parametric index sum are set between -6 to 8, allocated in each numerical range through the natural breaks' algorithm (Jenks & Caspall, 1971; Jenks, 1977), which are then standardized between -2 and 2 to correspond to a defined degree of exposure set within the Very Low and Very High ranges (Tab.2). This sTEi iteration differs from the first TEi discussed in Altafini & Cutini (2021a), since here negative values are not defaulted to zero but, instead, considered as they are for the construction of the categorizations.

Categorization – sTEi	Numerical Ranges	Standardized Ranges	Colour Ranges
Very High Territorial Exposure	Inferior or equal to -4	-2	Red
High Territorial Exposure	Between -4 and 0	-1	Orange
Moderate Territorial Exposure	Between 0 and 3	0	Yellow
Low Territorial Exposure	Between 3 and 6	1	Lime
Very Low Territorial Exposure	Superior or equal to 7	2	Green

Tab.2 Spatial Territorial Exposure Index (sTEi) – Ranges and Categorization

A breakdown of the parameters, in terms of their distribution within the spatial units (macroareas), and relation with the number of industrial assets and spaces provides an overview of the results attained for each of the partial analyses (Tables 3 and 4). An in-detail analysis regarding the sTEi spatial distribution (Fig.2, p.8), that furthers on the factors behind the spatial patterns can be found on Altafini & Cutini (2021); and Altafini (2022).

Parameter	Scores	Spatial Unit Count	(%)	Industrial Assets	(%)	Industrial Spaces	(%)
Si - Macroarea Size							
Isolated Macroarea	-1	430	31.48%	430	0.54%	430	2.76%
Small Macroarea	0	848	62.08%	8,905	11.17%	2,861	3.59%
Medium Macroarea	1	85	6.22%	23,086	28.95%	4,942	6.20%
Large Macroarea	2	3	0.22%	47,326	59.35%	7,328	47.09%
Ai - Agglomeration Index							
Single Units	-1	584	42.75%	829	1.04%	829	5.33%
Low Agglomeration	0	49	3.59%	353	0.44%	283	1.82%
Medium Agglomeration	1	533	39.02%	8,120	10.18%	3,445	22.14%
High Agglomeration	2	200	14.64%	70,445	88.34%	11,004	70.72%
Ii - Road- Network NAIN							
No - Spatial Correlation	-1	1,148	84.04%	15,714	19.70%	4,805	30.88%
Yes - Spatial Correlation	1	218	15.96%	64,033	80.30%	10,756	69.12%
Ci - Road- Network NACH							
No - Spatial Correlation	-1	261	19.11%	609	0.76%	406	2.61%
Yes - Spatial Correlation	1	1105	80.89%	79,138	99.24%	15,155	97.39%
Pi - Road- Network NPRC							
No - Spatial Correlation	-1	117	8.57%	211	0.26%	159	1.02%
Yes - Spatial Correlation	1	1,249	91.43%	79,536	99.74%	15,402	98.98%
Ki - Road- Network NKBC							
No - Spatial Correlation	-1	271	19.84%	815	1.02%	459	2.95%
Yes - Spatial Correlation	1	1,095	80.16%	78,932	98.98%	15,102	97.05%

Tab.3 Spatial Territorial Exposure Index (sTEI) – scores, macroareas count, number of Industrial Assets and number of Industrial Spaces for each parameter

Spatial Territorial Exposure Index	Macroarea Count	(%)	Total Area [km^2]	(%)
Very High Territorial Exposure	120	8.78%	100.89	2.28%
High Territorial Exposure	383	28.04%	356.50	8.04%
Moderate Territorial Exposure	556	40.70%	903.60	20.38%
Low Territorial Exposure	285	20.86%	1,339.64	30.22%
Very Low Territorial Exposure	22	1.61%	1,732.69	39.08%

Tab.4 Spatial Territorial Exposure Index (sTEI) – Macroareas count and total territorial area.

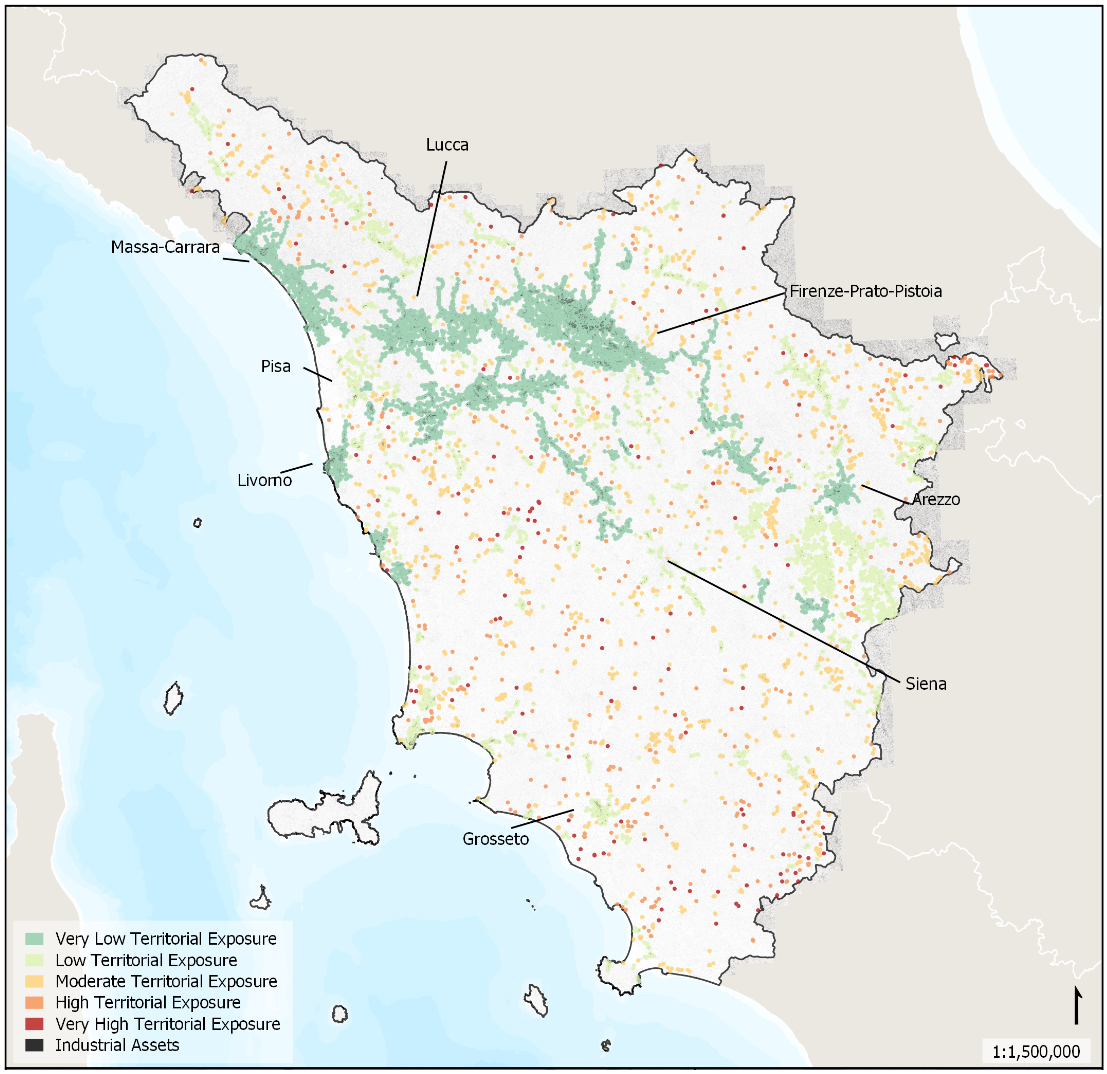


Fig.2 Spatial Territorial Exposure Index (sTEi) distribution patterns within the Tuscany region

The eTEi denotes the amount of territorial support that comes from the economic conditions, related to labour and capital distribution, within the territory. This is assembled though the attribution of scores for the following economic parameters: the Territorial density of Local Units (Firms) (Fi), Territorial density of Employees (Ei), Average Firm-Size Density (Zi), all associated to labour; and the average real-estate values given by the OMI real-estate values (Oi), that represent a proxy for the installed capital throughout the region.
Henceforth, the eTEi is defined as (see Tab.5 for value ranges and Tab. 6 and 7 for numerical breakdown):

$$eTE_i = F_i + E_i + Z_i + O_i \quad (3)$$

The value ranges for this parametric index slightly differ from its spatial counterpart being set from -8 to 8, allocated in each numerical range through the natural breaks' algorithm (Jenks & Caspall, 1971; Jenks, 1977), yet they are also standardized between -2 and 2, to correspond to defined degrees of exposure that range from Very Low to Very High.

Another important aspect, particular to the eTEi is that several spatial units do not possess observations – due to the lack of census data, hence a category of "No Data" had to be created. The categorizations for the eTEi are defined as (Tab.5, p.9):

Categorization – eTEi	Numerical Ranges	Standardized Ranges	Colour Ranges
No Data	Null values	-	Grey
Very High Territorial Exposure	Inferior or equal to -3	**-2**	**Red**
High Territorial Exposure	Between -3 and 0	**-1**	**Orange**
Moderate Territorial Exposure	Between 0 and 3	**0**	**Yellow**
Low Territorial Exposure	Between 3 and 6	**1**	**Lime**
Very Low Territorial Exposure	Superior or equal to 7	**2**	**Green**

Tab.5 Economic Territorial Exposure Index (eTEi) – Ranges and Categorization

Parameter	Scores	Spatial Unit Count	(%)	Industrial Assets	(%)	Industrial Spaces	(%)
Local Units (Firms) – Fi							
No Data	-	6,448	17.50%	3,894	4.88%	1,289	8.29%
Very Low Density	-2	9,181	24.92%	10,030	12.58%	4,067	26.15%
Low Density	-1	4,690	12.73%	13,587	17.04%	2,872	18.47%
Medium Density	0	9,431	25.60%	38,773	48.64%	5,595	35.98%
High Density	1	3,033	8.23%	8,704	10.92%	1,046	6.73%
Very High Density	2	4,057	11.01%	4,727	5.93%	683	4.39%
Number of Employees – Ei							
No Data	-	6,514	17.68%	3,894	4.89%	1,289	8.29%
Very Low Density	-2	7,808	21.19%	6,213	7.80%	3,072	19.76%
Low Density	-1	3,350	9.09%	4,402	5.53%	1,590	10.23%
Medium Density	0	7,221	19.60%	16,235	20.38%	3,957	25.46%
High Density	1	3,603	9.78%	15,261	19.16%	2,455	15.79%
Very High Density	2	8,344	22.65%	33,661	42.25%	3,181	20.46%
Firm-Size (Average) – Zi							
No Data	-	6,514	17.68%	3,943	4.95%	1,297	8.34%
Very Low Density	-2	8,615	23.38%	8,833	11.08%	3,956	25.44%
Low Density	-1	1,590	4.32%	8,543	10.72%	1,769	11.37%
Medium Density	0	8,620	23.40%	38,860	48.75%	5,781	37.17%
High Density	1	4,021	10.91%	10,100	12.67%	1,490	9.58%
Very High Density	2	7,480	20.30%	9,436	11.84%	1,259	8.10%
OMI Values (Capital) – Oi							
No Data	-	0	0.00%	0	0.00%	0	0.00%
Very Low Real-Estate Value	-2	9,928	26.95%	10,458	13.12%	3,238	20.82%
Low Real-Estate Value	-1	8,155	22.14%	21,078	26.44%	4,003	25.74%
Medium Real-Estate Value	0	5,526	15.00%	17,254	21.64%	3,331	21.42%
High Real-Estate Value	1	6,494	17.63%	17,429	21.86%	2,730	17.55%
Very High Real-Estate Value	2	6,737	18.29%	13,496	16.93%	2,250	14.47%

Tab.6 Economic Territorial Exposure Index (eTEI) – scores, macroareas count, number of Industrial Assets and number of Industrial Spaces for each parameter

A breakdown of the parameters, in terms of their distribution within the spatial units (census zones), provides an overview of the results attained for each of the partial analyses (Tab.6 and 7).

A further breakdown of the spatial relation of labour and capital with the number of industrial assets and spaces can be found on Altafini (2022). The spatialization of the eTEi is displayed on Fig.3 (p.10).

Economic Territorial Exposure Index	Spatial Unit Count	(%)	Total Area [km2]	(%)
No Data	8,104	22.00%	830.33	18.87%
Very High Territorial Exposure	9,899	26.87%	2,870.33	65.25%
High Territorial Exposure	5,316	14.43%	285.77	6.50%
Moderate Territorial Exposure	6,361	17.27%	286.15	6.50%
Low Territorial Exposure	4,684	12.71%	102.26	2.32%
Very Low Territorial Exposure	2,476	6.72%	24.26	0.55%

Tab.7 Economic Territorial Exposure Index (eTEI) – Spatial units count and total territorial area

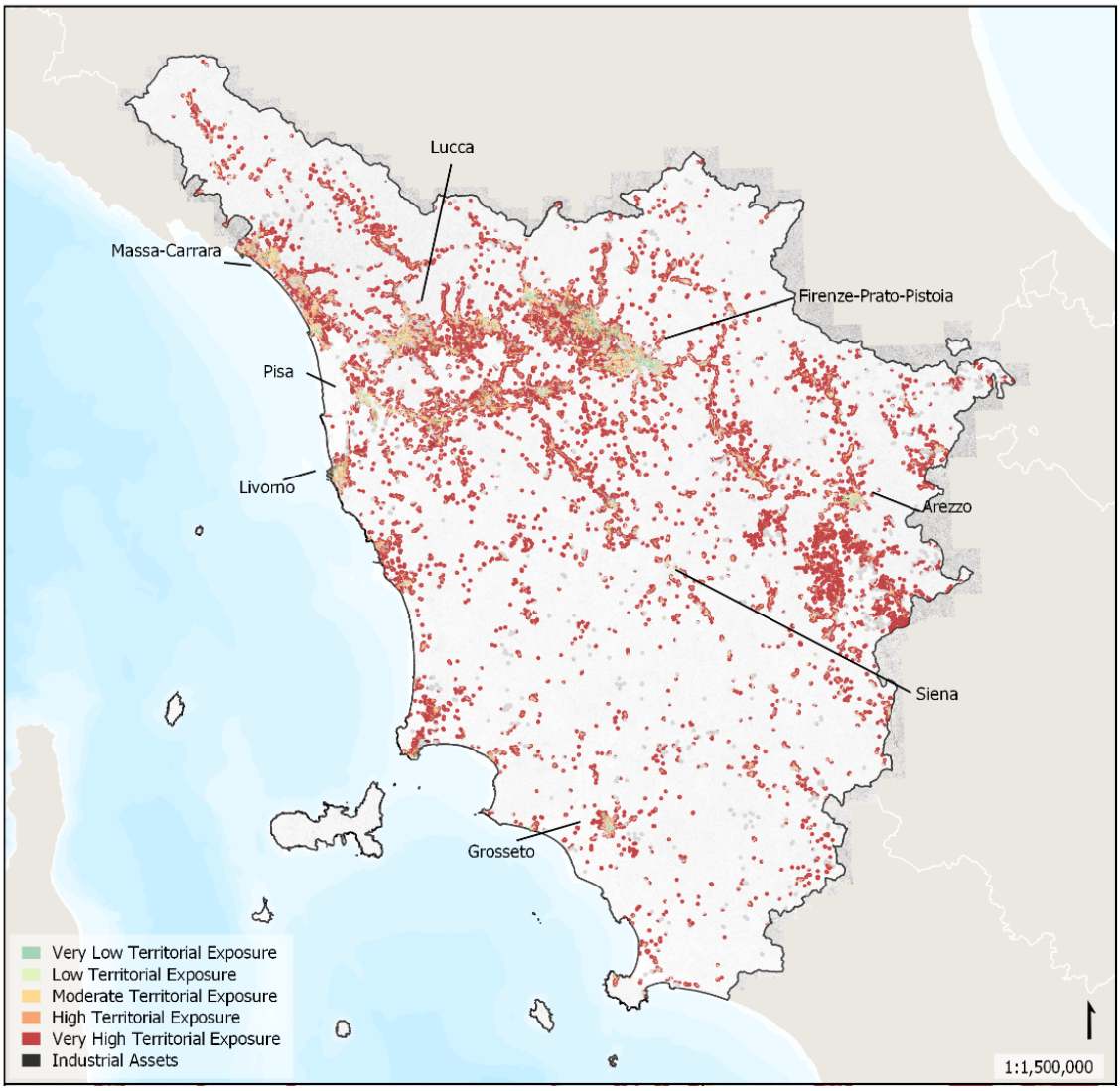


Fig.3 Economic Territorial Exposure Index (eTEi) distribution patterns within the Tuscany region

2.3 The Spatial Attractiveness Index methodology

In a similar manner to the previous indicators, the SAi is assembled through the attribution of scores that, in this case, are derived from each category of territorial exposure.

For the SAi, scores are standardized within the range between -2 to 2, a result from the sum between the sTEi and eTEi.

Henceforth, SAi definition is the following, as stated in Equation 1:

$$SA_i = sTE_i + eTE_i \quad (1)$$

The resulting index corresponds to a defined degree of spatial attractiveness, that ranges from Very Low to Very High. These ranges are inverse in relation to the TEi's, meaning that areas with Very Low Territorial Exposures will have Very High Spatial Attractiveness.

Since the fundamental spatial unit for the SAi the census zones, likewise as in the eTEi, some spatial units have no observations, which require the addition of a category for "No Data". With this in consideration, the categorizations are defined as (Tab.8):

Categorization – SAi	Standardized Ranges	Colour Ranges
No Data	-	Grey
Very Low Spatial Attractiveness	-2	Red
Low Spatial Attractiveness	-1	Orange
Moderate Spatial Attractiveness	0	Yellow
High Spatial Attractiveness	1	Lime
Very High Spatial Attractiveness	2	Green

Tab.8 Spatial Attractiveness Index (SAi) – Ranges and Categorization.

The datasets relationships and the methodological processes that result in the sTEi and eTEi, and then in the SAi are summarized in Fig.4:

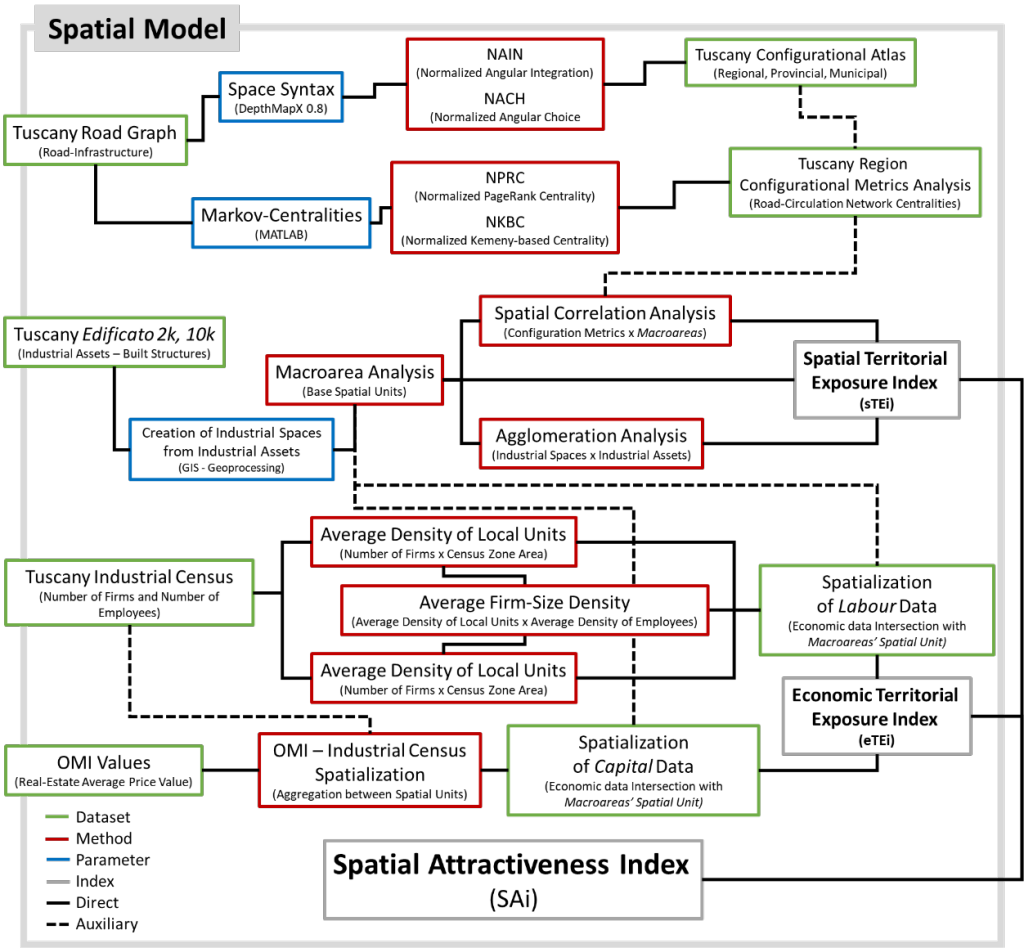


Fig.4 Datasets relationship and methodological scheme for the index construction

3. Results and Discussion

Significative territorial disparities are revealed through the SA_i spatialization, that shows the patterns of Spatial Attractiveness distribution within Tuscany (Fig.5). The results attained by the SA_i improve and refine – in terms of territorial detail – those obtained through the spatialization of the individual indexes of Spatial Territorial Exposure (sTE$_i$) (Altafini & Cutini, 2021) and Economic Territorial Exposure (eTE$_i$) (Altafini, 2022). A data breakdown for the SAi (Tab.9 and 10) demonstrates the numbers for spatial units, occupied total area, total industrial assets, and total industrial spaces, as well as how those are distributed within the several ranges of spatial attractiveness.

Spatial Attractiveness Index	Spatial Unit Count	(%)	Total Area [km2]	(%)
Very High Spatial Attractiveness	6,240	16.94%	109.55	2.49%
High Spatial Attractiveness	10,140	27.52%	473.95	10.77%
Moderate Spatial Attractiveness	4,849	13.16%	1,039.28	23.62%
Low Spatial Attractiveness	6,324	17.17%	1,648.90	37.48%
Very Low Spatial Attractiveness	1,183	3.21%	297.09	6.75%
No Data	8,104	22.00%	830.33	18.87%

Tab.9 Spatial Attractiveness Index (SAi) – Spatial units count and total territorial area

Spatial Attractiveness Index	Number of Industrial Assets	(%)	Number of Industrial Spaces	(%)
Very High Spatial Attractiveness	14,398	16.17%	1,583	11.19%
High Spatial Attractiveness	37,826	42.47%	5,286	37.36%
Moderate Spatial Attractiveness	8,956	10.06%	2,448	17.30%
Low Spatial Attractiveness	12,944	14.53%	1,410	9.96%
Very Low Spatial Attractiveness	2,450	2.75%	357	2.52%
No Data	12,486	14.02%	3,066	21.67%

Tab.10 Spatial Attractiveness Index (SAi) – Number of Industrial Assets and Spaces

From a quantitative standpoint, it can be observed that most spatial units are set within the High SAi ranges (27.52% - 5,286), that also hosts most of the industrial assets (42.47% - 37,826) and industrial spaces (37.36% - 5,286) (Tab.9 and 10). These results, plus the pattens that emerge from the spatialization (Fig.5 p.13), are in line with economic theory assumptions regarding capital and labour, and how the presence of those factors reinforce general tendencies of spatial agglomeration and attractiveness of a territory towards industrial placement. Even though not as predominant regarding the spatial units when compared to the High Spatial Attractiveness range with just 6,240 (16.94%) spatial units, the Very High Spatial Attractiveness range hosts the second highest quantity of industrial assets, with 16.17% (14,398) of the total. In effect, the spatial distribution differences of labour associated factors (i.e, local units, employees, and firm-size) are the main attributes that differentiate the High and Very High ranges of attractiveness, as areas that have greater values for these parameters are set in the upper range. When spatial units' total occupied area is considered, however, both higher ranges correspond to a rather small territory, with an aggregate covering just about 13.26% of the regional total (circa 583.5 km^2) (Tab.9).

The spatialization emphasizes that the territories within the highest ranges of attractiveness are comprised of industrial spaces with a limited extension, with industrial assets placed in a compact pattern, as observed in Fig.5 (p.13) and in Fig.6 (p.14).

This reinforces the previously attained results for the sTE$_i$, in its first iteration (Altafini & Cutini, 2021) suggesting that agglomeration is an important factor in reducing the overall condition of territorial exposure from a spatial standpoint. Hence, the model's spatialization demonstrates the economic assumption, that the spatial proximity among the firms tends to improve the overall spatial attractiveness of a territory to economic activities placement. Moreover, in the specific case of Tuscany, the SAi spatialization (Fig.5) reveals important

territorial differences that highlight the current divide amongst northern and southern areas of the region – that is similar to the north-south divide in development that exist in Italy. Still, while these differences are noticeable, their causes are only revealed through the exploration of the Territorial Exposure Indexes (Altafini, 2022). It is observed that the differences in infrastructure – especially in terms of road-circulation networks – among northern and southern hinterlands are the main cause of exposure, as the lack of proximity to those road-elements mark the differences among macroareas with higher and lower support (Fig.6).

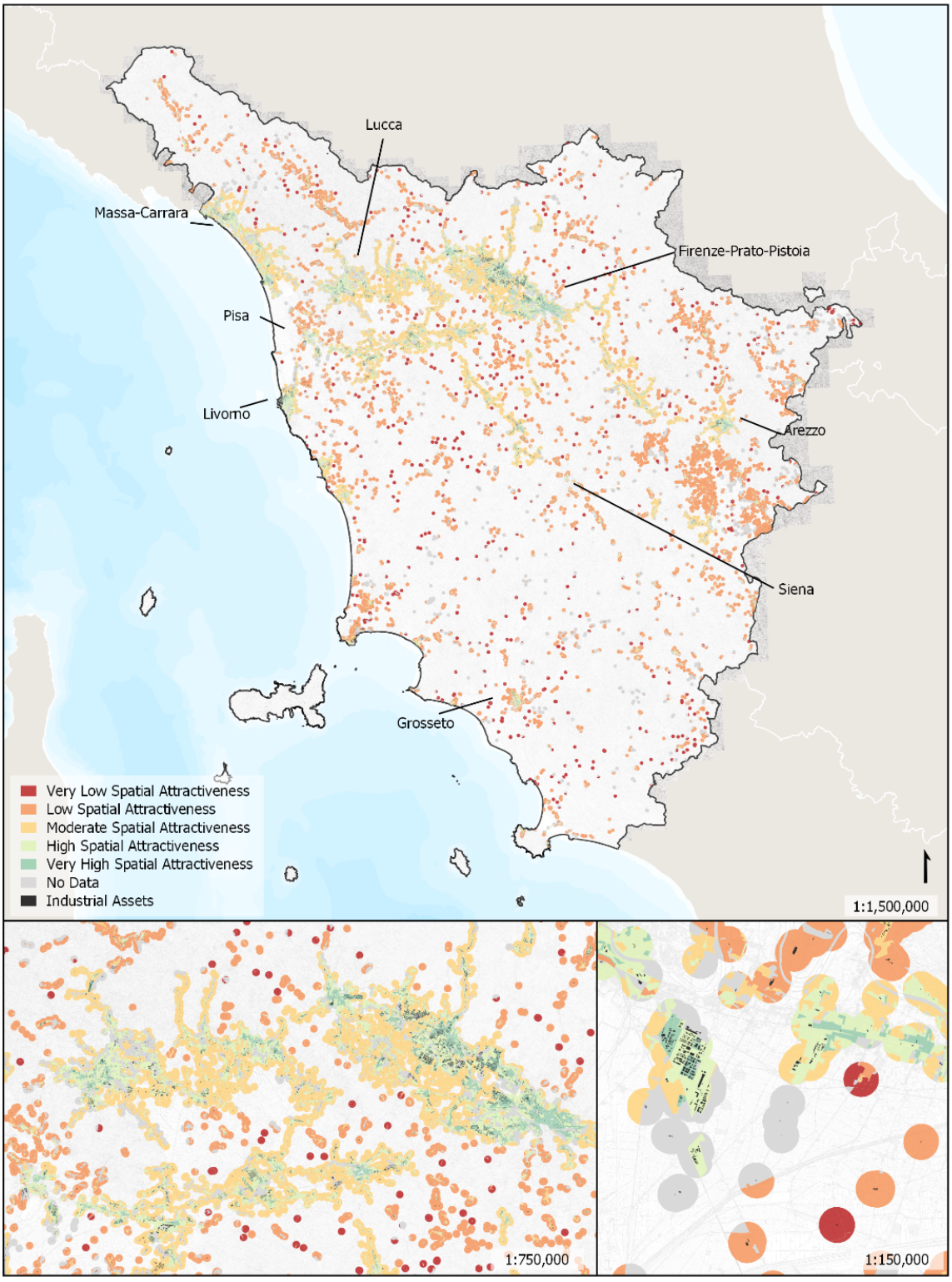


Fig.5 Spatial Attractiveness Index (SAi) distribution patterns within the Tuscany region.

The Moderate Spatial Attractiveness range assume a rather distinctive spatial pattern as, although they occupy the second largest area overall 1,039.28 km^2 (23.62%) (Tab.9, p.11, Fig.5, p.13), they comprise just 13.16% (4,849) of the spatial units and only 10.06% (8,956) of the total of industrial assets (Tab.9 and 10).
As a rule, the areas that comprise the Moderate Spatial Attractiveness ranges are located near the boundaries of the macroareas that are set in the Spatial Territorial Exposure's (sTE$_i$) Very Low ranges (Fig.5, Fig.6).

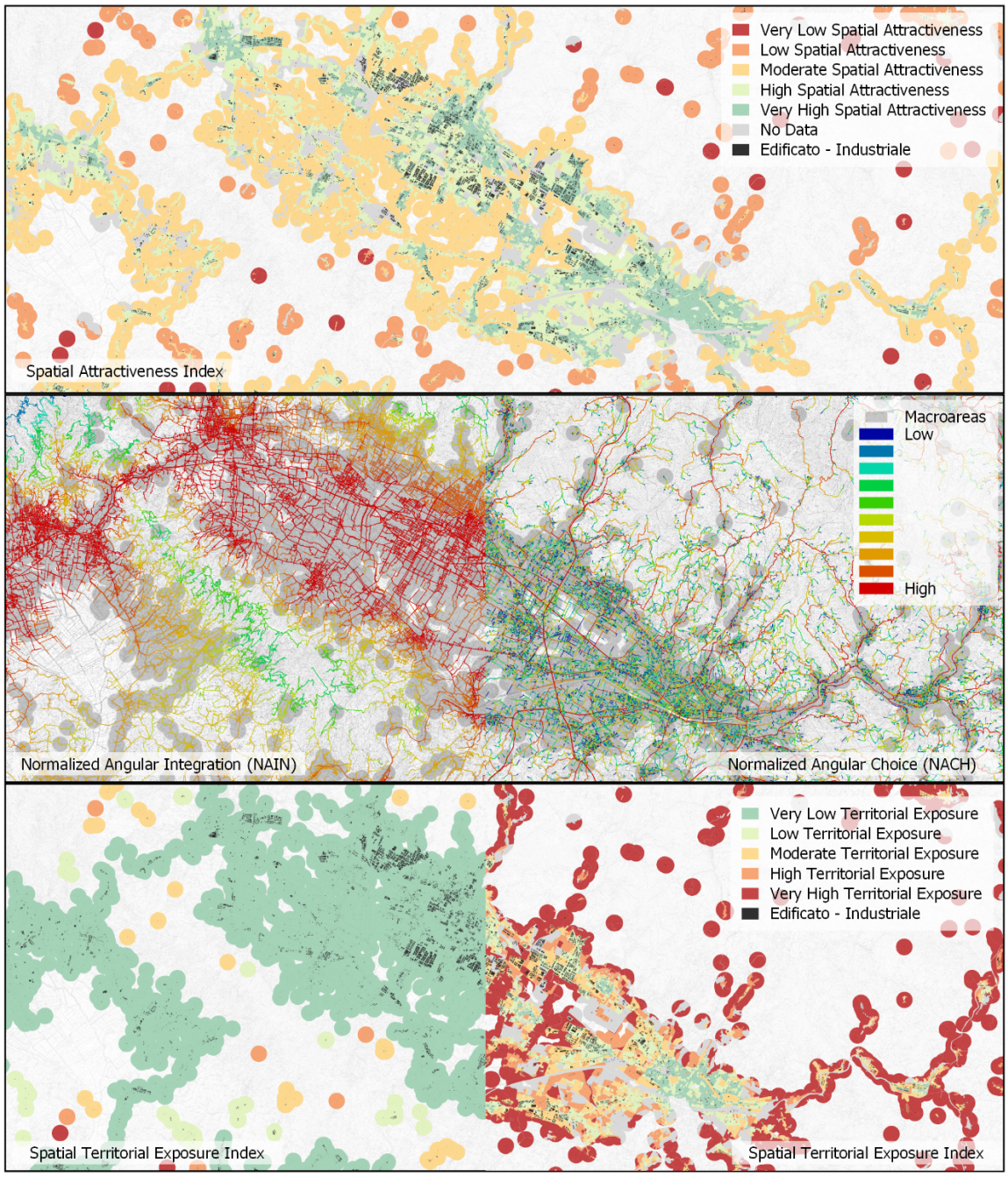


Fig.6 Spatial Attractiveness Index (SAi) – comparison with the Spatial Territorial Exposure (sTEi), the Economic Territorial Exposure (eTEi), the Normalized Angular Integration (NAIN) and the Normalized territorial distribution patterns – Firenze, Prato and Pistoia Area.

Although not noticeable at a first glance, the result highlights the importance of road-circulation network centrality patterns in the overall spatial attractiveness, above all, of the relative accessibility (Integration), property described by the Normalized Angular Integration (NAIN), a component of sTE$_i$'s R$_i$ parameter (Altafini & Cutini, 2021; Altafini, 2022). An in-depth analysis (Fig.6) demonstrates that the high values for relative accessibility cause the most differentiation between the ranges of sTE$_i$, diminishing the overall degree

exposure. Therefore, a high degree of accessibility compensates a local absence of capital and labour, as the nearness to areas that do have a concentration of these factors is improved, thus increasing the spatial attractiveness of these boundaries to economic activities placement.

These findings are in accordance with the conclusions of Froy (2021) on the importance of relative accessibility in the underlying urban spatial structure that supports the industrial agglomerates' organization – suggesting that many firm-to-firm relationships are dependent on the spatial proximity of those firms, and that efficient road-circulation network connections are determinant factors to placement, agglomeration, and the overall industrial environment (Altafini, 2022).

Still, even though relative accessibility has a role in establishing the local patterns of spatial proximity amongst industrial assets, it becomes a less important factor when regional connections are to be considered, since closeness patterns, at this scale, tend to be restricted to a compact core that comprehends the larger urban settlements. In that aspect, regional connections between the industrial spaces are better represented by the preferential routes in the road-circulation network – defined by the Normalized Angular Choice (NACH) component in the Ri parameter (Atafini, 2022).

Preferential routes, have a role in supporting the industrial spaces within the higher ranges of territorial exposure (Fig.6, p.14), establishing linkages or bridges between those and the larger industrial agglomerations. This lowers the overall degree of territorial exposure of these peripheral areas as it provides to the industrial assets located far from the relative accessibility core, access to areas that concentrate economic factors: firms, capital, and labour (Altafini & Cutini, 2022b). Hence, proximity to these routes improves the overall spatial attractiveness to industrial placement (Altafini, 2022).

The effects of a higher degree of territorial exposure in spatial attractiveness can be observed within the Low and Very Low Sai ranges (Fig.5; Fig.6). Those ranges correspond to an aggregate 20.38% (7,507) of the total spatial units, with several industrial spaces and industrial assets equivalent to, respectively, 17.28% (15,394) and 12.48% (1,767) of the regional totals (Tab.9 and 10, p.11).

Nevertheless, combined, the Low and Very Low Sai ranges occupy the largest territorial extent within Tuscany, with circa 44.23% (1,945.99 km^2) of the total macroareas territory.

The spatial distribution of the lower ranges of Spatial Attractiveness informs a remarkable pattern regarding territorial disparities; those are predominant throughout Tuscany's hinterlands (Fig.5, p.12) and located in smaller macroareas that are set beyond the relative accessibility core at regional scale (Fig.6, p.14). While the innermost spatial units within those areas tend to present higher degrees of Spatial Attractiveness – with Sai values ranging from Moderate to High, depending on the amount of industrial assets, capital, or labour – the outer boundaries tend to offer less territorial support and attractiveness to placement when compared to what is verified in the larger macroareas. The disparities between macroareas with boundaries in Moderate Sai ranges and those with boundaries in Low-Very Low Sai ranges are, however, not just dependent on their hinterland placement and the consequential decreases on the regional relative accessibility; in effect, differences among these two cases can be attributed to the overall cohesiveness and agglomeration of the industrial areas.

These patterns can be verified when the Sai, sTEi and eTEi spatialization results for Pisa (Fig.7, p.16) and Livorno greater areas (Fig.8, p.16) are analysed.

Lower SAi values found for Pisa and Livorno can be attributed to differences both in sTEi's parameters of macroareas' sizes (Si) and agglomeration (Ai). Therefore, despite the presence of internal spatial units with a good amount of economic support, as indicated in the eTEi spatialization, as well as other factors related to a lower territorial exposure – such as support of the road-circulation network –, it is the low internal cohesiveness of these areas that contributes the most to the increase in overall territorial exposure.

Macroareas that present higher degrees of agglomeration (Ai) (green in sTEi), also exhibit Moderate Spatial Attractiveness near their boundaries, while areas that present lower agglomeration – represented in lime and yellow in the sTEi, have instead boundaries with Very Low Spatial Attractiveness (Fig.7 and 8).

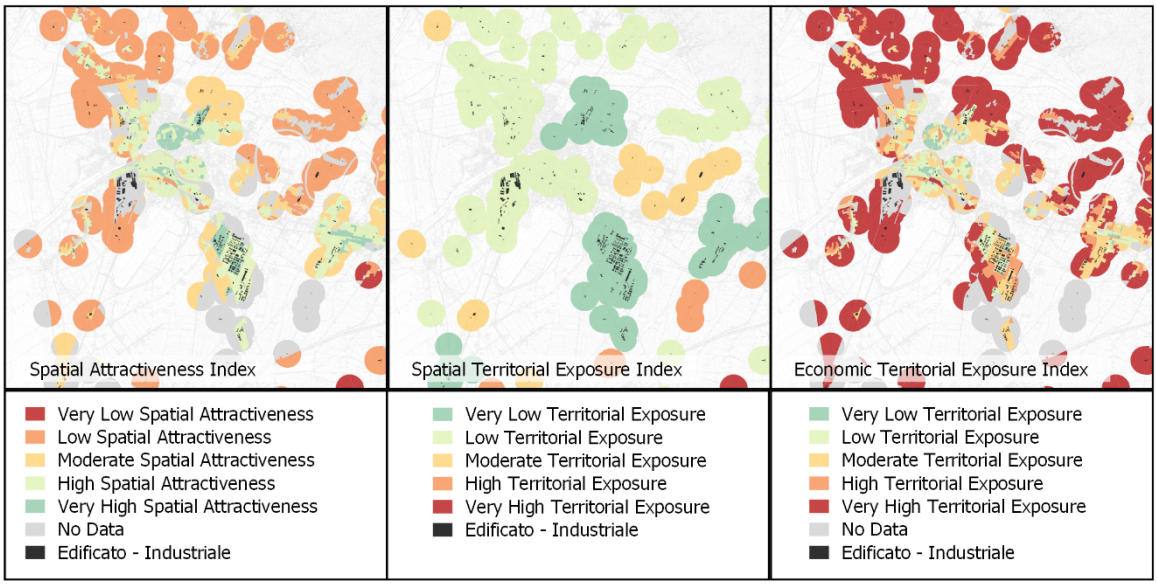


Fig.6 Spatial Attractiveness Index (SAi) – comparison with the Spatial Territorial Exposure (sTEi) and the Economic Territorial Exposure (eTEi) territorial distribution patterns for the Pisa urban area

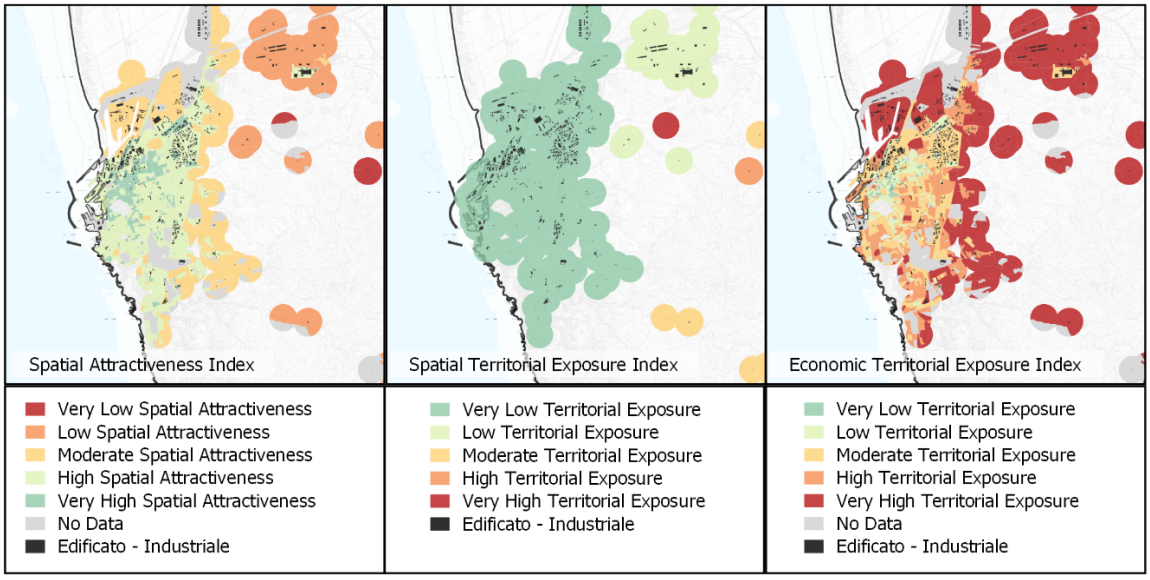


Fig.7 Spatial Attractiveness Index (SAi) – comparison with the Spatial Territorial Exposure (sTEi) and the Economic Territorial Exposure (eTEi) territorial distribution patterns for the Livorno urban area

The assembled Spatial Attractiveness Index (SAi) can provide a novel dimension for spatial-economic based territorial analysis. It is tailored to consider parameters derived both from the territorial endowments, such as the disposition of the built-structures, and the centralities of the road-circulation network, as well as from the economic structure, associated to labour, capital, and firm-size. A distinctive of this model is that it considers those aspects at a level of detail and within a scale that goes beyond what is usually addressed in the fields of Regional Economics and Economic Geography. Nevertheless, are limitations in what the model can currently explain, not related to its structure, which designed to be flexible, but related to data quality and availability. A more granular dataset regarding the industrial functions, with sector specialization and type/intensity of the activities, could be used to integrate this approach to the network-based approach proposed by Froy (2021). This would lead to a better depiction of the inner configuration of the industrial areas, from a relational

standpoint, while also merging it with the conditions that allow those relationships to happen. This could be a next step for this research towards understanding other kinds of territorial imbalances.

The relevance of the road-circulation network patterns and of the road-infrastructure can be attested in the results for the spatial attractiveness model, hence, the configurational properties of these networks reveal themselves as determinants for interpreting territorial disparities' patterns among the economic activities' distribution at localized scales in the regional continuum, which can contribute to improving competitiveness, and working towards providing evidence for a rebalance of the industrial systems, as part of decision-making strategies (Gargiulo & Sgambati, 2023). These attributes, more than often, are mis-considered both by Regional Economists and Economic Geographers and must be part of the digitalization efforts oriented to understand vulnerable territories (Garau et al., 2023) and support the novel smart cities, in an integrated approach (Barresi & Pultrone, 2013; Pultrone, 2023). While by no means we disregard the approaches made in these fields, especially, since the Evolutionary branch of the Economic Geography is walking towards this direction, we propose that the general abstraction of the spatial component, ever-present in current economic-based analysis, is to be shifted towards a broader overview that considers the real characteristics – or the variables that constitute the spatial microfoundations – within the territories. As proved by both the Spatial and Economic Territorial Exposure Indexes, as well as by the Spatial Attractiveness Index, we already in possess of the technical knowledge and the instruments to do so.

4. Conclusive remarks

Throughout this research, we identified that there was a certain distance amid the interpretations from Urban and Regional Planning and from Spatial Economics about "what is space?". As discussed in the introduction, this gap seems to arise from the apparent "neglect" (Krugman, 1991) of the spatial economics' branches by the mainstream economics, as the crisis of the first neoclassical consensus in the 1970-1990's period contested the methodological foundations of the spatial models developed within economics. While space is undoubtedly considered as an important factor in economics, it is well-noticed in their approaches – be in Urban-Regional Economics or in Economic Geography – that regions and territories tend to be interpreted from an abstracted standpoint – meaning that their internal characteristics or disparities are often deemed as intangible factors (Thisse & Walliser, 1998). Hence, the spaces will constitute themselves of a mere background, with a set of homogeneous qualities on where the different dynamics take place; certainly, a contrast in relation to the in-detail overviews found within more territorial-planning-based disciplines and approaches.

It can be stated, then, that the spatial models developed in economics possess – here inspired in Robert Lucas' (1976) critique on the neoclassical synthesis – rather unsolid "microfoundations", thus, a limited understanding of what characteristics present on space can influence in location, support, and resilience to economic trends. In that matter, abstracting details on the representation of space leads to its interpretation as a mere structural component – an invariant – when space is neither structural, nor invariant; on the contrary, it changes its structure in accordance with fluctuations in the physical, economic, and historical contexts. Under this argument we identified a significant shortcoming of the spatial-economic theories and models in general. Nevertheless, can be addressed through considering principles and instruments that became ubiquitous in urban and regional planning, such as the use of Geographic Information Systems and the creation of Digital Twins, that are based on virtually reproducing the real dynamics between material and economic factors, allowing to interpret those as tantamount determinants to understand – "what is really where, and why?". It is through this approximation between the disciplines, which must surpass the "intangibilities of space" that assumed by the economics. This will allow a movement of transition towards to a second renaissance of Urban-

Regional Economics' and the Economic Geography's spatial-economic models, and the creation of more effective instruments to address the dynamics that occur in the real world.

This paper – and the thesis in which it was based – were structured within these *lacunae.* While its main result is the Spatial Attractiveness Index (SAi), its construction is derived from a combined set of spatial and economic analyses – the indexes of Spatial and Economic Territorial Exposure (sTEi & eTEi). Even if those indexes can be interpreted independently, when worked in conjunction they contribute towards the general objective that is rupturing with the paradigms of an "intangible space" and proposing novel methodological instruments and spatial models capable to support an in-depth analysis of space and its territorial disparities, applicable for urban and regional planning, but foremost, to economics. These approaches novelty consists in incorporating territorial variables associated to infrastructure (i.e. built-structures position and the road-circulation networks) while creating spatial units that allow to interpret their configurational and morphological characteristics along economic variables (i.e. capital and labour) to understand their combined support towards the placement of economic activities. Challenges remain, above all, regarding the incorporation of more economic variables to this analytical framework. Although datasets are available that can help assess the economic vitality of industrial agglomerates, such as sector, firm size, productivity, and revenues, there are spatialization issues since the data is collected at the firm level and may reveal sensitive information about the productive activity that could lead to identification. Additionally, research costs are a concern since many of these databases are privately owned and require significant funds for a comprehensive data acquisition at a regional scale. These could be the next steps in terms of understanding the territorial imbalances.

Despite these limitations, the proposed spatial model and framework, based on real spatial representations, can clearly identify territorial disparities in industrial agglomerates throughout a region, as seen in the proof-of concept for Tuscany. Moreover, it demonstrates how the presence and placement of territorial endowments can affect their economic dynamism within the different parts of a same region. Therefore, the SAi and the Territorial Exposure Indexes provide more detailed territorial representations than the spatial models typically used Urban and Regional Economics studies and comprehend a step towards an economic analysis based on Digital Twins.

References

Agenzia Entrate (2018) Manuale della Banca Dati Quotazioni dell'Osservatorio del Mercato Immobiliare Istruzioni tecniche per la formazione della Banca Dati Quotazioni OMI. Guerrieri, G; Festa, M; Longhi, S; Cantone G; Papa, F (eds.). Direzione Centrale Osservatorio Mercato Immobiliare e Servizi Estimativi, Roma.

Alonso, W., (1964). *Location and Land* Use. Locat. L. Use. https://doi.org/10.4159/harvard.9780674730854

Altafini, D. & Cutini, V. (2020). Tuscany Configurational Atlas: a GIS-based multiscale assessment of road-circulation networks centralities hierarchies. *Computational Science and Its Applications – ICCSA 2020*, 20th International Conference, Cagliari, Italy, July 1–4, 2020, Proceedings, Part III. https://doi.org/10.1007/978-3-030-58808-3_22.

Altafini, D. & Cutini, V. (2021a). Territorial disparities in Tuscan industrial assets: a model to assess agglomeration and exposure patterns. *TeMA – Journal of Land Use, Mobility and Environment*, *14* (2), 161-176. https://doi.org/10.6092/1970-9870/7976

Altafini, D, & Cutini, V. (2021b). Territorial Disparities in Tuscan Industrial Assets: A Method to Assess Average Firm-Size Spatial Distribution. In: Gervasi O. et al. (eds) *Computational Science and Its Applications – ICCSA 2021*. Lecture Notes in Computer Science, vol 12952. Springer, Cham.

Altafini, D; Poloni, F, Meini, B, Bini, D, Cutini, V. (2022). Markov-Chain-based centralities and Space Syntax' Angular Analysis: an initial overview and application. In: Proceedings of the 13th Space Syntax Symposium, 20th to 24th June 2022. Western Norway University of Applied Sciences (HVL), Bergen, Norway.

Altafini, D., Bini, D. A., Cutini, V., Meini, B., & Poloni, F. (2023). An Edge Centrality Measure Based on the Kemeny Constant. *SIAM Journal on Matrix Analysis and Applications*. *44* (2). https://doi.org/10.1137/22M1486728

Altafini, D. (2022). Spatial-economic models to evaluate industrial agglomerations: novel instruments for urban-regional analysis. Ph.D. Dissertation. University of Pisa.

Bagnasco, A. (1977). *Tre Italie. La problematica territoriale dello sviluppo italiano*. Il Mulino, Bologna.

Bavelas, A. (1950). Communication Patterns in Task-Oriented Groups. *Journal of the Acoustical Society of America*, 22, 725-730.

Barresi, A. & Pultrone, G. (2013). European Strategies for Smarter Cities. *TeMA - Journal of Land Use, Mobility and Environment*, *6* (1), 61-72. https://doi.org/10.6092/1970-9870/1455

Boschma, R. (2005). Proximity and innovation: a critical assessment. *Regional Studies, 39*, 61–74. https://doi.org/10.1080/0034340052000320887.

Boschma, R. (2015). Towards an evolutionary perspective on regional resilience. *Regional Studies, 49* (5), 733-751

Duranton, G., Henderson, J.V., & Strange, W. (Eds.). (2015). *Handbook of Regional and Urban Economics:* Regional and Urban Economics. Vol. 5A. Amsterdam. Elsevier – North-Holland

Froy, F. (2021). *A marvellous order: how spatial and economic configurations interact to produce agglomeration economies in Greater Manchester*, PhD Thesis UCL (University College London)

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

Gargiulo, C., & Sgambati, S. (2023). The investments of NextGenerationEU vs urban competitiveness of Italian metropolitan areas. *TeMA - Journal of Land Use, Mobility and Environment*, *16* (3), 545-564. https://doi.org/10.6093/1970-9870/10271

ISTAT. (2001). 8° Censimento ISTAT dell'industria e servizi. Istituto Nazionale di Statistica, Roma

ISTAT. (2016). Descrizione dei dati geografici e delle variabili censuarie delle Basi territoriali per I censimenti: anni 1991, 2001, 2011. Istituto Nazionale di Statistica.

ISTAT. (2011). 9° Censimento ISTAT dell'industria e servizi. Istituto Nazionale di Statistica, Roma. Available at: https://www.istat.it/it/archivio/104317

Hillier, B., Yang, T., & Turner, A. (2012). Normalising least angle choice in Depthmap - and how it opens up new perspectives on the global and local analysis of city space, *The Journal of Space Syntax*, *3* (2), 155–193.

Hillier, B. (2007). *Space is the machine: a configurational theory of architecture. Space Syntax.*

Jenks, G. F. (1977). Optimal Data Classification for Choropleth Maps. Occasional Paper No. 2. Lawrence, KS*: Department of Geography, University of Kansas.*

Jenks, G. F., & Caspall, F. C. (1971). Error on choroplethic maps: Definition, measurement, reduction. *Annals of the Association of American Geographers, 61* (2), pp.217–244.

Kemeny, J. G., & Snell, J. L. (1960). Finite Markov Chains. Princeton, NJ: D. Van Nostrand. (Corollary 4.3.6)

Krugman, P. (1991). Increasing returns and economic geography. *Journal of Political Economy*, *99*, (3), 483-499. https://doi.org/10.1086/261763

Lefèbrve, H. (1996). *Writings on Cities.* Blackwell, Oxford.

Lefèbrve, H. (1974). *La production de l'espace*. *L'Homme et la société, 31* (1), 15-32.

Lucas, R. (1976). Econometric Policy Evaluation: A Critique. In Brunner, K.; Meltzer, A. (eds.). *In Carnegie-Rochester Conference Series on Public Policy* (Vol. 1, 19–46). ISBN 0-444-11007-0. North-Holland

Mills, E.S. (ed.) (1987). *Handbook of Regional and Urban Economics*: Urban Economics. Vol 2. Amsterdam. Elsevier – North-Holland

Pasinetti, L. (2000). Critique of the neoclassical theory of growth and distribution. *BNL Quarterly Review Quarterly Review 53*, 215, 383-431. https://doi.org/10.13133/2037-3643/9924

Pultrone, G. (2023). The city challenges and the new frontiers of urban planning. *TeMA - Journal of Land Use, Mobility and Environment, 16* (1), 27-45. https://doi.org/10.6093/1970-9870/9392

QGIS. (2022) *Firenze LTR.* Version 3.28. Available at; https://qgis.org/it/site/forusers/download.html

Regione Toscana (2019a). Direzione Urbanistica e Politiche Abitative - Sistema Informativo Territoriale e Ambientale – SITA.: *Edificato 2k, 10k 1988-2013.* http://www502.regione.toscana.it/geoscopio/cartoteca.html

Regione Toscana (2019b). Direzione Urbanistica e Politiche Abitative - Sistema Informativo Territoriale e Ambientale – SITA.: *Grafo stradario e ferroviario della Regione Toscana* - Itnet. http://www502.regione.toscana.it/geoscopio/cartoteca.html

Sabidussi, G. (1966). The centrality index of a graph. *Psychometrika 31* (4), 581–603. https://doi.org/10.1007/BF02289527

Samuelson, P. (1947). *Foundations of Economic Analysis*, Harvard University Press.

Samuelson, P. (1966). A Summing Up. *The Quarterly Journal of Economics, 80* (4), 568-583. School of Graduate Studies, UCL, London.

Solow, R. (1956). A contribution to the theory of economic growth. *The Quarterly Journal of Economics*. *70* (1), 65–94. doi:10.2307/1884513. hdl: 10338.dmlcz/143862. JSTOR 1884513.

Sraffa, P. (1960). *Production of Commodities by Means of Commodities: Prelude to a Critique of Economic Theory*. *Science and Society, 25* (2). Cambridge: Cambridge University

Sraffa, P. (1926). The Laws of Returns under Competitive Conditions. *The Economic Journal*, *36* (144), 535-550.

Sraffa, P. (1925). Sulle relazioni fra costo e quantità prodotta, *Annali di economia 2* (1), 277 – 328.

Smith, N. (2008). *Uneven Development: Nature Capital and the Production of Space*, 3rd ed. The University of Georgia Press, Georgia.

Thisse, J. & Walliser, B. (1998). Is space a neglected topic in mainstream economics? *Recherches Economiques de Louvain /Louvain Economic Review, 64* (1), 11-22. https://doi.org/10.1017/S0770451800004139.

Turner, A (2001). Angular Analysis. In: *Proceedings of the 3rd International Symposium on Space Syntax,* 7-11. Georgia Institute of Technology, Atlanta, Georgia.

Weber, A., (1929). Theory of the Location of Industries. The University of Chicago Press, Chicago. https://doi.org /10.1086/254099

Author's profile

Diego Altafini

Marie Skłodowska Curie Actions/UK Research and Innovation Fellow at the Welsh School of Architecture, Cardiff University. Dr. Altafini has obtained his Ph.D in Energy, Systems, Territory and Construction Engineering at the University of Pisa (2022), and has a background in both Urban and Regional Planning (masters – 2018), and Economics (bachelor – 2014). Currently, his research is focused on the development of digital support systems based on digital twins for minoring territorial disparities in urban and regional areas, as the principal investigator of the MSCA/UKRI - DECIDE Project (101107846-DECIDE/EP/Y028716/1). From 2023, he also is a research collaborator working with the University of Pisa in the Horizon EU – Driving Urban Transitions (DUT) – EMC2 Project, a research consortium between France, Italy, Austria and Sweden.

Valerio Cutini

Full professor of Tecnica e Pianificazione Urbanistica and vice-director of the department of energy, systems, territorial and construction engineering at the Università di Pisa. Obtained its Ph.D. in Ingegneria Edilizia e Insediativa at the Università di Bologna (1991). Since 1997, Valerio Cutini teaches at the Università di Pisa on the courses of di Ingegneria Civile Ambientale and Ingegneria Edile-Architettura, and in several international universities as a visiting professor. It conducts research focused on the analysis of urban settlements and regional networks, assessing their development and evolutionary process of their morphology and functional aspects. Currently, he is also the coordinator of the Italian group within the Horizon EU – Driving Urban Transitions (DUT) – EMC2 Project, a research consortium between France, Italy, Austria and Sweden.

TeMA Journal of Land Use, Mobility and Environment

TeMA 1 (2024) 109-127
print ISSN 1970-9889, e-ISSN 1970-9870
DOI: 10.6092/1970-9870/10430
Received 9th November 2023, Accepted 2nd April 2024, Available online 30th April 2024

Licensed under the Creative Commons Attribution – Non Commercial License 4.0
http://www.serena.unina.it/index.php/tema

Planning the transition of cities. Innovative research approaches and trajectories

Francesca Moraci [a]*, Carmelina Bevilacqua [b], Pasquale Pizzimenti [c]

[a] DArTe Department
Università degli Studi Mediterranea, Reggio Calabria, Italy
e-mail: fmoraci@unirc.it
ORCID: https://orcid.org/0000-0002-9967-0092
* Corresponding author

[b] PDTA Department
Università degli Studi Roma La Sapienza, Rome, Italy
e-mail: carmelina.bevilacqua@uniroma1.it
ORCID: https://orcid.org/0000-0002-8433-0773

[c] DArTe Department
Università degli Studi Mediterranea, Reggio Calabria, Italy
e-mail: pasquale.pizzimenti@unirc.it
ORCID: https://orcid.org/0000-0003-0186-1307

Abstract
In light of the ecological, digital, and just transition envisaged by the EU for reaching the ambitious Green Deal objective by 2050 and its inherent complexity, this paper focused on the nexus between Ecosystem Services and Key Enabling Technologies as a potential and significant element for the future development of promising research trajectories in urban planning. The transition of cities has become a top priority in academic and policy debates, attracting increasing attention from scholars and policymakers. Ecosystem Services are crucial elements for human well-being, and despite their inclusion in urban plans, there are still issues to address requiring innovative research approaches and trajectories to explore for planning the ecological, digital, and transition of cities. Two main elements are explored in this contribution: 1) the centrality of ecosystem services and the potential of related key enabling technologies for the planning of the ecological and digital transition of cities; 2) the current ecosystem services assessment analytical approaches characterized by a spatially explicit perspective presenting relevant implications for the planning dimension. As a result, the paper outlines a research-based conceptual framework aimed at defining promising innovative research approaches for new trajectories to be explored in urban planning.

Keywords
Transition; Ecosystem services; Key enabling technologies; Data-driven planning approach; Urban planning and governance

How to cite item in APA format
Moraci, F., Bevilacqua, C. & Pizzimenti, P. (2024). Planning the Transition of Cities. Innovative research approaches and trajectories. *Tema. Journal of Land Use, Mobility and Environment*, *17* (1), 109-127. http://dx.doi.org/10.6092/1970-9870/10430

1. Introduction

The paper aims to outline possible innovative research trajectories to explore for planning the transition of cities, which are called to face severe pressures and challenges, such as climate changes, energy issues, and poverty, underscoring the urgency for more sustainable cities (Salat & Bourdic, 2012; Giannakidou & Latinopoulos, 2023). The European Union (EU) has introduced the Green Deal (EU, 2019) as a strategic framework aimed at propelling the transition towards a carbon-neutral economy, decoupling economic growth from resource exploitation (EU, 2019). Simultaneously, it endeavors to "protect, conserve, and enhance the EU's natural capital, and protect the health and well-being of citizens from environment-related risks and impacts" with a commitment to ensuring a just and inclusive transition (EU, 2019). Such a direction towards the definition of a more sustainable path implies to rethink EU policies across sectors for the supply of clean energy and at the same time safeguarding natural ecosystems, also exploiting the potential of new technologies and digital transformation, which assume significance in catalyzing such a transformative shift for the Union (EU, 2019). The envisioned ecological and digital transition, permeating all economic sectors, is calling also for a new demand for sustainability in cities, in which restructuring processes find their synthesis and where the balance between a more sustainable economic development and human well-being emerge as central element for their future development. Consequently, it is deemed significant to comprehend the intricate dynamics interlinking urban changes with socio-ecological-technological transformations to gain insights into the nexus between ecological integrity and human well-being for the prospective development trajectory for cities (Alberti et al., 2018). In light of the accelerated pace of worldwide urbanization processes (Ahern et al., 2014; Lai & Zoppi, 2023), the demand for ecosystem services (ESs) and natural capital is steadily increasing (Gómez-Baggethun & Barton, 2013), and addressing the challenges related to sustainability in cities claims for new approaches in urban planning and design (Ahern et al., 2014; Mazzeo & Polverino, 2023). Urban transformations heavily affect natural ecosystems and the production of their services, (Lai & Zoppi, 2023), and preserving natural habitats and reducing pressures on natural ecosystems is significant for protecting the territory and urban areas from endogenous and exogenous fragilities (Caprari & Malavolta, 2024). The relevance of the ESs topic is growing in the academic and policymaker's arena, especially concerning its inclusion in urban planning, deemed crucial for promoting sustainable urban development (Cortinovis et al., 2020; Cortinovis & Geneletti, 2019; Tan et al., 2020, Lai & Zoppi, 2023) and resilience (Claron et al., 2022). The concept of Ecosystem Services (ESs) has significantly contributed to urban planning by integrating diverse fields of knowledge to assess the benefits humans derive from nature (Marques et al., 2022). While it is largely explored in the ecology and increasing in the economic assessment fields, its presence in the urban planning literature deserves more attention (Qiu et al., 2022). One of the most significant features of ESs is their systemic perspective, which views sustainability as a complex phenomenon rather than just an environmental concern by incorporating cultural, social, and economic dimensions (Marques et al., 2022). This interdisciplinary approach encompasses a range of research areas and methodologies, including those within urban planning related to the ESs concepts such as Green Infrastructures, Ecosystem-based Adaptation, and Nature-based solutions (Marques et al., 2022) land consumption reduction, the renaturalisation of territories, the production exploitation of renewable energy sources, and adaptation to the effects of climate change (Mazzeo & Polverino, 2023). Despite the relevance of the ESs concept, Qiu et al. (2022) have identified a set of knowledge gaps and challenges in linking ESs research to urban planning: a gap between science and practices, a gap between science and policy, and a gap in urban green governance. On the one hand, the efforts to protect natural ecosystems and biodiversity are at the top of the policy agenda, as in the EU case with the EU Biodiversity Strategy for 2030 (EC Eurostat, 2021). Conversely, rapid urbanization processes negatively affect biodiversity and the ESs offered for human well-being (Sirakaya et al., 2018). Although urban plans already include ES-related actions and different tools for their implementation, there are still issues to address (Cortinovis & Geneletti, 2018; Geneletti et al., 2020): knowledge transfer into planning practices;

embedding ES information into planning processes; usable methods to assess urban ES at a relevant scale while accounting for multi-functionality of ecosystems analyses of ES demand in plans; and ES are not considered a strategic issue in urban planning. Including ESs in urban planning – which is an example of a decision-making process where the complexity of policy questions is addressed – is central to the promotion of sustainable urban development and then for city transition (Cortinovis et al., 2020; Qiu et al., 2022).

Here, it is argued that planning the transition should harness the potential of key enabling technologies (KETs) and place ESs as central element for a sustainable transition of cities and territories (Cortinovis & Geneletti, 2018). Such an approach is supported by recently developed perspectives that emphasize the relevance of ESs knowledge in urban planning as a valuable strategy for tackling complex challenges in contemporary urban development (Cortinovis et al., 2020). At the same time, sustainable transformative development is calling for a new, robust science of cities to give urban policymakers the body of knowledge necessary to address the current issues (UN, 2019). This perspective refers to the advancements of technologies and the emergence of data-driven approaches, central in the so called and emerging "*urban science*" or "*science of cities*", in which data and advanced data-analysis methods and techniques are exploited to better understand real-world phenomena (Bettancourt, 2021). This new approach is given by the rapidly expanding computational science field and its potential connection with urban studies that are shaping the so-called urban informatics, which applies big data and computational methods to urban management, policy, and planning (Kontokosta, 2021), and that can provide valuable resources to comprehend better the complex relationships between cities and ecosystems (Koc & Acar, 2021). The centrality of technologies and data is also emphasized by EU policies on KETs, deemed pivotal for the future of the EU (EU-EPRS, 2021). In a recent EU parliament study six relevant emerging technologies for the future of the Union have been outlined (EU-EPRS, 2021): advanced manufacturing, advanced (nano) materials, Life-science technologies, Micro-nano electronics and photonics, Artificial intelligence, Security and connectivity technologies. Various EU programs, such as Horizon Europe prioritize KETs, with Big Data and Artificial Intelligence technologies considered cross-cutting elements among the nine identified KET areas, namely: Manufacturing technologies, Key digital technologies, Advanced materials, Artificial intelligence and robotics, Next generation internet, Advanced computing and big data, Circular industries, Low carbon and clean industries, Space (EU EPRS, 2021).

Therefore, the main research questions are the following: How can emerging key enabling – and associated – technologies enhance the knowledge on ESs for the advancement of urban planning practice in facilitating cities' transition towards sustainability and increase their resilience? Furthermore, what could be the implications of such a data-driven perspective for planning? These research questions encompass the exploration of cutting-edge technologies and their potential to support the assessment and management of ESs for cities from a research-based perspective, thereby promoting interesting research trajectories to explore. Two main elements are explored in this contribution: 1) the centrality of ecosystem services and the potential of related key enabling technologies for the planning the ecological and digital transition of cities; 2) the current ecosystem services assessment analytical approaches characterized by a spatially explicit perspective presenting relevant implications for the planning dimension.

Given the raising relevance of ESs for urban planning, and the raising awareness on the potential of key emerging technologies in addressing contemporary challenges, the paper analyzes the current integrated and comprehensive ESs assessment analytical approaches characterized by spatially explicit perspectives. Such methods are the UN SEAA-EA (UN, 2021), the EU Mapping ES (EC, 2013; EC-JRC, 2020), and the EU INCA Project (EC-Eurostat, 2021). The aim is to outline a research-based conceptual framework characterized by a data-driven planning approach for managing the transition centered on ES by exploiting the potential of KETs for planning. This perspective is articulated in three main drivers, operating at multiple scales and dimensions but interconnected by the data-driven planning perspective centered on ESs and KETs.

These research drivers contribute to defining promising research trajectories to explore and provide interesting insights and implications for the planning process by envisioning data-driven planning centered on ESs for future urban and territorial transformation processes.
The paper is structured as follows: The next section emphasizes the relevance of ESs and KETs for planning cities' transition by outlining the main areas to explore in relationship with the planning dimension, highlighting the relevance of the spatial dimension, spatially explicit information, and KETs in addressing this topic. The third section outlines the main spatially explicit approach characteristics for the mapping and assessment of ESs in the EU. The discussion and conclusion section frame the results into a conceptual framework for an innovative data-driven planning perspective aimed at the transition of cities by defining promising research drivers to explore and the overall implications for planning.

2. The EU overall policy framework for the ecological and digital transition towards a more sustainable future

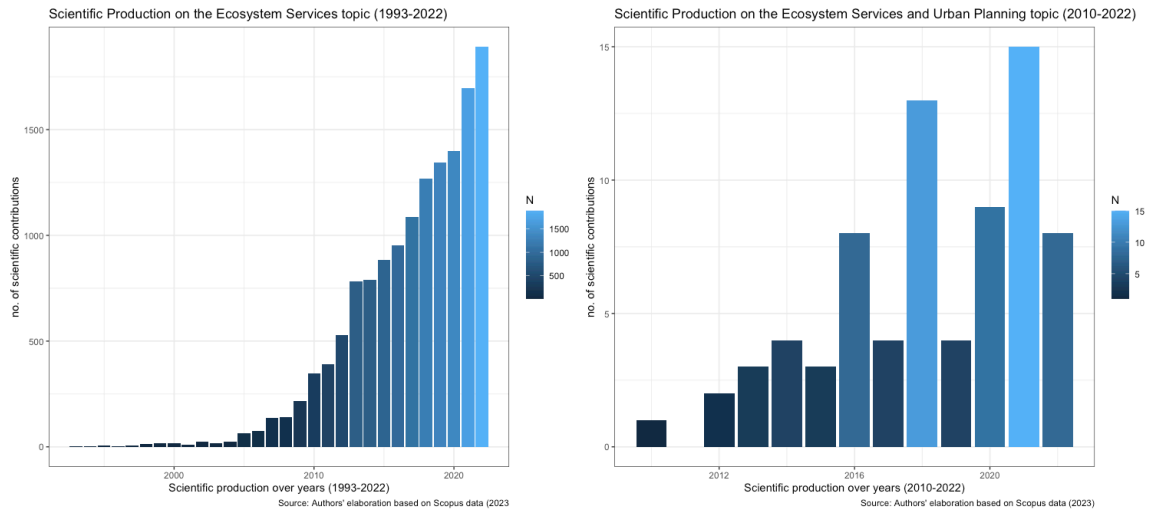
The EU Green Deal is reshaping the policy framework for the Union's future, emphasizing the ecological and digital transition paths toward sustainability (EU, 2019). However, it is essential to recognize that connecting and aligning these two transitions can be challenging, as they have different natures and dynamics (Muench et al., 2022). While the green transition is driven by the urgent need to achieve climate neutrality and sustainability through substantial political and social efforts, the digital transition is an ongoing process of technology-driven change, with a significant role played by the private sector. Given the potential risks, a primary challenge for the EU is to ensure that both the ecological and digital transitions are fair, inclusive, and just (Muench et al., 2022). Within this overarching framework, cities play a fundamental role in the transition process, requiring reevaluating their urban development strategies and planning tools to address ongoing changes and challenges. Both transitions are integrated into EU policies and priorities. The ecological transition aligns with EU goals to protect the environment, minimize climate-related risks, and safeguard human health and biodiversity. The European Green Deal, for instance, aims to position Europe as the world's first climate-neutral continent by promoting cleaner energy sources and green technologies (European Commission, 2023). This initiative responds to climate change and seeks to preserve and enhance the EU's natural capital while safeguarding citizens from environment-related risks and impacts. This is achieved by reducing emissions and decoupling economic growth from resource consumption (European Commission, 2019). At the same time, digital transformation processes and tools are deemed important to achieve the objectives of the EU Green Deal (European Commission, 2019). The fast-paced development of technologies and tools in big data and artificial intelligence unveil not only the not-yet well-defined risks of such unexplored areas but also the potential implications for everyday people's lives. Concerning cities and urban planning, such a technological wave, thanks to the amount of data generated in cities, is already deploying its potential in terms of implications. A recent study of the EU Parliament (Pellegrin et al., 2021, 19) outlined how AI in cities is mainly related to "data collection, interpretation, and analysis in support of policy decision-making and planning and improved delivery of services of public interest." Specifically, its employment in cities is mainly characterized by a data-analytics approach (Pellegrin et al., 2021, 19). This interpretation follows the recent scientific debate in the urban studies area on the role of (big) data and new technologies in the advancement of the so-called urban data science (or science of cities) with the emergence of urban analytics (Batty, 2019; Bettencourt, 2021; O'Brien, 2022), favoring the development of innovative data-driven approaches for the better understanding of cities complex dynamics and more up-to-date and tailored information for decision-makers, and the management of cities. In this overall policy framework, characterized by the ecological and digital transition, we focused on the nexus between ESs and KETs as a potentially significant element for the future development of promising research trajectories in the urban planning field for planning city transition.3. The centrality of ESs and Key Enabling Technologies for planning cities' transition. Cities depend on natural

ecosystems and their components to sustain long-term human well-being (Gómez-Baggethun & Barton, 2013) thank to the services (ESs) they provideES (Bezák & Lyytimäki, 2011; McPhearson et al., 2014). ESs are commonly defined as the direct and indirect contributions of ecosystems to human well-being outlining a complex set of relationships between humans and nature (Cortinovis et al., 2020; Tan et al., 2020). Such a complexity materializes in cities that contain approximately 70 percent of the world's population and will produce 85 percent of global economic output by 2050 (UN, 2019). Specifically, ESs "refer to those ecosystem functions that are used, enjoyed, or consumed by humans, which can range from material goods (such as water, raw materials, and medicinal plants) to various non-market services (such as climate regulation, water purification, carbon sequestration, and flood control" (McPhearson et al., 2014, 504). Although the ESs concept was initially developed between the 1960s and the 1970s to highlight the importance of the biodiversity of ecosystems for humans, only during the 1990s was the concept significantly explored for the understanding of relations between ecosystem functions and human welfare in urban areas (Bezák & Lyytimäki, 2011). Since the work of the Millennium Assessment in 2005, ESs classification has been further detailed through several studies and approaches, and a finalized agreed classification of ESs at the international level has not been produced yet (UN, 2021). The UN SEEA-EA, following the standard classification developed about ESs classification, provides three main categories of ES (see Tab.1):

i) provisioning services,
ii) regulating and maintenance services,
iii) cultural services (UN, 2021).

Ecosystem Service	Description
Provisioning Services	Represent the contributions to benefits that are extracted or harvested from ecosystems
Regulation and maintenance services	Result from the ability of ecosystems to regulate biological processes and to influence climate, hydrological and biochemical states, and thereby maintain environmental conditions beneficials to individuals and society
Cultural Services	Represent the experiential and intangible services related to the perceived or actual qualities of ecosystems whose existence and functioning contributes to a range of cultural benefits

Tab.1 Description of the main ES categories. UN SEEA-EA (UN, 2021, 130)

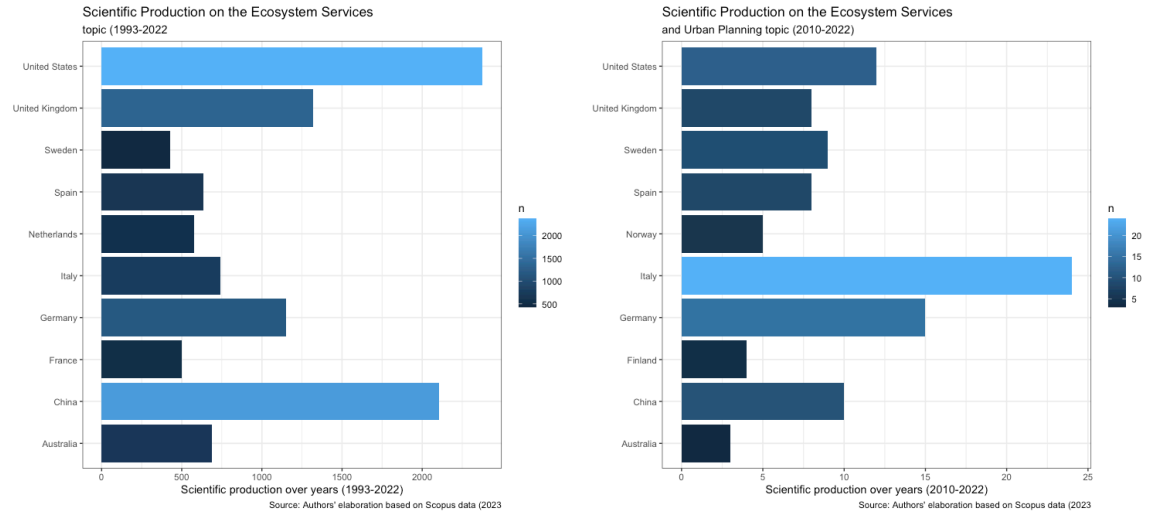


(a) **(b)**

Fig.1 Scientific Production on the ES 1993-2022 (a) and on the ES and Urban Planning 2010-2022; (b)

Fig.1a shows how the ESs topic is gaining interest in the academic arena, with a scientific production that increased constantly in the period 1993-2022. At the same time, in the last decade, the scientific production

on the nexus of ESs and urban planning has increased (Fig.1b). The first sees a concentration in the United States and China (Fig.2a), while the second, in a different timeframe – sees most of the scientific production in Italy (Fig.2b).



(a) **(b)**

Fig.2 Scientific Production on the ES 1993-2022 by country (a) and on the ES and Urban Planning 2010-2022 by country (b)

ESs are central to the planning discourse for at least three main reasons (Cortinovis et al., 2020; Tan et al., 2020): first, their provision depends on the availability and spatial distribution of ecosystems and their components which depends on land-use allocations assigned by the urban planning process (supply); second, by defining the land use and its spatial arrangements, urban planning also determine population distribution and urban functions shaping the demand for ESs; third, by defining the physical and institutional arrangements of the city, urban planning contribute to the definition of who can benefits from urban ESs (management). Moreover, urban areas are crucial for the ESs investigation as they are the place where the majority of ESs are consumed and the majority of pollution and waste are produced (Mazzeo & Polverino, 2023) ESs in cities deserves more attention, and a set of aspects on ESs planning in cities are not adequately covered by research activities (McPhearson et al., 2014). Such aspects can be synthesized in the need for more knowledge on the ESs status in terms of mapping/assessment, the inequalities deriving from the mismatch between the spatial distribution of ES supply and demand in cities, and the need to operationalize ESs frameworks for a better inclusion of biodiversity principles into governance practices, sustainability, and resiliency policy initiatives (McPhearson et al., 2014). The ESs assessment and evaluation across space and time requires a multidisciplinary approach, as integrating different mapping and assessing methods can represent the response to the challenge of real-world policy questions (Cortinovis et al., 2020). The integration of ES into urban planning frameworks can be facilitated by sophisticated data and innovative ESs analysis methods and technique, which allows the exploration of the potential of ESs mapping to inform urban and regional planning policies (Claron et al., 2022). Recent research approaches have highlighted the emergence of a need for renewing urban planning cognitive tools through GIS digital geographical processes and geospatial analysis techniques (Capriati & Malavolta, 2024). At the same time, the empirical identification and assessment of ESs relationship with urban land cover and uses emerge as a topic to address (Lai & Zoppi, 2023), together with the spatial identification of their variation in cities (Giannakidou & Latinopoulos, 2023), the implementation of Nature-Based Solutions in cities for climate changes adaptation (Mazzeo & Polverino, 2023) and circular dynamics by focusing on urban metabolism (Federico et al., 2023), and also the potentials related to the co-creation activity in contributing for a more sustainable city (Łaźniewska et al., 2021). Some of the existing challenges related to a better comprehension of ESs (quantification, mapping, assessment, dynamics) can be

addressed by the recent technological advancement in Machine Learning (ML) and Big Data (Manley et al., 2022), which can result helpful in mitigating, adapting to, and managing the pressures cities are exposed to. Recently, ML methods and techniques have improved, allowing big data to be manipulated and analyzed easily and quickly (Willcock et al., 2021). Concerning the ESs topic and its inclusion in urban planning, ML techniques – for example through the application of supervised (classification, regression) and unsupervised (clustering) and big data can be useful tools to address the challenges of data availability, understanding and estimating uncertainty, and the better understanding of socio-ecological aspects of ecosystems and (Manley et al., 2022). The application of new and alternative relevant big databases, the increasing size and resolution of big data, and the availability of ML algorithms for better understanding the complex dynamics of ESs can provide useful tools for filling the gaps in the current knowledge of ESs (Manley et al., 2022). Such relevance is clearly outlined in the EU priorities for the 2021-2027 programming period. KETs and associated technologies are deemed significant for an interconnected, digitalized, resilient, and healthier Europe and increase its competitiveness in the world economy (European Commission, 2023). The OECD has recently investigated the supporting role of emerging technologies in measuring ESs by emphasizing two main elements (Van Bodegom et al., 2020):

i) the importance of new technologies in providing high-resolution assessment at the local scale, which can result useful for the local decision-making processes,
ii) new technologies can increase the ESs assessment tools with respect to the key criteria for the applicability and adoption in the decision-making process (credibility, salience, legitimacy, and feasibility), and to whom indicators selected for the measurement of ES should be aligned (Van Bodegom et al., 2020).

At the same time, the report outlines three main areas of emerging technologies useful in supporting ESs measurement and assessment activities (Van Bodegom et al., 2020):

a) higher resolution local input data;
b) data science for locally fit transfer functions;
c) insights in trade-offs and synergies among ecosystem services.

From the overall framework developed by the OECD (Van Bodegom et al., 2020), it is possible to outline preliminary areas of investigation related to KETs to explore for data-driven planning of cities transition centered on ESs:

1) Remote Sensing technology and methods: useful for monitoring the biophysical parameters and metrics with the potential to address the basic issues of spatially quantifying the ESs (Feng et al., 2010). Therefore, such technologies can be used to measure changes in urban green spaces, vegetation health, and land use patterns, offering real-time data for evidence-based planning;
2) Data Analytics and ML: ML and Big Data analysis can serve as valuable tools that can assist in tackling issues related to data accessibility, uncertainty, and gaps in socio-ecological research within the field of ESs (Manley et al., 2022). Leveraging big data analytics and ML algorithms enables predictive modeling for ESs and urban planning, enhancing the ability to anticipate and respond to urban challenges;
3) Geospatial Analysis methods and tools: Advanced geospatial data and Geographic Information Systems (GIS) can provide critical insights into ESs distribution, assisting urban planners in decision-making for sustainable land use and resource management (Nemec & Raudsepp-Hearne, 2013).

Tab.2 provides a synthetical description for each category to introduce the main technological areas and their development useful for the design of interesting research trajectories to explore with respect to the aim of the paper. The technologies outlined in Tab.2 are partially already applied in cities. A recent EU Parliament study (Pellegrin et al., 2021) on AI and urban development has outlined the already deployed approaches for the exploitation of data and data analytics in cities, namely "Predictive Analytics (build statistical models that can classify/predict the near future) Real-Time Analytics (analyze data as it is created to provide instantaneous, actionable business intelligence to affect immediate change) Near Real-Time Analytics (analyze indexed data to

provide visibility regarding current environment, provide usage reports) Historical Analytics (build data warehouses, run batch queries to predict future events, generate trend reports)" (Pellegrin et al., 2021, p. 19).

Technology Area for ES	Description of benefits	Technology
High Resolution local input data	More accurate estimates of ecosystem services at a local scale; visualization and understanding for linking ecosystem services to the local areas; more insight in the local spatial distribution of ES supply and influencing mechanisms; less biased estimates; more detailed information for ES assessment based on land use type (Van Bodegom et al., 2020).	Satellite (remote sensing) technologies
Data science for locally fit transfer functions	New (and open) datasets help in transfer functions calculation; defining value transfer functions by allowing deriving the optimal function (through machine learning); exploitation of already available machine learning technologies (ARIES tool) (Van Bodegom et al., 2020).	data-driven models using artificial intelligence (Machine Learning/AI)
Insights in trad-offs and synergies among ecosystem services	Digitalisation of (calculations of) ecosystem services facilitate overlaying the spatial occurrences of ecosystem services; identifying hotspots of ecosystem services; Information on spatial (co-)occurrences help to identify trade-offs and synergies among ecosystem services; Helps to evaluate ecosystem multifunctionality (Van Bodegom et al., 2020).	Geo-spatial analysis

Tab.2 Description of the main emerging technology areas characteristics for ES measurement

These areas of investigation appear promising in terms of potential knowledge and insights to gain for a better understanding of phenomena in cities. As an example, the urban informatics approach has emerged for exploiting data and new technologies to better understand the complexity of cities (O'Brien, 2022). It merges urban studies, social sciences, data science, and computer science for the definition of data-driven approaches able to better explain urban phenomena by examining social interactions, mobility patterns, environmental dynamics, etc. Given these abilities, it represents valuable support to inform policymakers and planners (O'Brien, 2022). This preliminary analysis of the ESs topic, its relevance for planning, and the role that KETs can play to support a data-driven perspective for planning the transition of cities highlight the relevance of the spatial dimension of ESs intended as the understanding of detailed and location-specific information about their distribution, their status, their evolution and value for cities and territories deemed relevant for the better comprehension of complex socio-ecological dynamics at the core of transformative processes. Therefore, spatially explicit information is deemed crucial for supporting local decision-making processes and stakeholders as ecosystems are heterogenous and their services vary across space and time (Van Bodegom et al., 2020).

3. The spatial dimension of Ecosystem Services

This section focuses on the analysis of spatially explicit ES assessment and accounting methods that are considered valuable in addressing the knowledge gap regarding the nexus between ESs and planning. Three interrelated analytical approaches are examined: the United Nations System of Environmental Economic Accounting – Ecosystem Accounting (SEEA EA) (United Nations, 2021); the EU Mapping Ecosystem Services (MAES) framework (EC-JRC, 2020), developed as part of the EU Biodiversity Strategy; the EU INCA Project (EC Eurostat, 2021), which serves as a synthesis of the previous approaches. These three approaches share commonalities and similarities, as their goals overlap, and, in the case of the MAES and EU INCA project, they build upon the UN SEEA-EA analytical approach. They are explored with the aim of identifying the relevance and centrality of spatially explicit data and indicators in ESs assessment and accounting and the potential of KETs for a data-driven planning of cities' transitions centered on the nexus ESs and KETs.

Such analytical frameworks have been selected given their relevance and possible implications for planning, as the information on ecosystem extent and conditions result helpful not only for their assessment but also

for informing policy and decision-making in sectors that impacting or depending on ecosystems and natural resources, including land-use planning, (UN SEEA-EA, 2021).

3.1 The United Nations System of Environmental-Economic Accounting – Ecosystem Accounting (SEEA EA)

The United Nations System of Environmental-Economic Accounting Ecosystem Accounting (SEEA EA) (UN, 2021) is a spatially explicit and integrated statistical framework designed to structure biophysical data and information about ecosystems, monitoring changes in their extent and condition, assessing ESs and potentially their assets by linking such information with measures on economic and human activities (EU Commission-JRC, 2022). The SEEA-EA framework integrates five distinct measurement perspectives relevant to the developed framework (UN, 2021): spatial perspective (ecosystems occurrence within a defined area), ecological perspective (focus on their integrity, status, health, and condition), societal benefits perspective (source of benefits for people, economy, and society), asset value perspective (assets providing services and benefits for the future depending on their status), Institutional ownership perspective (ecosystems in relation to economic and legal entities). The core units of the SEEA-EA accounts are Ecosystem Assets, which refer to spatially contiguous areas that are internally consistent regarding their ecosystem type, conditions, and ES flows (EU Commission-JRC, 2022). The recent EU report on mapping and assessing ecosystem conditions has outlined the five core accounts (see Fig.3) that characterize data on ecosystem assets in the SEEA-EA framework (EU Commission-JRC, 2022):

i) Ecosystem extent accounts that record the area for each ecosystem within an *ecosystem accounting area*. Their extent is measured over time by ecosystem type and quantifying the changes in extent from one type to another of ecosystem;
ii) Ecosystem conditions that measure the condition of ecosystem assets in terms of selected characteristics at specific points in time providing information on the health of ecosystems;
iii-iv) ESs flow accounts (physical and monetary) quantify the supply of ESs by ecosystem assets and the exploitation of those services by economic units, included households;
v) Monetary ecosystem assets accounts provide information on stocks and changes in stocks of ecosystem assets.

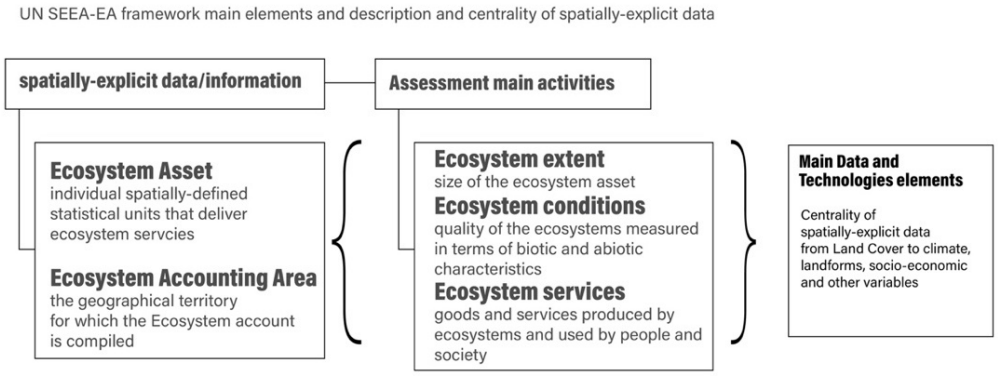


Fig.3 UN SEEA-EA framework main elements and description and centrality of spatially-explicit data

In this framework, one of the key features is the ability to integrate spatially referenced data about ecosystems, such as location, size, and condition of ecosystems in a given area, and track their changes over time (UN, 2021). Therefore, the availability of spatial data in describing ecosystems and their economic uses is deemed significant for the accounting activity, as well as the thematic and spatial detail of these data, their geospatial comparability, and integration in shared spatial data infrastructure (UN, 2021).

4.2 The EU – Mapping and Assessment of Ecosystems and their Services (MAES) work

In 2011, the EU defined a Biodiversity Strategy with the primary objective of inverting the decline of biodiversity and the services provided by ecosystems. One notable feature of this Strategy was its introduction of an ecosystem framework within the context of biodiversity policy (EC-JRC, 2020). One of the key actions outlined in the Strategy, Mapping and Assessment of Ecosystems and their Services (MAES) was expressed in Action 5 (EC-JRC, 2020). This action called upon Member States, with support from the Commission, to conduct comprehensive mapping and assessments of the condition of ecosystems and their associated services within their national territories, including the economic assessment of these services and advocating for the integration of these values into accounting and reporting systems at both the EU and national levels (EC-JRC, 2020). The main challenge for Action 5 was to increase and operationalize the currently available scientific knowledge on ecosystems and their services in the EU to support and guide policy decisions (EC, 2013).
The MAES Working Group has developed an operational framework involving policymakers and researchers (EC-JRC, 2020) and promotes a spatially explicit approach to mapping and assessing ecosystem conditions. The operational framework is characterized by four main elements (EC-JRC, 2020):

i) a conceptual frame – developed in the initial stage of the work – that connects ecosystems, biodiversity, and people, serving a conceptual basis for the design of integrated ecosystem assessment, that assumes how pressures, conditions, and services within ecosystems are interconnected;
ii) a common framework to describe the ES assessment process from mapping ecosystems to the assessment of ecosystem conditions, ES;
iii) typologies for Ecosystems, pressures, conditions, and ESs;
iv) a selection of indicators per ecosystem type to assess the pressures, conditions, and ESs.

The MAES work resulted in an agreed analytical framework that includes standards and indicators for mapping ecosystem conditions and ESs (EC-JRC, 2020). Standards include typologies for ecosystems and ESs and indicators – spatially explicit – for assessing ecosystem conditions and services per ecosystem type (EC-JRC, 2020). The conceptual model on which it is rooted assumes that the delivery of certain ESs is dependent both on the spatial accessibility of ecosystems as well as their conditions (Burkhard et al., 2018).

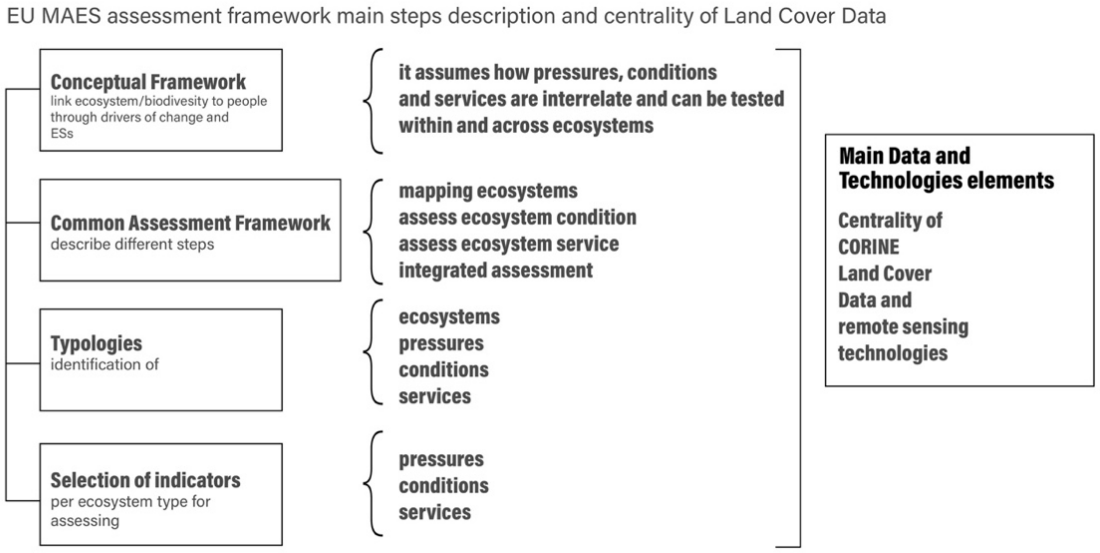


Fig.4 EU MAES assessment framework main steps description and centrality of Land Cover Data

The MAES framework is articulated in four main elements (EC-JRC, 2020) (see Fig.4):

i) a conceptual framework that establishes a linkage between ecosystems and biodiversity with people via drivers of change and ESs;

ii) a common assessment framework for describing the different steps for the ecosystem assessment, from their mapping, assessment of ecosystem condition, services and integrated assessment;
iii) identification of typologies for ecosystems, pressures, conditions, and services;
iv) a selection of indicators per ecosystem type finalized at the assessment of pressures, condition, and services.

In the MAES approach, the exploitation of data for measuring ecosystems and their extents, as well as indicators to measure their conditions, is deemed relevant (EC-JRC, 2020). Land Cover data (EU CORINE Land Cover) have been assumed as a reference dataset for delineating the extent of ecosystems, analyzing the trends in the extent of ecosystems, and have been used as an input layer for the calculation of trends for specific ecosystem condition indicators (EC-JRC, 2020). Such data and indicators should refer to the current spatial distribution of ecosystems and their use specifically for each ecosystem type, defining in this way a spatially explicit knowledge about ecosystem conditions and influencing pressures (EC-JRC, 2020). Mapping and assessment of ecosystem conditions exploit data that are available at multiple spatial scales (from site-level measurements to remote sensing and modeled data at the landscape level) (EC-JRC, 2020).

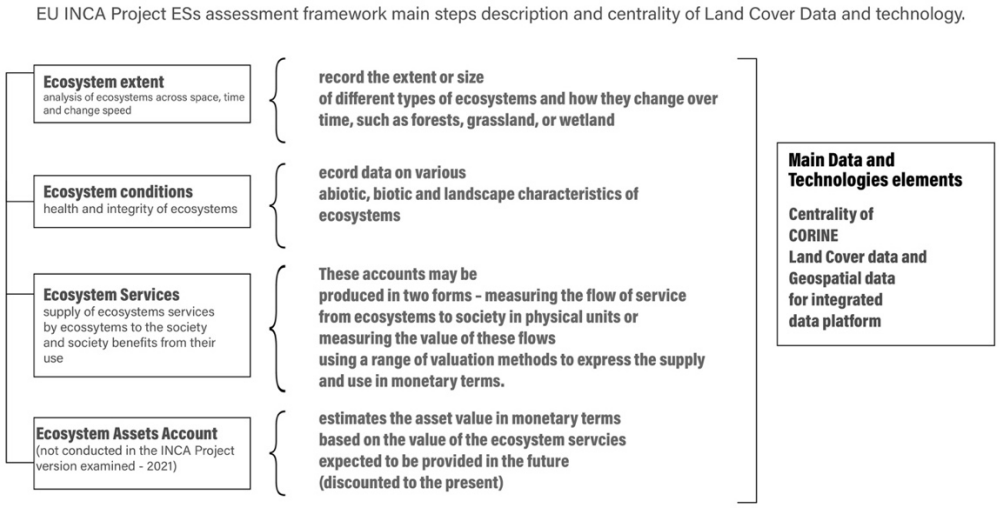


Fig.5 EU INCA Project ESs assessment framework main steps description and centrality of Land Cover Data and technology

For example, remote sensing-derived indicators are considered optimal (when available) to provide "several parameters such as land cover, which is used for calculating forest connectivity and landscape metrics, but also indices of plant physiology and stress (i.e., functional) such as NDVI or structural metrics such as tree cover density" (EC-JRC, 2022: p. 67) (see Fig.5).

4.3 The EU INCA Project

The EU INCA Project (EC Eurostat, 2021), launched in 2015, provides a bedrock in the ESs accounting and assessment by improving the spatially explicit perspective reported in the UN SEEA (UN, 2021). The approach focuses on the need for established and regular measurement of ecosystem extent, condition, change over time, and the quantity of services these ecosystems supply (EC Eurostat, 2021). The EU INCA project approach was closely linked to the MAES (EC-JRC, 2020) at the EU level and has provided inputs at the global level to the UN SEEA EEA (UN, 2021). Concerning the MAES approach, the INCA project adopted "a more rigorous and structured accounting approach to describe ecosystems, their services, and how they change over time" (EC Eurostat, 2021, 12). The INCA project has focused on the accounting for ecosystems following a threefold measurement activity, which is embedded in the SEEA framework (EC Eurostat, 2021, 11-12): i) Ecosystem extent accounts; ii) Ecosystem condition accounts; iii) ESs accounts; iv) Ecosystem Assets Account (see Fig.6).

This analytical approach grounded on spatially-explicit data and information unveils interesting potential insights on gaining knowledge on ESs.

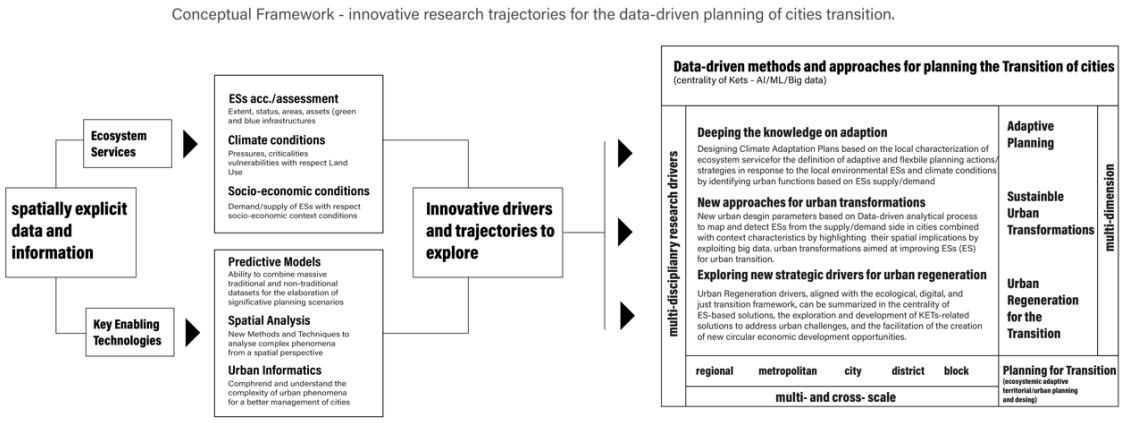


Fig.6 Research drivers and trajectories for the data-driven planning of cities transition centered on ESs and KETs

The first is related to *Ecosystem extent accounts* (1), which record the extent or size of different types of ecosystems and their change over time. The Ecosystem extent accounts are built exploiting the Corine Land Cover data (land use data) from the EU Copernicus Earth Observation Program (EC Eurostat, 2021). The Ecosystem extent account provides insight into the type, distribution, and share of different ecosystem types at the country level (or other chosen territory) by providing dimensional data (area) on the increase or decrease ('stock') of ecosystems across a country (or territory) over time and at which speed this change occurred (EC Eurostat, 2021). The spatial data on distribution of ecosystem type provide useful insights for the calculation of the accounting of ecosystem conditions and ES.

The second measure, *Ecosystem conditions accounts* (2) collects data on abiotic, biotic, and landscape characteristics of the ecosystem. Ecosystem condition is related to the ecosystem's *health* or ecological integrity, which can be measured by selecting an appropriate set of ecosystem variables (EC Eurostat, 2021). Condition accounts register information on abiotic, biotic, and landscape characteristics of ecosystems for measuring and assessing their quality. This information is important to determine the type and quantity of services that the ecosystem can provide, as the poor management/degradation conditions of ecosystems can lead to the loss in delivering multiple services (EC Eurostat, 2021). According to the analytical approach developed for the INCA Project (EC Eurostat, 2021), ecosystem conditions can be measured in two ways. The first, by selecting appropriate sets of ecosystem variables describing the changes in the condition of ecosystems changes. In this case, usually, higher values of such variables are, in most cases, associated with a higher condition of ecosystems and, thus, a higher potential to deliver multiple ES. Alternatively, the *conditions* can also be detected by measuring the pressures acting on ecosystems, such as nitrogen pollution, land conversion, invasive alien species (EC Eurostat, 2021).

The third, the *ES accounts* (3), record the supply of various ES by ecosystems to society and how the latter benefits from their use. ES are crucial for humans' well-being and the economic systems. The Ecosystem service accounts measure the flows or quantities of services that the society is using (demand). These accounts can be measured in two forms: i) measuring the flow of service from ecosystems to society in physical units; ii) measuring the value of these flows using a range of valuation methods to express the supply and use in monetary terms (EC Eurostat, 2021). The data and information derived from the ecosystem extent and conditions are inadequate to measure and assess the linkages (transactions) between ecosystems and economies. Therefore, understanding and mapping the supply and demand of ESs is an important element to consider (EC Eurostat, 2021). In the mapping and quantifying the supply and demand of ESs there could be

two potential interesting insights. The first is related to detecting *unmet demand* situations in which economic and societal needs for ESs remain unsatisfied (when the ecosystem needed to provide the requested services is not present). The second is related to those situations where ESs are overexploited (used beyond their sustainability levels). However, in the accounting process, the focus is on the actual flows of ESs, which are measured through supply and use (demand) tables. The INCA project approach – for the assessment of ESs – relies on the measurement of two drivers affecting the use of ESs: the ESs potential and the ESs demand. The first is an estimate of what an ecosystem can offer in terms of services, and it is based on the limits of ES. The ES potential can be mapped by exploiting the information and data derived from the ecosystem extent account (surface area) and the ecosystem conditions account (conditions of the ecosystems) and based on other climatic and environmental data (EC Eurostat, 2021). The second, the ESs use – or demand – can be mapped and aggregated for an accounting area, and the actual use can be estimated "as the share of demand that can be satisfied by the potential" (of ESs) (EC Eurostat, 2021, 26).

The last one, the *Ecosystem Assets accounts* (4), record stocks of assets and changes in these assets. Ecosystem asset accounts estimate the value of ecosystems. The asset value in monetary terms is usually determined based on the value of the ESs expected to be provided by a particular ecosystem in the future, discounted to the present (This account was not described in the Accounts' report examined).

The EU INCA Project emphasizes the foundational relevance and importance of data and technologies for making Ecosystem accounting operational (EC Eurostat, 2021). Such a process requires the integration of different data both on ecosystems and economies (EC Eurostat, 2021) (see Fig.7). Geo-spatial data and technologies are crucial to analyze their conditions and detect their distribution (EC Eurostat, 2021). Therefore, the organization, finding, and analysis of meaningful (geo)spatial data through integrated platforms is crucial (EC Eurostat, 2021). Such elements are deemed important in terms of possible urban planning implications given the potential knowledge available on ESs – thanks also to KETs.

5. Discussion and conclusions: an innovative research perspective for a data-driven planning of cities transition centered on ESs and KETs, and its possible planning implications

The paper focused on the nexus between ESs and KETs as a potentially significant element for the future development of promising research trajectories in urban planning, we have argued the potential centrality of the linkages between ecosystem services and key enabling technologies for a better understanding of the complex dynamics and relationships occurring in cities and territories in line with the ecological and digital transition paths. Such relevance emerges from the analysis of the main adopted ecosystem services assessment methodologies, which are grounded on spatially explicit methods for their assessment and are deemed important for this contribution. This perspective places data-driven planning as one of the central elements in guiding cities and territories through their transition and opens to multidisciplinary research approaches that can shape innovative pathways to enhance cities' and territories' sustainability and resilience and generate interesting planning implications.

The need for cities to adapt to new contexts implies new evolutionary perspectives for planning, intended not as the simple direction of urban development towards predetermined urban configurations but rather for enhancing cities' capacity to adapt to their dynamic environment (Rauws & De Roo, 2016). The urgent challenges for cities and territories regarding their sustainability and resilience have heightened the necessity for a more profound understanding and more innovative methods of planning and managing urban areas (Bibri, 2021). The analytical approaches examined related to ESs have emphasized the relevance of spatially explicit and related data, information, and technologies for the analysis of ESs together with the importance of focusing on the local scale. The conceptual framework developed for this paper (see Fig.6) considers two central elements for planning the city's transition towards sustainability and resilience from a data-driven

planning perspective: ESs (and their spatially explicit relevance) and KETs. Fig.6 illustrates the connection between ESs and KETs in defining new research trajectories that characterize innovative data-driven planning perspectives and identify promising research drivers to explore. The possible research drivers to explore reflect the current challenges that cities are called to face and, therefore, that planning is called to address: the development of effective climate change mitigation and adaptation measures, the need to reduce the impacts of urban changes (transformations) on natural ecosystems for improving human well-being while maintaining biodiversity, the challenge of implementing urban transition through urban planning thanks to the integrated approach intrinsic to urban regeneration. These research drivers leverage the centrality of the nexus ESs-KETs for urban planning in response to the overall aim set out by the EU in the Green, and we outline them as follows:

1) Adaptive and Regenerative Planning – for addressing urban and territorial fragmentation for climate change;
2) Sustainable Urban Transformation design – for exploring the implementation of multidisciplinary approaches for urban transformation planning and design;
3) Urban Regeneration for the transition – for exploring the development of new drivers for urban regeneration to plan cities' transitions.

Each of the potential research drivers to explore is provided consistency with the "planning" need and the technological elements that can be associated.

The first research driver focuses on deepening the knowledge of adaptation (towards adaptive planning) of cities and territories in the context of the EU priority to define a more sustainable development path by decoupling economic development from natural resources. It emphasizes the potential of data-driven approaches for designing and implementing local Climate Adaptation Plans to offer robust and relevant information based on the local characterization of ESs for tackling urban and territorial fragmentation through transformative interventions that are more consistent with local dynamics. Data integration in tradition urban planning approaches can provide useful understanding of territorial vulnerabilities, transformations generated by climate changes, and socio-demographic dynamics (Capriati & Malavolta, 2024), paving the ground for a better comprehension of socio-ecological dynamics. Local climate adaptation plans can be designed and implemented, starting with green and blue infrastructure (ESs providers) enhancement as a central element for the future development of cities. This setting implies considering multi-dimensional and multi-scalar elements that characterize local dynamics from the social, economic, and environmental dimensions. From the technological perspective, it implies collecting, analyzing, and modeling vast amounts of data to build a knowledge framework on the dynamic local environment. Combining satellite data sources with conventional data can be complemented by the potential of Artificial Intelligence through Machine Learning for developing predictive models capable of simulating short-, medium-, and long-term scenarios based on the variation of context-related variables (ESs variation/sensitivity, socio-economic factors, planning considerations, and climate dynamics).

The second research driver outlines the need for exploring new approaches in defining and designing urban transformations (sustainable urban transformation) through a data-driven analytical process for mapping and detecting ESs from the supply/demand perspective in cities, complemented by contextual characteristics that highlight their spatial implications through the utilization of big data. It could aim to define the planning and design of the restructuring processes generated by the ecological and digital transition mechanisms by defining sustainable urban transformation processes. Specifically, by capturing complexities inherent in urban environments, it would be possible to unveil patterns and relationships that can inform more effective and responsive urban planning strategies. This data-driven perspective could contribute for formulating an analytical process for shaping urban planning and governance approaches, with the aim of defining urban transformations that enhance ESs. This process can contribute to the identification of the impacts of urban transformations by assessing them from an ecosystem perspective (intended as the ability to reduce the pressures on natural ecosystems) and detect the potential leverage elements for urban transition by exploiting

data from satellites, sensors, and other available sources to identify and detect ESs at the district level, facilitating the planning and design of sustainable urban transformations. Such approaches could reinforce and improve already existing perspectives, for example those related to the implementation of urban design strategies centered on Nature-Based solutions in defining urban transformations (Mazzeo & Polverino, 2023).The third research driver focuses on the exploration of new strategic drivers for urban regeneration (urban regeneration for transition) for implementing transition-oriented strategies, mechanisms, and tools more aligned with the current challenges that cities are called to face. Urban transformations, which serve as catalysts for socio-ecological and socio-technical demands for change in cities, can be planned by adapting urban regeneration strategic drivers adaptable to contextual conditions. Urban Regeneration drivers, aligned with the ecological, digital, and just transition framework, can be summarized in the centrality of ESs-based solutions, the exploration and development of KETs-related solutions to address urban challenges, and the facilitation of the creation of new circular economic development opportunities. Additionally, they could encompass the deployment of social inclusion-related processes by acting on cross-cutting elements such as public services accessibility, education, and labor policies and reducing inequalities for the most vulnerable groups. Specifically, given the EU priorities for the Green Deal, it can ensure, if properly managed, a just and inclusive transition in the definition of a more sustainable path for cities thanks to its multi-dimensional (social, economic, and environmental) nature. In this context, the recent emergence of urban informatics (O'Brien, 2022) can result in the understanding of urban dynamics (social, economic, environmental) and, consequently, implementing tailored actions and interventions adapted to the specific context needs.

Besides the implications of such a research perspective regarding knowledge advancements on the topic under investigation, a stronger inclusion of ESs in urban planning is considered central for the promotion of sustainable urban development (Cortinovis et al., 2020). Although ES-related actions and different tools for their implementation are already included in several urban plans' experiences, there are still issues to address in terms of knowledge transfer into planning practice and in usable methods for embedding effectively ESs information into planning processes (Cortinovis & Geneletti, 2018). The research drivers outlined in this section could potentially provide useful and helpful insights in this direction.

The integration of the nexus ESs-KETs into urban planning can potentially result in a more holistic, resilient, and sustainable approach to city development that considers the complex interactions between natural systems, human activities, and technological innovations. Such an approach would be characterized by a high degree of flexibility, intended here as the ability to interpret the change in local dynamics conditions and respond through adaptive strategies centered on the supply/demand of ESs. The identification of criticalities and pressures on ecosystems, through the ESs perspective, can result in the identification of urban functions that make urban areas more responsive – and less vulnerable – to climate changes and able to withstand and adapt to shocks and stresses.

The exploitation of advanced geospatial data analytics based on AI/ML/Big data for ESs assessment can reinforce this perspective, as it could enable urban planners to build a knowledge framework tailored to reducing the pressures on natural ecosystems since the initial phases of the planning processes, and it could result helpful in the elaboration of adaptive planning scenarios based on real-time information, improving the efficiency of resource allocation, infrastructure development, and land use management.

The operative implications for the planning-design process could be multiple. First, exploring these research drivers can contribute to enriching and enhancing planning practice. The potential of KETs exploitation could enhance the knowledge and interpretation, also from an evolutionary and historical perspective, of urban-territorial and landscape structures. In addition, developing KETs and associated technologies and approaches allow for speeding up the data collection and analytical processes finalized in the design of Comprehensive General Plans and implementation tools. The combination of traditional and new datasets deriving from such technologies – such as satellite and remote sensing – allows a better comprehension of the complex

phenomena affecting cities and territories from the global and local levels. Second, the fast-paced growth of AI and ML techniques, together with the augmented capacity and performance of advanced calculators, could allow the process of massive amounts of data and elaborate accurate and solid predictive models, which in turn can provide valuable support for the elaboration of different planning scenarios. Third, by identifying the ESs demand and supply, thanks to their quantification through KETs, such elements could be re-framed into Zoning in terms of detailed regulations for facilitating more sustainable mixed land use, compact development, and green building practices through renovated design parameters aimed to reduce the pressures on natural ecosystems, increasing energy savings and performances, and promoting circular economy.

The urban regeneration approach could merge these potentials. Thanks to its highly adaptive strategic drivers, it could be the umbrella to facilitate the transition of cities by promoting urban transformation processes able to catalyze the context conditions on the ecological (ESs), digital (KETs), and just (socially inclusive) development drivers. Moreover, institutional and regulatory aspects could potentially support this perspective. The first implies the development of institutional activities focusing on ESs as leveraging elements for institutions in terms of organizational and management aspects, partnerships, and networking, which could influence the design of policies or policy actions already defined or in place – from the EU to the local level.

The second, on the basis of the knowledge gained on local ESs, could identify financial instruments able to valorize and optimize ESs and experimental elements (best practices, pilot projects, experimentation) that can be framed and organized for the improvement of the existing instruments. From the economic and financial perspective, providing financial incentives and subsidies to citizens, businesses, and organizations that adopt sustainable practices can support the planning of cities' transition.

We are aware of the intrinsic limitations of the depicted scenarios. However, as outlined in Fig.1 and Fig.2, the interest in this topic and its relationship with urban planning is gaining relevance, and the research drivers outlined in this contribution, together with the potential implications for planning exposed, are part of a complex and multi-faceted debate the oriented at addressing the current challenges that cities are calling to face in their transition to sustainability. Further studies could explore the research drivers outlined with a more in-depth literature examination or complement it with the analysis of urban plans for a better understanding of ESs inclusion in urban planning. Furthermore, while the paper's outlines of the main characteristics of the UN approach (UN, 2021), it pays attention exclusively to the EU perspective. Further studies can expand the investigation by including also other analytical approaches developed in other countries (United States, China, etc.).

In conclusion, as cities face the rapid pace of urbanization and its associated challenges, innovative research trajectories and drivers to explore offer possible pathways toward more sustainable, inclusive, and resilient urban futures. By embracing data-driven decision-making and planning, leveraging new technologies, fostering community engagement, and pioneering policy innovation, cities can chart a transformative course that prioritizes the well-being of their residents.

Funding

This paper is the result of the synergistic activities related to the following PNRR research projects - funded by the European Union - NextGenEU - and Horizon 2020 funded Research Projects: "Tech4You Innovation Ecosystem - Pilot Project 4.6.1 "Climate adaptation plans for the reduction of the ecological footprint and ecological debt, aimed at improving the conservation and transformation response in terms of resilience and quality of life in the Calabrian and Lucanian urban and territorial systems" (Goal 4.6 - Planning for Climate Change to boost cultural and natural heritage: demand-oriented ecosystem services based on enabling ICT and AI technologies), funded by the European Union – NextGenerationEU - PNRR - Missione 4 "Istruzione e Ricerca" - Componente 2 "Dalla Ricerca all'Impresa" - Investimento 1.5 "Ecosistemi dell'Innovazione; the "ECO-SET - A Multidisciplinary approach to plan ES for cities in Transition" – project funded by the European Union – NextGenerationEU - PNRR - Missione 4 "Istruzione e Ricerca" - Componente 2 "Dalla Ricerca

all'Impresa" - Investimento 1.1 - Fondo per il Programma Nazionale della Ricerca (PNR) e Progetti di Ricerca di Rilevante Interesse Nazionale (PRIN); the "PLANET – PLANning Ecosystem services for cities in Transition - project funded by the European Union – NextGenerationEU - PNRR - Missione 4 "Istruzione e Ricerca" - Componente 2 "Dalla Ricerca all'Impresa" - Investimento 1.2 "Finanziamento di progetti presentati da giovani ricercatori"; and the TREND – Transition with Resilience for Evolutionary Development - TREnD (Transition with Resilience for Evolutionary Development) which has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No. 823952.

References

Ahern, J., Cilliers, S., & Niemelä, J. (2014). The concept of ecosystem services in adaptive urban planning and design: A framework for supporting innovation. *Landscape and Urban Planning, 125*, 254-259. https://doi.org/10.1016/j.landurbplan.2014.01.020

Alberti, M., MacPhearson, T., & Gonzalez, A. (2018). Embracing Urban Complexity. In: T. Elmqvist, X. Bai, N. Frantzeskaki, et al. (Eds.). *Urban Planet: Knowledge towards Sustainable Cities*. 45-67, Cambridge: Cambridge University Press. https://doi.org/10.1017/9781316647554.004

Alberti, M., Palkovacs, E.P., Des Roches, S., De Meester, L., Brans, K.I., Govaert, L., Grimm, N.B., Harris, N.C., Hendry, A.P., Schell, C.J., Szulkin, M., Munshi-South, J., Urban, M.C., & Verrelli, B.C. (2020). The Complexity of Urban Eco-evolutionary Dynamics. *BioScience, 70*(9), 772-793. https://doi.org/10.1093/biosci/biaa079

Batty, M. (2019). Urban analytics defined. *Environment and Planning B: Urban Analytics and City Science, 46(3)*, 403-405. https://doi.org/10.1177/2399808319839494

Bettencourt, L.M.A. (2021). Introduction to urban science: evidence and theory of cities as complex systems. Cambridge (MA), The MIT Press, https://doi.org/10.7551/mitpress/13909.001.0001

Bezák, P., & Lyytimäki, J. (2011). Complexity of urban ecosystem services in the context of global change. *Ekologia Bratislava, 30*(1), 22-35. https://doi.org/10.4149/ekol_2011_01_22

Bibri, S. (2021). Data-driven smart sustainable cities of the future: An evidence synthesis approach to a comprehensive state-of-the-art literature review. *Sustainable Futures, 3,* 100047. https://doi.org/10.1016/j.sftr.2021.100047

Burkhard, B., Santos-Martin, F., Nedkov, S., & Maes, J. (2018). An operational framework for integrated mapping and assessment of ecosystems and their services (MAES). In: *One Ecosystem, 3*, e22831, JRC109464. https://doi.org/10.3897/oneeco.3.e22831

Caprari G., & Malavolta, S. (2024). Analysis of territorial fragilities through GIScience. *TeMA - Journal of Land Use, Mobility and Environment, (1)*, 169-190. https://doi.org/10.6093/1970-9870/10200

Claron, C., Mikou, M., Levrel, H., & Tardieu, L. (2022). Mapping urban ecosystem services to design cost-effective purchase of development rights programs: The case of the Greater Paris metropolis. *Land Use Policy, 122*. https://doi.org/10.1016/j.landusepol.2022.106349

Cortinovis, C., Geneletti, D., Adem Esmail, B., & Zardo, L. (2020). *Planning for Ecosystem Services in Cities*. Cham, Switzerland: Springer. http://www.springer.com/series/8868

Cortinovis, C., & Geneletti, D. (2018). Ecosystem services in urban plans: What is there, and what is still needed for better decisions. *Land Use Policy, 70*, 298.312. https://doi.org/10.1016/j.landusepol.2017.10.017

Cortinovis, C., & Geneletti, D. (2019). A framework to explore the effects of urban planning decisions on regulating ecosystem services in cities. *Ecosystem Services,38,* 1-13 100946. https://doi.org/10.1016/j.ecoser.2019.100946

De Rauws, W., & De Roo, G. (2016). Adaptive planning: Generating conditions for urban adaptability. Lessons from Dutch organic development strategies. *Environment and Planning B: Planning and Design, 43*(6), 1052-1074. https://doi.org/10.1177/0265813516658886

European Commission, Directorate-General for Environment (2013). *Mapping and assessment of ecosystems and their services – An analytical framework for ecosystem assessments under action 5 of the EU biodiversity strategy to 2020 – Discussion paper – final*. April 2013, Publications Office. https://data.europa.eu/doi/10.2779/12398

European Commission (2019). *The European Green Deal. Communication from the Commission*. Brussels, 11.12.2019 COM(2019) 640 final

European Commission, Joint Research Centre (2020). *Mapping and assessment of ecosystems and their services – An EU wide ecosystem assessment in support of the EU biodiversity strategy*. Publications Office. https://data.europa.eu/doi/10.2760/757183

European Commission, Eurostat (2021). Accounting for ecosystems and their services in the European Union (INCA) – Final report from phase II of the INCA project aiming to develop a pilot for an integrated system of ecosystem accounts for the EU – 2021 edition, Publications Office, 2020. https://data.europa.eu/doi/10.2785/197909

European Commission, Joint Research Centre (2022), *EU-wide methodology to map and assess ecosystem condition – Towards a common approach consistent with a global statistical standard, Publications Office of the European Union*. https://data.europa.eu/doi/10.2760/13048

European Commission (2023). *Key enabling technologies for Europe's technological sovereignty*. https://doi.org/10.2861/24482

Federico, K., Di Giustino, G., Ferraioli, E., & Lucertini, G. (2023). Circular and metabolic perspectives in urban contexts. Integrated flows analysis for an ecological transition. *TeMA - Journal of Land Use, Mobility and Environment, (2)*, 143-157. https://doi.org/10.6093/1970-9870/10196

Feng, X., Fu, B., Yang, X., & Lü, Y. (2010). Remote sensing of ecosystem services: An opportunity for spatially explicit assessment. *Chinese Geographical Science, 20*(6), 522-535. https://doi.org/10.1007/s11769-010-0428-y

Geneletti, D., Cortinovis, C., Zardo, L., & Adem Esmail, B. (2020). Reviewing Ecosystem Services in Urban Plans. In D. Geneletti, C. Cortinovis, L.Zardo, B.A. Esmail. *Planning for Ecosystem Services in Cities*. Springer Briefs in Environmental Science. Cham: Springer. https://doi.org/10.1007/978-3-030-20024-4_2

Giannakidou A., & Latinopoulos, D. (2023). Identifying spatial variation in the values of urban green at the city level. *TeMA - Journal of Land Use, Mobility and Environment, 16*(1), 83-104. https://doi.org/10.6093/1970-9870/9290

Gómez-Baggethun, E., & Barton, D.N. (2013). Classifying and valuing ecosystem services for urban planning. *Ecological Economics*, 86, 235-245. https://doi.org/10.1016/j.ecolecon.2012.08.019

Koc, M., & Acar, A. (2021). Investigation of urban climates and built environment relations by using machine learning. *Urban Climate, 37.* https://doi.org/10.1016/j.uclim.2021.100820

Kontokosta, C. E. (2021). Urban Informatics in the Science and Practice of Planning. *Journal of Planning Education and Research, 41*(4), 382-395. https://doi.org/10.1177/0739456X18793716

Lai, S., & Zoppi, C. (2023). Factors affecting the supply of urban regulating ecosystem services. Empirical estimates from Cagliari, Italy. *TeMA - Journal of Land Use, Mobility and Environment, (2)*, 7-32. https://doi.org/10.6093/1970-9870/10194

Łaźniewska, E., Janicka, I., & Gorecki, T. (2021). Co-creation of the green smart city concept. Analysis of the maturity of municipalities in the Polish-German borderland region. *TeMA - Journal of Land Use, Mobility and Environment, 14* (3), 319-342. https://doi.org/10.6093/1970-9870/8116

Manley, K., Nyelele, C., & Egoh, B.N. (2022). A review of machine learning and big data applications in addressing ecosystem service research gaps. *Ecosystem Services*, *57*. https://doi.org/10.1016/j.ecoser.2022.101478

Marques, A.L., Alvim, A.T.B., & Schröder, J. (2022) Ecosystem Services and Urban Planning: A Review of the Contribution of the Concept to Adaptation in Urban Areas. *Sustainability, 14*, 2391. https://doi.org/10.3390/su14042391

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

McPhearson, T., Hamstead, Z. A., & Kremer, P. (2014). Urban ecosystem services for resilience planning and management in New York City. *Ambio, 43*(4), 502-515. https://doi.org/10.1007/s13280-014-0509-8

Nemec, K.T., & Raudsepp-Hearne, C. (2013). The use of geographic information systems to map and assess ecosystem services. *Biodivers Conserv, 22*(1), 15 (2013). https://doi.org/10.1007/s10531-012-0406-z

O'Brien, D.T. (2022). Urban Informatics: Using Big Data to Understand and Serve Communities. Boca Raton, FL: Chapman Hall / CRC Press

Pellegrin, J., Colnot, L., & Delponte, L. (2021). Research for REGI Committee – Artificial Intelligence and Urban Development. Brussels: European Parliament, Policy Department for Structural and Cohesion Policies

Qiu, L., Dong, Y., & Liu, H. (2022). Integrating Ecosystem Services into Planning Practice: Situation, Challenges and Inspirations. *Land,11*(4), 545. https://doi.org/10.3390/land11040545

Scowen, M., Athanasiadis, I.N., Bullock, J.M., Eigenbrod, F., & Willcock, S. (2021). The current and future uses of machine learning in ecosystem service research. *Science of the Total Environment*, *799*, 149263. https://doi.org/10.1016/j.scitotenv.2021.149263

Sirakaya, A., Cliquet, A., & Harris, J. (2018). Ecosystem services in cities: Towards the international legal protection of ecosystem services in urban environments. *Ecosystem Services, 29*, 205-212. https://doi.org/10.1016/j.ecoser.2017.01.001

Tan, P.Y., Zhang, J., Masoudi, M., Alemu, J.B., Edwards, P.J., Grêt-Regamey, A., Richards, D.R., Saunders, J., Song, X.P., & Wong, L. W. (2020). A conceptual framework to untangle the concept of urban ecosystem services. *Landscape and Urban Planning, 200*. https://doi.org/10.1016/j.landurbplan.2020.103837

United Nations (2019). I*ndependent Group of Scientists appointed by the Secretary-General, Global Sustainable Development Report 2019: The Future is Now – Science for Achieving Sustainable Development*. New York: United Nations

United Nations (2021). *System of Environmental-Economic Accounting-Ecosystem Accounting White cover (pre-edited) version*. New York, United Nations. https://seea.un.org/ecosystem-accounting

Van Bodegom, P., Remme, R., Kitamori, K., Cervantes, M., Karousakis, K., Jolly, C., Mackie, A., & Botta, E. (2020). *New technologies and approaches to measure ecosystem services locally and to engage local stakeholders. OECD Issue Paper, 2020 Green Growth and Sustainable Development Forum*, 24-26. Paris: OECD. https://issuu.com/oecd.publishing/docs/ggsd_2020_issue_paper-ecosystem_services_and_stake

Willcock, S., Martinez-Lopez, J., Dandy, N., & Bullock, J. M. (2021). High spatial-temporal resolution data across large scales are needed to transform our understanding of ecosystem services. *Land, 10*(7). https://doi.org/10.3390/land10070759

Image Sources

Fig.1 to Fig.6: Authors' elaboration

Author's profile

Francesca Moraci

Full Professor, PhD, Architect, is Professor in Urban Planning at the Università degli Studi Mediterranea of Reggio Calabria, where she has led several national and international researches and is currently Coordinator of the Pilot Project 4.6.1 (Climate adaptation plans for the reduction of the ecological footprint and ecological debt, aimed at improving the conservation and transformation response in terms of resilience and quality of life in the Calabrian and Lucanian urban and territorial systems) and of the Goal 4.6 (Planning for Climate Change to boost cultural and natural heritage: demand-oriented ecosystem services based on enabling ICT and AI technologies) within the Tech4You Innovation Ecosystem, funded by the Italian PNRR (M4C2 – Inv. 1.5), and is Scientific Responsible for the UNIRC research unit for the ECO-SET (A Multidisciplinary approach to plan ES for cities in Transition) Research Project funded by the Italian PNRR (M4C2 – Inv. 1.1). Director of the STuTeP – Territorial and Urban Strategies for Planning - Research Laboratory, she teaches Urban Planning and Design within the Architecture Degree Program (in Double Degree for international students). She is the author of almost 200 scientific publications, including monographs, journals articles and essays, as well as websites and other online publications.

Carmelina Bevilacqua

Associate Professor in Urban Planning at the University of Roma LaSapienza. She has led several EU (7th FQ, Horizon 2020) and National (PRIN, PRIN-PNRR) funded Research Projects on the overall topic of urban regeneration and economic development. She is Principal Investigator for the ECO-SET (A Multidisciplinary approach to plan ES for cities in Transition) Research Project funded by the Italian PNRR (M4C2 – Inv. 1.1). Her research interests focus on the role of data-driven planning perspective for the facilitation of cities' transition and the sustainability of urban transformation. She teaches urban design within the Architecture Degree Program at the University of Roma LaSapienza. She is author of over 100 scientific publications, including monographs, journal articles and essays, as well as websites and other online publications.

Pasquale Pizzimenti

Fixed-Term Researcher (RTDA) in Urban Planning at the Università degli Studi Mediterranea of Reggio Calabria. He is Principal Investigator for the PLANET (Planning ES for cities in transition) research Project, funded by the Italian National Recovery and Resilience Plan (M4C2 – Inv. 1.2 "Young Reseachers"). He is a former Marie Curie Fellow for the ZES (opportunity zones for innovation – H2020-MSCA-IF-Global 2018) and has participated as MC early stage and experienced researcher in several EU-funded (7th FP – Horizon 2020) Research Projects. His main research interests focus on urban regeneration and the planning of cities transition by exploring data-driven planning approaches for investigate urban complexity, the urban dimension of knowledge and innovation dynamics and the role of urban governance and planning in managing the complexity of the current urban transformations. He is author of several scientific publications on the topic.

We are online!

TeMA Lab

Follow us on Twitter

TeMA Lab and our Journal are on Twitter!
TeMA Lab is the Laboratory of Land Use, Mobility and Environment of the Department of Civil, Building and Environmental Engineering, at Università degli Studi di Napoli Federico II. Our field of expertise relates to urban systems, their complexity and the challenges that they will face in near future: adaptation to climate change, ageing population, energy consumptions, development of sustainable mobility and so on. Follow us to be constanly updated!.

www.twitter.com/TeMALab_unina

TeMA Journal of Land Use, Mobility and Environment

TeMA 1 (2024) 129-145
print ISSN 1970-9889, e-ISSN 1970-9870
DOI: 10.6093/1970-9870/10688
Received 24th January 2024, Accepted 19th April 2024, Available online 30th April 2024

Licensed under the Creative Commons Attribution – Non Commercial License 4.0
www.tema.unina.it

The cost of shopping: measuring virtual and physical access for obtaining goods

Jing Chen [a]*, Mengying Cui [b], David Levinson [c]

[a] School of Engineering Audit
Nanjing Audit University, Nanjing, China
e-mail: chenjingdjd@163.com
ORCID: https://orcid.org/ 0000-0002-5948-8851
* Corresponding author

[b] College of Transportation Engineering
Chang'an University, Xi'an, China
e-mail: mengying.cui@chd.edu.cn
ORCID: https://orcid.org/ 0000-0001-7790-8533

[c] School of Civil Engineering
The University of Sydney, Sydney, NSW, Australia
e-mail: david.levinson@sydney.edu.au
ORCID: https://orcid.org/ 0000-0002-4563-2963

Abstract
The rise of e-commerce, bolstered by advances in information and communication technology (ICT), has made it possible for consumers to shop online without the need to physically travel. The unexpected emergence of COVID-19 further accelerated this shift towards online shopping. This paper compares virtual versus physical access to goods, drawing from dual access theory. It aims to offer a comprehensive understanding of the disparities in accessibility between digital and brick-and-mortar shopping experiences. Our results indicate that, when considering the complete private costs — including the intrinsic costs of shopping and those incurred *en-route* like travel and delivery fees — online shopping typically offers greater accessibility and is more cost-effective than its in-store counterpart. While physical access to shopping displays a pattern where the central city has a distinct advantage over the suburbs, virtual access presents a more uniform distribution throughout the city.

Keywords
Accessibility; Online VS in-store shopping; Physical VS virtual; Dual access; Wuhan city; COVID-19.

How to cite item in APA format
Chen, J., Cui, M. & Levinson, D. (2024). The Cost of Shopping: Measuring Virtual and Physical Access for Obtaining Goods. *TeMA - Journal of Land Use, Mobility and Environment*, *17* (1), 129-145. http://dx.doi.org/10.6093/1970-9870/10688

1. Introduction

Accessibility, fundamental in transport and land use policies, represents the convenience of reaching various opportunities (Hansen, 1959). Numerous studies have been dedicated to exploring accessibility related to jobs, schools, transport hubs, and other essential destinations (Alotaibi et al., 2021; Bondemark, 2020; Cui & Levinson, 2020; Guida & Caglioni, 2020; Lee & Kim, 2023; Levinson, 1998; Manfredini & Di, 2018; Pirra et al., 2021; Preston & Rajé, 2007; Schuetz et al., 2012). Given the interconnection of economic growth and urban planning, shopping access has gained traction, predominantly from the perspective of customers physically visiting stores to procure goods (Apparicio, Cloutier, & Shearmur, 2007; Hamidi, 2020; Larsen & Gilliland, 2008; Sakai, Kawamura, & Hyodo, 2019; Visser & Lanzendorf, 2004; R. E. Walker et al., 2010; Woudsma et al., 2008).

With the advent of e-commerce and information and communication technologies (ICTs), online shopping has surged (Saphores & Xu, 2021). Data from the National Bureau of Statistics in 2019 revealed that online retail sales in China stood at 853.9 billion CNY, which amounted to 20.7% of the total, giving China the highest share of online retail (Mofcom.PRC, 2019). Although numerous studies dissect the dynamics between online and brick-and-mortar shopping, the investigation into their accessibility remains scant. The COVID-19 pandemic, which imposed widespread travel restrictions (Altay & Şenay, 2023), prompts a re-evaluation of shopping accessibility. This necessitates an inclusion of scenarios where customers predominantly engage in online, telephonic, or mail-order shopping, awaiting home delivery. This mode is termed "virtual access." In contrast, the traditional form, primarily rooted in travel costs and including the monetary expense of the products, is termed "physical access."

The standard procedure for calculating physical access relies on the cumulative opportunity measure, which assesses how many opportunities are attainable within a set travel time (Li & Kim, 2020; Schuetz et al., 2012). Some scholars highlight the significance of balancing supply and demand in accessibility, leading to the 2-step floating catchment area (2SFCA) method (Alford-Teaster et al., 2021; Guida & Caglioni, 2020; Wang & Luo, 2005). Nonetheless, the 2SFCA overlooks the influence of travel time and cost. Integrating such measures, including gravity-based models (Handy & Niemeier, 1997) which weigh cost impedance when assessing opportunities, or utility-based models (Ben-Akiva & Lerman, 2018) which differentiate individual travel costs and destination values, into virtual access poses challenges:

- Traditional access methodologies primarily revolve around potential spatial interactions and derived benefits. In virtual access, however, shoppers aren't physically traveling (though delivery may entail some travel, such as a self-pickup cabinet situated in an apartment's lobby—this aspect wasn't factored into our considerations). Consequently, determining spatial friction in virtual access can be complicated;
- Defining "opportunities" in the context of virtual access is tricky. While some argue that virtual access opportunities should form a segment of the total, presupposing no addition from ICTs (Shen, 1998, 2000), others assert that the frequency of online shopping introduces more opportunities (Ding & Lu, 2017; Farag et al., 2006; Farag et al.,2007).

Cui and Levinson (2019b) introduced a new accessibility measure wherein travel cost required to access a set number of opportunities is the performance metric. Instead of emphasizing the quantity of available opportunities, this method uses them as a preset benchmark or constraint. This approach sidesteps debates about the equivalence of opportunities in both physical and virtual domains, especially when the main interest lies in fulfilling a specific opportunity (e.g., acquiring an item) rather than counting alternative sources of said opportunity. The focus shifts to the expense of ensuring goods arrive at the demanded location (like food at home), rather than at the supplied point (e.g., a store or warehouse). Furthermore, in a physical context, the sum of travel time and additional monetary costs represents the *en-route* expense, whereas in a virtual setting, delivery time and fees signify the initial spatial disparity and eventual convergence of goods and buyers. Importantly, the worth of travel and delivery times differ, influencing the comparison between physical and

virtual accesses. Other cost components, such as shopping durations (in-store vs. online), product prices — which might fluctuate across platforms and delivery schedule delays, warrant consideration.

This article distinguishes between physical and virtual shopping accesses and delineates their real-world applications. We establish a methodological foundation anchored on dual-access theory. Wuhan City, China, serves as our case study to underscore the framework's applicability. The subsequent sections are structured as follows: Section 2 outlines the methodology for assessing physical and virtual access, including data. Sections 3 presents findings. Section 4 reflects on the insights and concludes the paper.

2. Methodology

The schematic representation of our approach to determine both physical and virtual shopping accessibility is illustrated in Fig.1. This encompasses the necessary data, techniques employed, and the consequent outputs.

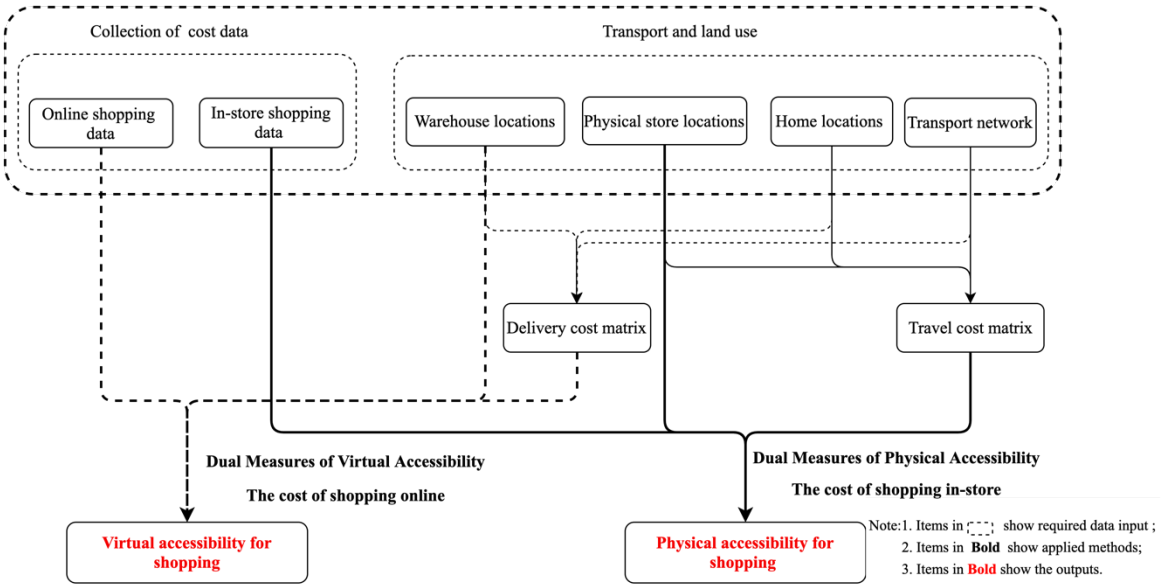


Fig.1 Schematic of computing physical and virtual shopping accessibility

Travel durations for traditional shopping and online shopping delivery are deduced via GIS- based analysis. Specifically, these durations cover the span from starting points (homes for traditional shopping, warehouses for online shopping) to respective endpoints (retail outlets for in-store shopping, residences for online shopping).

For online shopping, the data capture encompasses costs associated with the goods, total waiting duration (incorporating both delivery and order processing time), time invested in online shopping, the monetized value of this online shopping time, and the monetary value attached to delivery duration. In contrast, for in-store shopping, the data comprise travel time, time spent inside the store, the associated monetary value of both these durations, and the costs for the goods purchased in-store. Time valuations can be estimated from shopper surveys.

2.1 Dual physical access

Cui and Levinson (2019b) described the dual access measure as the travel expense needed to reach a specified number of opportunities. This is essentially the converse of Hansen (1959)'s primal measure, which quantifies the opportunities accessible for a predetermined travel cost. The dual approach is particularly advantageous when the availability of opportunities isn't the primary concern, but rather the associated travel time or cost is the focal point (Cui & Levinson, 2020, 2019b). This is consistent with the scenario of shopping accessibility.

For dual physical access, denoted as A_i the mathematical representation is:

$$A_i = C_{iO_N} \quad (1)$$

Where:

- C signifies the pertinent cost;
- i represents the origin zone, and
- O_N marks the position of the Nth closest opportunity (O).

2.2 Cost analysis for physical access

The cost associated with ensuring goods reach the desired location (home) encompasses the round-trip travel expense between customers and stores, the temporal expense of shopping in-store, and the cost of the goods themselves.

The travel expense arises from journeys to and from local stores. Ideally, this should account for time-related expenses, crash costs, emission-related expenses, and direct financial expenses such as tolls and fuel (Cui & Levinson, 2019a). However, in practice, only the travel time and out-of-pocket financial expenses hold significant relevance to travelers. Firstly, these constitute a substantial proportion of the overall travel expenses, approximately 80% for driving. Secondly, most individuals aren't aware of the emission and crash costs they incur or impose during their journey. For simplification, only the travel time, vehicle operational costs, and parking fees (when applicable) are considered in our calculation. However, the travel time is monetized to make these components cumulative. In certain scenarios, shopping may not be the sole purpose of a trip. Such instances require careful valuation of the travel time. This paper presumes shopping as the singular activity during physical journeys.

The duration of in-store shopping starts from the moment customers enter the store and ends upon their exit. Its length is influenced by the number of items being purchased, and its value can be affected by perceptions of time and qualitative factors (like whether shopping is enjoyable or burdensome). The exact valuation of shopping time, whether it's considered beneficial (negative cost) due to positive recreational or social aspects, or burdensome (positive cost), can be complex. Given the essential nature of groceries, this paper treats the value of shopping time as a positive cost. Following Walker & Cude (1983), we approximate the value of shopping time to the hourly wage rate in our case study.

The cost of goods is more direct. Potential discounts provided should also be considered. Thus, the cost function for in-store shopping, used in the physical access computation, is expressed as:

$$C_{ij}^{p} = \tau \cdot T_{t,ij}^{p} + C_{t,ij} + \mu^{p} \cdot T_{s}^{p} + C_{g}^{p} \cdot (1 - \rho^{p}) \quad (2)$$

Where:

- τ: Value of travel time;
- $T_{t,ij}^{p}$:Travel time to and from the pertinent local stores, with i denoting the customer's residence and j the store location;
- $C_{t,ij}$: Monetary travel cost, associated with travel distance, mode, and other relevant factors;
- μ^{p}: Value of in-store shopping time;
- T_{s}^{p}: Duration of in-store shopping;
- C_{g}^{p}: Goods' cost for in-store shopping;
- ρ^{p}: Seller-offered discounts to in-store buyers.

Note that when shopping is the sole reason for a trip, the travel time and cost, represented by $T_{t,ij}^{p}$ and $C_{t,ij}$, are simply derived from the round trip between a home (i) and local stores (j). However, everyday shopping is often coupled with other activities, such as work. As a result, the specific travel time and expense for shopping are ascertained by the detour of the journey chain, for instance, traveling from work to a store and then to home, as opposed to a direct route from work to home. This cost might be zero if the store lies directly enroute between a person's home and workplace (Huang & Levinson, 2015).

2.3 Cost analysis for virtual access

In the context of virtual access, costs are conceptualized differently than in the physical realm.

In Wuhan City, as of 2020, there exist two predominant online shopping platforms offering distinct delivery services: immediate delivery and package delivery. Immediate delivery is particularly suited for time-sensitive products such as fruits or vegetables. For this type of delivery, a designated courier is appointed, ensuring orders are delivered in mere hours. In contrast, package delivery often requires a span of 1 to 7 days. For this method, goods are typically collated from a warehouse and dispatched to customers via urban distribution centers and local delivery storefronts.

With advances in cold chain logistics in China, time-sensitive items can be procured within a 2-day window. Additionally, online merchants often absorb a portion of the delivery expenses, which augments the total cost offset relative to immediate delivery. Stores offering immediate delivery services operate within a specific coverage area, often defined by delivery time or distance. Suburban areas, having sparse store density, might lack access to immediate delivery services. On the contrary, package delivery services span the entire city. Given our intent to constrast virtual and physical access across the city, this paper will focus on package delivery.

Defining online shopping duration presents a challenge for several reasons: first, online shopping might be spontaneously prompted by unrelated online activities such as reading news or viewing videos, especially when advertisements or promotions are featured prominently. Second, online shopping doesn't always occur in one continuous session. A user might, for instance, add products to their cart during a brief break, only to return and finalize their purchase later. Chiu, Lo, Hsieh, and Hwang (2019) suggested that consumers tend to spend more time shopping online than in physical stores. However, Schmid and Axhausen (2019) posited the opposite, arguing that online shopping conserves time as consumers incur lesser search costs and access more comprehensive information. To facilitate our calculations, we posit that total online shopping time correlates with the number of items purchased. Nonetheless, this domain warrants extensive research, especially given the evolving nature of online shopping technology.

The cost function for online shopping, pertinent to virtual access, is expressed as:

$$C_{ik}^{v} = \sigma \cdot T_{w,ik} + C_{d,ik} + \mu^{v} \cdot T_{s}^{v} + C_{g}^{v} \cdot (1 - \rho^{v}) \quad (3)$$

Where:

- σ: Value of waiting time (schedule delay);
- $T_{w,ik}$: Waiting time for customers, where k denotes the location of online sellers;
- $C_{d,ik}$: Delivery cost;
- T_{s}^{v}: Time spent shopping online;
- μ^{v}: Value of online shopping time;
- C_{g}^{v}: Online shopping goods' cost;
- ρ^{v}: Discounts offered to online patrons.

2.4 Data collection

Wuhan City serves as the focal point for this study. It is the administrative seat of Hubei Province and stands as the most populous city in central China (Han & Wu, 2004). The city encompasses an area close to 8,500 km^2 and boasts a population nearing 12 million as of 2019.

The data for this research is derived from several sources, as illustrated in Fig.1.

Wuhan City's Road network was sourced from OpenStreetMap and procured via BBBike. This free server facilitates the export of customized sections from OpenStreetMap projects in various formats such as OSM, Shapefile, or GeoJSON, covering over 200 global locales. We opted for the shapefile format, given its seamless integration with Geographic Information System (GIS) software, namely ArcGIS or QGIS, and its utility in computing travel costs.

The study demarcates the region into 1km×1km grid sections, using the centroids to represent origins denoting customer locations for access metrics. While grocery store sites indicate physical access endpoints, the virtual access private cost doesn't demand knowledge of package origins since delivery duration hinges on the shipping costs customers are amenable to. Typically, in Chinese urban areas like Wuhan City, complimentary shipping entails a two-day wait, making it a popular choice for forward-thinking consumers. Anomalies arise when dispatches originate from distant provinces such as Xinjiang or Inner Mongolia, resulting in delivery times exceeding two days, or from Hubei, guaranteeing next-day delivery expectations. In these scenarios, local delivery store locations, crucial for determining 'last-mile delivery' durations, influence package waiting time variations across the city.

Grocery and local delivery store locations were extracted from the Gaode map (Gaode, 2020), and their distributions are presented in Fig.2.

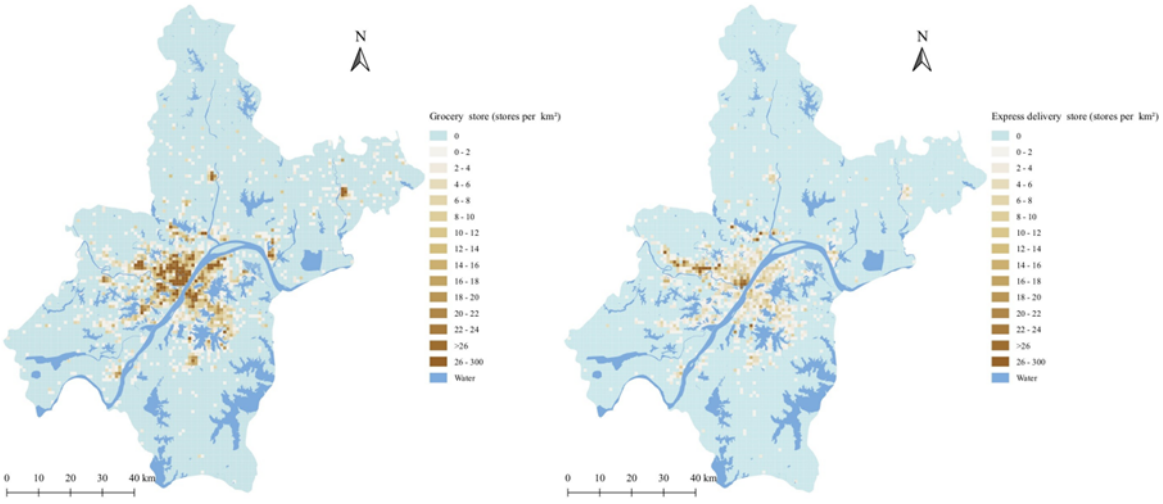


Fig.2 (a) Grocery stores and (b) delivery stores densities in Wuhan City (number/km^2)

3. Results

Physical and virtual access are studied for the case of Wuhan City to understand their spatial distribution patterns and to differentiate them. The methodology for these calculations is depicted in Fig.1 and can be potentially applied to other cities.

3.1 Parameter specification

The parameters present in the cost functions for in-store shopping (Eq.2) and online shopping (Eq.3) including shopping time, cost of goods, and values of time for travel, shopping, and waiting for packages require calibration prior to computing access.

The value of time is generally measured by how much people are willing to pay to save their time (Carrion & Levinson, 2013). The value varies depending on location, purpose, and mode. Previous research has valued travel time and delivery time based on shopping choice models constructed on travel cost, travel time, and delivery time (Hsiao, 2009; Schmid & Axhausen, 2019). We have employed the estimates from Hsiao (2009) as the focus of his studies was on Asian Cities. Few studies have addressed the value of shopping time. However, Walker and Cude (1983) suggested that the value of shopping time could be approximated by the hourly wage rate, which we have applied to Wuhan City. Our estimates of online and on-store shopping time and cost, and delivery cost are developed in the Appendix (section 5).

Tab.1 summarizes the parameters and their corresponding values used in this study, when considering the purchase of 4 items.

Name	Value
Value of travel time	5.29 US$/hour (0.62CNY/min) (Hsiao, 2009)
Value of waiting time	0.76 US$/day (0.0037CNY/min) (Hsiao, 2009)
Value of online shopping time	2.57 US$/hour (18 CNY/hour) (Mohrss.PRC, 2020)
Value of in-store shopping time	2.57 US$/hour (18 CNY/hour) (Mohrss.PRC, 2020)
Online shopping time	27.59 min
In-store shopping time	31.79 min
Delivery cost	4 CNY
Online shopping cost	83.45 CNY
In-store shopping cost	87.81 CNY

Tab.1 Parameter specification: values of parameters used in physical and virtual access measurements

3.2 Access Measurements: Physical vs. Virtual

In Wuhan City, grocery stores are typically situated near residential areas, making them accessible by foot. Thus, for scenarios where shopping is the sole purpose of travel, the minimal walking distance between residences and the nearest store (round trip) determines the travel time required for physical access, assuming a walking speed of 1.24 m/s (Knoblauch, Pietrucha, & Nitzburg, 1996; Walsh, Xian, Levinson, & Rayaprolu, 2019).

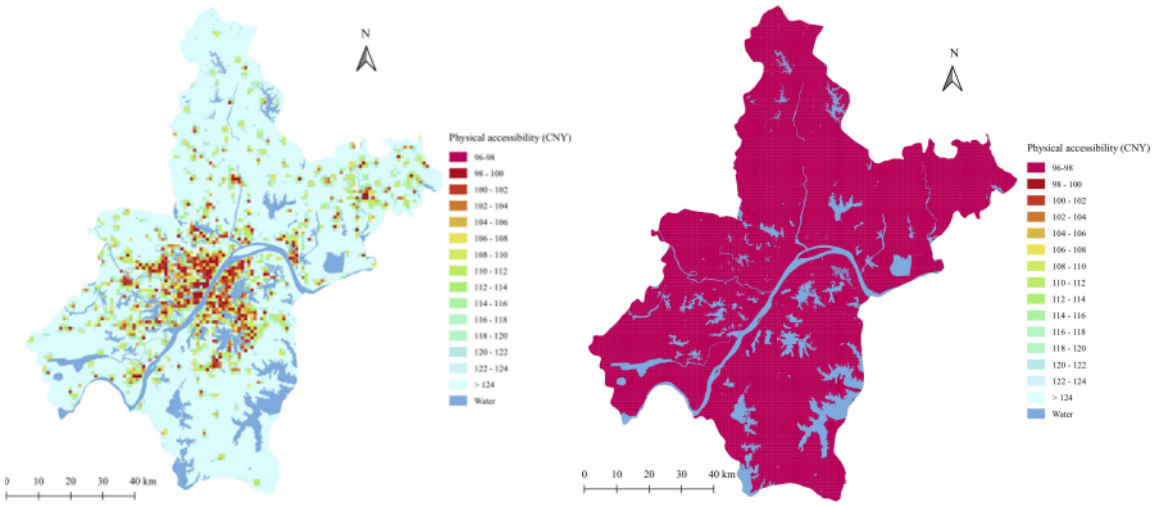


Fig.3 Physical access to 4 items in Wuhan city: (a) shopping as the sole purpose of travel and (b) shopping as part of a multi-stop journey

Fig.3 illustrates the physical access in Wuhan City when considering a basket of 4 items from a single store. The distribution suggests that residents in central Wuhan City enjoy better access to local grocery stores than

those living in suburban areas. This spatial distribution is influenced by the clustering of grocery stores, as seen in Fig.2a.

In some situations, shopping is merely one stop in a trip chain. Ideally, this stop shouldn't introduce any detours, meaning that both travel time and cost would not serve as an impedance to in-store shopping activities. This scenario can maximize accessibility, as depicted in Fig.3.

For virtual access, the situation differs. As previously mentioned, if the same delivery services are chosen, there are negligible variations in delivery time and cost. Consequently, we have used the mean value from our experiments, 4 CNY, to represent the delivery cost. Additionally, 863.38 minutes (which is 80% of 1,079.23 minutes) is established as the standard duration for packages to travel from the sender to local delivery stores. The last segment of the delivery, representing the remaining 20% of waiting time, is dependent on the shortest distance from delivery stores to the customers' location. In China, this leg is often completed using electric tricycles, for which we've assumed a speed of 15 km/h based on the study by Zhang, Chen, Li, and Zhong (2019).

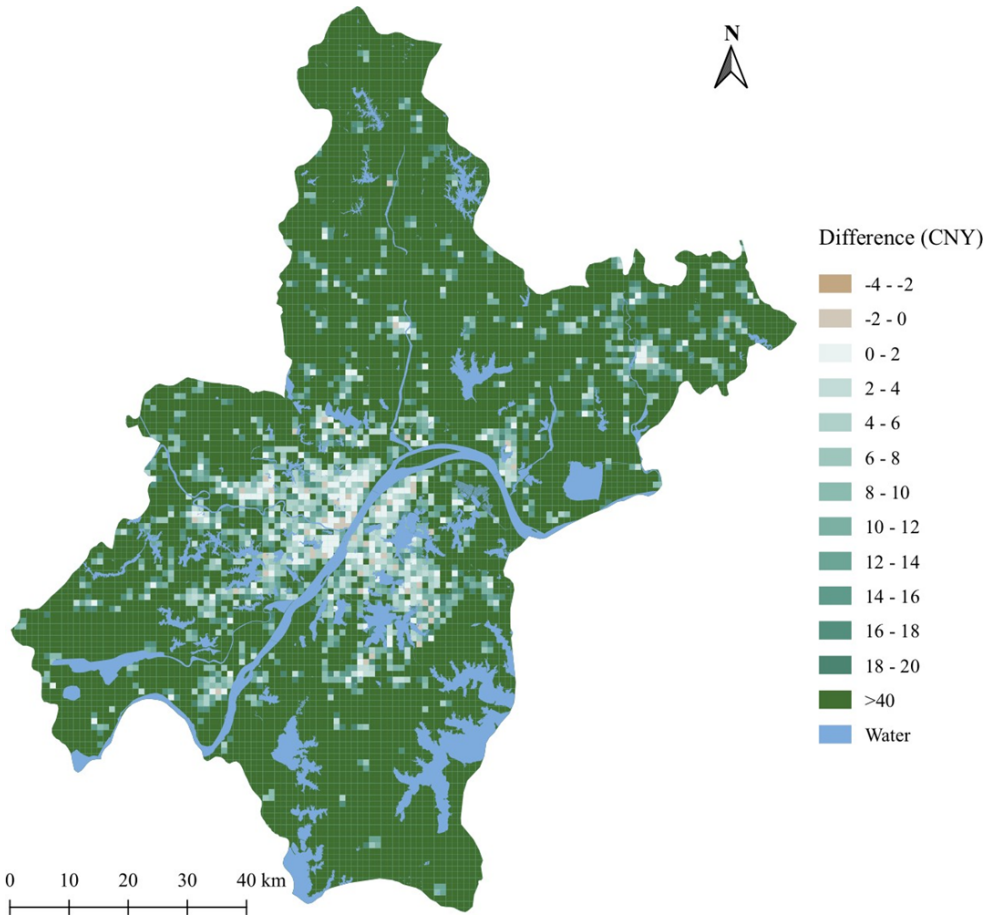


Fig.4 Virtual access for shopping in Wuhan City

Virtual access is determined by aggregating the shopping cost, the time cost of online shop- ping, and both the time and monetary costs of delivery, as visualized in Fig.4. The distribution is mostly uniform across the city, with exceptions in the northern and southern rural regions. In these areas, the local delivery stores are considerably distant. Virtual access offers a consistent online shopping experience in Wuhan City, suggesting that there is minimal variation in access to online shopping across the city. Thus, reducing delivery times could further enhance the equality of online shopping experiences.

Fig.5 contrasts the differences between physical and virtual access. The green regions indicate areas where in-store shopping access is superior to online access. These areas are prevalent throughout the city, implying

that while virtual access is generally favorable, in-store shopping becomes a competitive option for residents in the city's core.

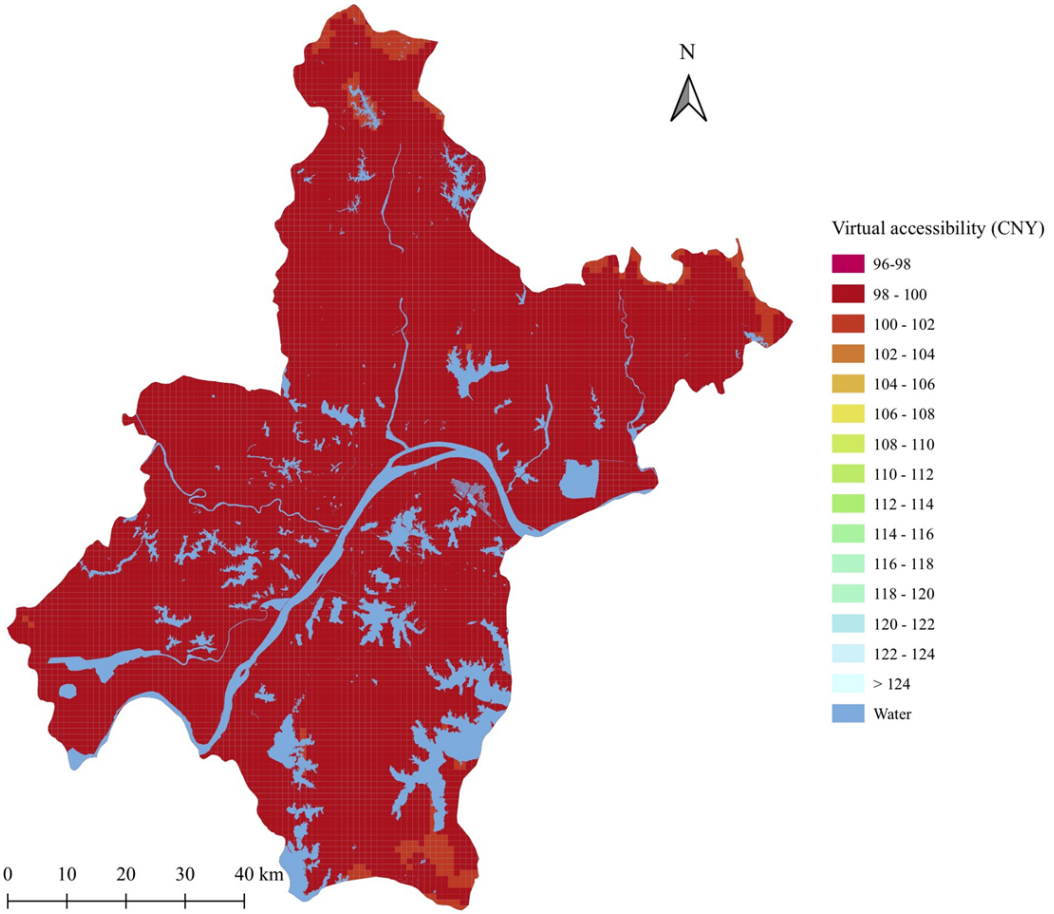


Fig.5 Difference map: physical access minus virtual access

3.3 Sensitivity analysis

The time values for physical travel, package waiting, and both in-store and online shopping have been taken from previous studies. To examine the effect of these values on accessibility measures, sensitivity analyses were conducted.

Fig.6 and Fig.7 display the changes in physical access as the value of travel time and value of in-store shopping time are increased by 25%, 50%, 75%, and 100%, respectively. This takes into account economic growth. While the spatial distributions are largely consistent with Fig.3a, higher values for both parameters correspond to reduced accessibility, aligning with the dual access theory. Nevertheless, as indicated in Fig.6 and Fig.7, the value of in-store shopping has a more profound impact on physical access compared to the value of travel time. This comparison, however, becomes less significant when shopping is merely a stop in a trip chain. It underscores the idea that the influence of travel time value on physical access depends on the additional time spent for shopping within a trip.

Parallel trends are observed for virtual access, as shown in Fig.8 and Fig.9. Virtual access demonstrates a more pronounced shift with the increasing value of online shopping time compared to the value of waiting time.

Tab.2 lists the population-weighted average values for both physical and virtual access. In Wuhan City, virtual access ranks higher than physical access, as evidenced by Fig. 5. Furthermore, the time cost of online shopping plays a more decisive role than in-store shopping for accessibility metrics. This is corroborated by the greater sensitivity of virtual access to online shopping time value, compared to the sensitivity of physical access to the

value of in-store shopping time. Similarly, package waiting time has a larger impact on virtual access than the value of travel time does on physical access.

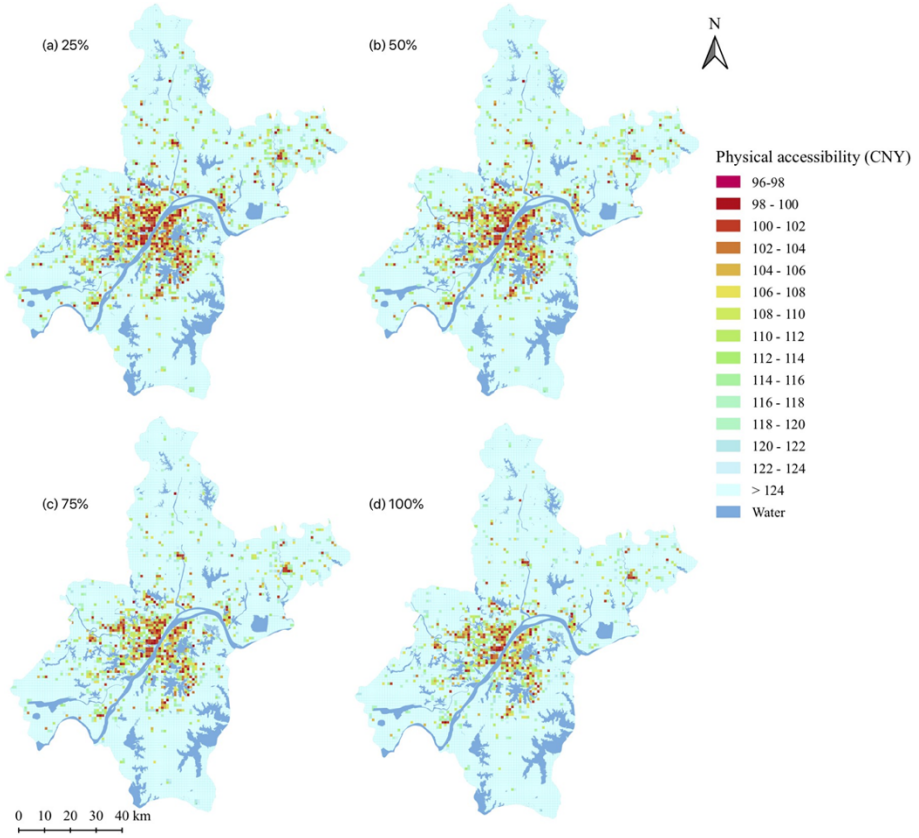


Fig.6 Physical access with the value of travel time increased by 25% to 100%

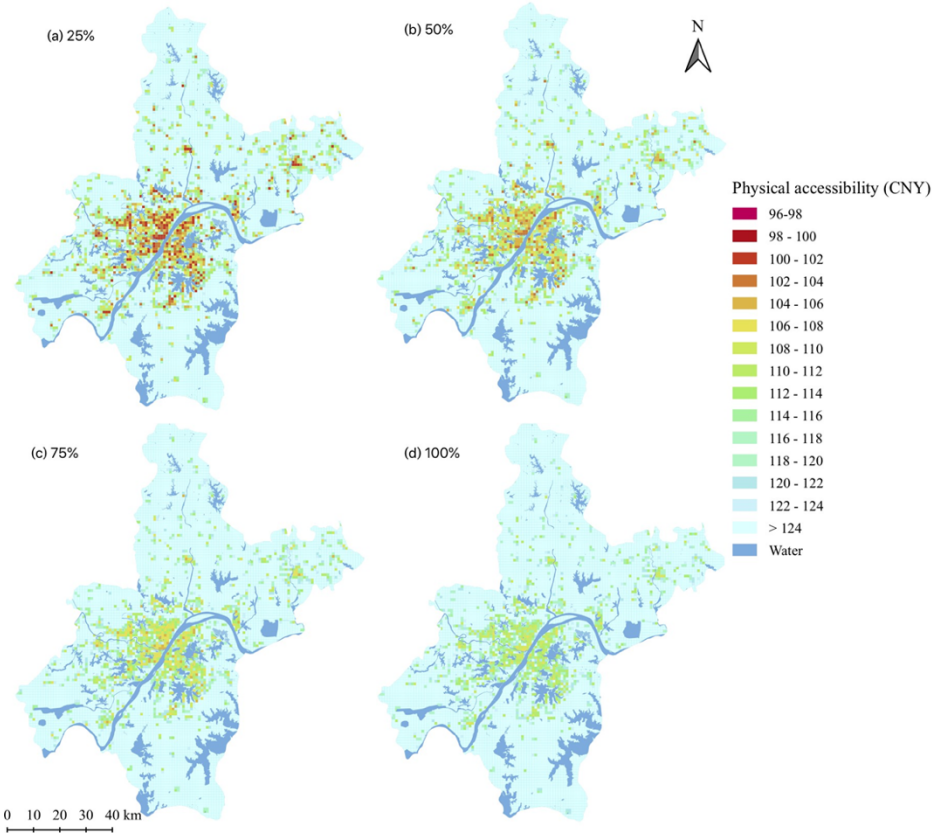


Fig.7 Physical access with the value of in-store shopping time increased by 25% to 100%

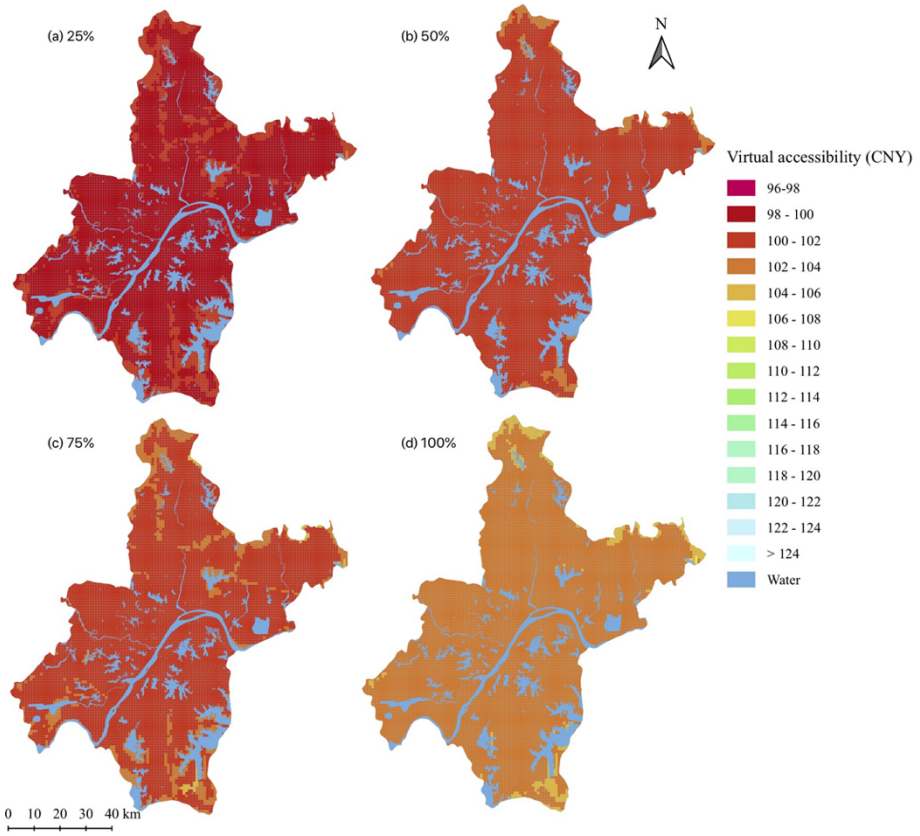


Fig.8 Virtual access with the value of waiting time increased by 25% to 100%

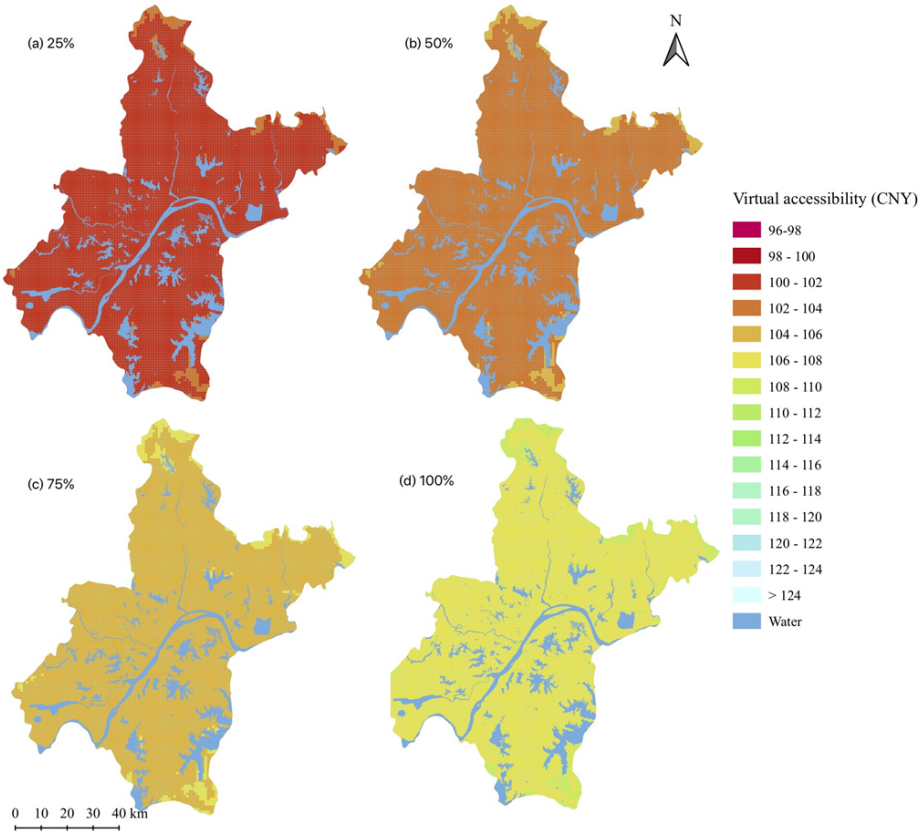


Fig.9 Virtual access with the value of online shopping time increased by 25% to 100%

Name	Variables	Description	Access [CNY]
Physical access			194.05
	Value of travel time	Increase 25%	218.23
		Increase 50%	242.41
		Increase 75%	266.59
		Increase 100%	290.78
	Value of in-store shopping time	Increase 25%	196.42
		Increase 50%	198.80
		Increase 75%	201.18
		Increase 100%	203.56
Virtual access			99.02
	Value of waiting time	Increase 25%	99.85
		Increase 50%	100.67
		Increase 75%	101.49
		Increase 100%	102.31
	Value of online shopping time	Increase 25%	101.09
		Increase 50%	103.16
		Increase 75%	105.23
		Increase 100%	107.30

Tab.2 Population-weighted average access for shopping in Wuhan City

4. Discussion and conclusion

This paper extends the notions of virtual and physical access and introduces a methodological framework to compute them. Wuhan City has been chosen as the case study for a proof-of-concept demonstration.

Distinct differences emerge when contrasting physical with virtual access. Blocks boasting higher levels of physical access are predominantly found in the central part of the city. In contrast, virtual access appears to be more uniformly dispersed across regions. From this standpoint, given access to the Internet, online shopping offers a more equitable experience than physical shopping.

Through the lens of online shopping accessibility, residing in the suburbs holds no significant disadvantage when juxtaposed against living in the central city. Factoring in the probable reduction in travel time alongside the partial substitution effect by Shen (2000), and given the fairly consistent travel time budget as noted by (Levinson & Kumar, 1994), it emerges that virtual access might grant more time for other travel and activities. Virtual access opens the door to many opportunities in the digital realm, some of which remain beyond the reach of physical commuting. This is especially true when virtual access saves time from inconsequential trips, thereby expanding the available travel time budget.

A deeper understanding of both physical and virtual shopping access in urban areas can significantly contribute to transport and land use planning.

The values associated with travel time, waiting time, and both in-store and online shopping time differ across individuals due to factors like income levels, gender, or individual preferences and urgency requirements. Moreover, shopping often dovetails with other activities, which implies that the actual travel cost might undercut our initial assumptions, potentially leading to superior (or lower cost) physical access. Future research could should consider time values for activities like travel, waiting, and shopping. The joint consideration of virtual and physical access can pave the way for a holistic assessment of multifaceted activity and travel outcomes, as posited by (Lavieri et al., 2018). Many digital resources are exclusively or at least partially inaccessible through physical means. Hence, gauging virtual access requires a keen awareness of the overlapping digital and physical realms.

Appendix: experiment of in-store and online shopping

To estimate empirical values of time and cost for shopping virtually and online for the accessibility calculations, experiments were crafted tasking the same 35 participants to engage in both in-store and online shopping, chronicling the time and expenses at each phase as well as itemizing their purchases. Participants were required to acquire identical grocery items both offline and online, ensuring the experiment's sole variance lay in the shopping mode rather than product quantity or type. This ensured any discrepancy in shopping duration was due to the mode, not product diversity (Participants were assured of their data privacy). Online acquisitions were made via platforms like Tmall or JD.com, known for their package delivery services, sidestepping immediate delivery scenarios. Data compilation occurred in April and May 2020, post the ebbing of the COVID-19 pandemic in Wuhan City and the subsequent lifting of lockdowns, albeit with certain behavioral restrictions intact. This data will further inform parameter calibrations for access computations.

Variables	Description	Count	Percentage (%)	Mean	S.D.
Gender	Male (1)	14	40.0	0.40	0.50
	Female (0)	21	60.0		
Age (years)	<19 (1)	0	0.0	2.94	0.76
	19-25 (2)	8	22.8		
	26-35 (3)	24	68.6		
	36-45 (4)	0	0.0		
	46-55 (5)	3	8.6		
Education	High school or less (1)	1	2.8	3.57	0.65
	Colleges/technical school (2)	0	0.0		
	Undergraduate (3)	12	34.3		
	Graduate or more (4)	22	62.9		
Income (CNY)	<3,000 (1)	7	20.0	3.03	1.25
	3,000 - 5,000 (2)	3	8.6		
	5,000 - 10,000 (3)	9	25.7		
	10,000 - 20,000 (4)	14	40.0		
	20,000 - 30,000 (5)	2	5.7		

Tab.3 Descriptive statistics of experiment participants (N=35)

Variables	Description	Mean	Min	Max	S. D.
$T_{t,ij}^{p}$	Travel time (min)	41.91	8	117	31.08
$C_{t,ij}$	Travel cost (CNY)	3.71	0	27	7.35
T_{s}^{p}	In-store shopping time (min)	33.86	3	90	21.54
C_{g}^{p}	In-store shopping cost (CNY)	94.66	4.5	320	64.44
N_{S}^{P}	Number of items (in-store)	4.74	1	13	2.90
$T_{w,ik}$	Waiting time (min)	1079.23	422	3150	535.58
T_{s}^{v}	Online shopping time (min)	28.60	5	120	24.35
$C_{d,ik}$	Delivery cost (CNY)	3.66	0	15	5.24
C_{g}^{v}	Online shopping cost (CNY)	90.05	4.5	310	62.37
N_{s}^{v}	Number of items (online)	4.74	1	13	2.90

Tab.4 Descriptive statistics of variables collected from experiments of in-store and online shopping (N=35, 1 CNY ≈ 0.1428 US$)

Tab.4 furnishes the descriptive statistics. As per Tab.4, among the experiments conducted, online shopping emerges as the cost- efficient alternative. On average, it saves consumers approximately 5.26 minutes and 4.61 CNY compared to in-store shopping. The typical waiting period for online shopping stands at around

1079.23 minutes (close to 18 hours), translating to next-day delivery for most orders. Given the study area's central position in China, inter-province delivery time variations are minimal.

The relationship between shopping time, cost of goods, and the number of purchased items is detailed in Tab.5. As anticipated, the data indicates a linear correlation with positive estimates, statistically significant at the 5% level.

Name		In-store shopping			Online shopping		
		Estimate	**Std. Error**	**Signif.**	**Estimate**	**Std. Error**	**Signif.**
Shopping time	Constant	20.10	6.59	0.004 **	22.03	7.97	0.009 **
	Number of items	2.90	1.19	0.020 *	1.39	1.44	0.343
	R^2		0.1529			0.0273	
Shopping cost	Constant	50.85	19.46	0.013 **	48.01	18.87	0.016 **
	Number of items	9.24	3.51	0.013 *	8.86	3.41	0.014*
	R^2		0.1733			0.1703	

*** p-value<0.001, ** p-value<0.01, * p-value<0.05, . p-value <0.1

Tab.5 Regressions of shopping time and cost (N=35)

Acknowledgments

The authors would like to thank those citizens in Wuhan City who participated in the experiment. The authors also thank the reviewers for their valuable suggestions.

References

Alford-Teaster, J., Wang, F., Tosteson, A. N., & Onega, T. (2021). Incorporating broadband durability in measuring geographic access to health care in the era of telehealth: A case example of the 2-step virtual catchment area (2SVCA) Method. *Journal of the American Medical Informatics Association, 28* (11), 2526–2530. https://doi.org/10.1093/jamia/ocab149

Alotaibi, S., Quddus, M., Morton, C., & Imprialou, M. (2021). Transport investment, railway accessibility and their dynamic impacts on regional economic growth. *Research in Transportation Business & Management, 43,* 100702. https://doi.org/10.1016/j.rtbm.2021.100702

Apparicio, P., Cloutier, M.-S., & Shearmur, R. (2007). The case of Montréal's missing food deserts: evaluation of accessibility to food supermarkets. *International Journal of Health Geographics*, *6* (1), 4. https://doi.org/10.1186/1476-072X-6-4

Ben-Akiva, M., & Lerman, S. R. (2018). *Discrete choice analysis: Theory and Application to Travel Demand*. MIT Press.

Bondemark, A. (2020). The relationship between accessibility and price – The case of Swedish food stores. *Journal of Transport Geography, 82*, 102615. https://doi.org/10.1016/j.jtrangeo.2019.102615

Carrión, C., & Levinson, D. (2013). Valuation of travel time reliability from a GPS-based experimental design. *Transportation Research. Part C, Emerging Technologies, 35*, 305– 323. https://doi.org/10.1016/j.trc.2012.10.010

Chiu, Y., Lo, S. K., Hsieh, A. Y., & Hwang, Y. (2019). Exploring why people spend more time shopping online than in offline stores. *Computers in Human Behavior, 95*, 24–30. https://doi.org/10.1016/j.chb.2019.01.029

Cui, M., & Levinson, D. (2020). Multi-activity access: How activity choice affects opportunity. *Transportation Research. Part D, Transport and Environment, 85*, 102364. https://doi.org/10.1016/j.trd.2020.102364

Cui, M., & Levinson, D. (2019a). Link-based Full Cost Analysis of Travel. In *98th annual meeting of Transportation Research Board*, Washington DC., 2019.

Cui, M., & Levinson, D. (2019b). Primal and dual access. *Geographical Analysis, 52*(3), 452-474. https://doi.org/10.1111/gean.12220

Ding, Y., & Lu, H. (2017). The interactions between online shopping and personal activity travel behavior: an analysis with a GPS-based activity travel diary. *Transportation*, *44* (2), 311– 324. https://doi.org/10.1007/s11116-015-9639-5

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

Farag, S., Krizek, K. J., & Dijst, M. (2006). E-shopping and its Relationship with In-store Shopping: Empirical Evidence from the Netherlands and the USA. *Transport Reviews, 26*(1), 43–61. https://doi.org/10.1080/01441640500158496

Farag, S., Schwanen, T., Dijst, M., & Faber, J. (2007). Shopping online and/or in-store? A structural equation model of the relationships between e-shopping and in-store shopping. *Transportation Research. Part A, Policy and Practice, 41* (2), 125–141. https://doi.org/10.1016/j.tra.2006.02.003

Gaode. (2020). Gaode map api. https://lbs.amap.com.

Guida, C., & Caglioni, M. (2020). Urban accessibility: the paradox, the paradigms and the measures. A scientific review. *TeMA-Journal of Land Use, Mobility and Environment*, *13* (2), 149-168. https://doi.org/10.6092/1970-9870/6743

Hamidi, S. (2019). Urban sprawl and the emergence of food deserts in the USA. *Urban Studies, 57*(8), 1660–1675. https://doi.org/10.1177/0042098019841540

Han, S. S., & Wu, X. (2004). Wuhan. *Cities, 21*(4), 349–362. https://doi.org/10.1016/j.cities.2004.03.007

Handy, S., & Niemeier, D. (1997). Measuring accessibility: An exploration of issues and alternatives. *Environment & Planning. A, 29*(7), 1175–1194. https://doi.org/10.1068/a291175

Hansen, W. G. (1959b). How accessibility shapes land use. *Journal of the American Institute of planners, 25*(2), 73–76. https://doi.org/10.1080/01944365908978307

Hsiao, M. (2009). Shopping mode choice: Physical store shopping versus e-shopping. *Transportation Research. Part E, Logistics and Transportation Review, 45* (1), 86–95. https://doi.org/10.1016/j.tre.2008.06.002

Huang, A., & Levinson, D. (2015). Axis of travel: Modeling non-work destination choice with GPS data. *Transportation Research. Part C, Emerging Technologies, 58*, 208–223. https://doi.org/10.1016/j.trc.2015.03.022

Knoblauch, R. L., Pietrucha, M. T., & Nitzburg, M. (1996). Field studies of Pedestrian walking Speed and Start-Up Time. *Transportation Research Record*, *1538*(1), 27–38. https://doi.org/10.1177/0361198196153800104

Lahoorpoor, B., Wu, H., Rayaprolu, H., & Levinson, D. M. (2022). Prioritizing active transport network investment using locational accessibility. *TeMA-Journal of Land Use, Mobility and Environment, 15*(2), 179-192. http://dx.doi.org/10.6092/1970-9870/9174

Larsen, K., & Gilliland, J. (2008). Mapping the evolution of "food deserts" in a Canadian city: Supermarket accessibility in London, Ontario, 1961–2005. *International Journal of Health Geographics, 7* (1), 16. https://doi.org/10.1186/1476-072x-7-16

Lavieri, P. S., Dai, Q., & Bhat, C. R. (2018). Using virtual accessibility and physical accessibility as joint predictors of activity-travel behavior. *Transportation Research. Part A, Policy and Practice, 118*, 527–544. https://doi.org/10.1016/j.tra.2018.08.042

Lee, J., & Kim, J. (2023). Social equity analysis of public transit accessibility to healthcare might be erroneous when travel time uncertainty impacts are overlooked. *Travel Behaviour and Society, 32*, 100588. https://doi.org/10.1016/j.tbs.2023.100588

Levinson, D. (1998). Accessibility and the journey to work. *Journal of Transport Geography, 6*(1), 11-21. https://doi.org/10.1016/S0966-6923(97)00036-7

Levinson, D., & Kumar, A. (1994). The rational locator: why travel times have remained stable. *Journal of the American Planning Association, 60* (3), 319–332. https://doi.org/10.1080/01944369408975590

Li, J., & Kim, C. (2020). Exploring relationships of grocery shopping patterns and healthy food accessibility in residential neighborhoods and activity space. *Applied Geography, 116*, 102169. https://doi.org/10.1016/j.apgeog.2020.102169

Manfredini, F., & Di Rosa, C. (2018). Measuring Spatial Accessibility for Elderly. An Application to Subway Stations in Milan. *TeMA-Journal of Land Use, Mobility and Environment*, 85-94. https://doi.org/10.6092/1970-9870/5800

Mofcom.PRC. (2019). E-Commerce in China 2018.

Mohrss.PRC. (2020). National minimum wage in different regions 2020.

Pirra, M., Carboni, A., & Deflorio, F. (2022). Freight delivery services in urban areas: Monitoring accessibility from vehicle traces and road network modelling. *Research in Transportation Business & Management, 45*, 100680. https://doi.org/10.1016/j.rtbm.2021.100680

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

Reynolds Walsh, L., Xian, T., Levinson, D., & Rayaprolu, H. S. (2019). Walking and talking: The effect of smartphone use and group conversation on pedestrian speed. *TeMA-Journal of Land Use, Mobility and Environment, 12*(3), 283–294. https://doi.org/10.6092/1970-9870/6088

Sakai, T., Kawamura, K., & Hyodo, T. (2019). Evaluation of the spatial pattern of logistics facilities using urban logistics land-use and traffic simulator. *Journal of Transport Geography*, *74*, 145–160. https://doi.org/10.1016/j.jtrangeo.2018.10.011

Saphores, J., & Xu, L. (2021). E-shopping changes and the state of E-grocery shopping in the US - Evidence from national travel and time use surveys. *Research in Transportation Economics*, *87*, 100864. https://doi.org/10.1016/j.retrec.2020.100864

Schmid, B., & Axhausen, K. W. (2019). In-store or online shopping of search and experience goods: A hybrid choice approach. *Journal of choice modelling, 31*, 156–180. https://doi.org/10.1016/j.jocm.2018.03.001

Schuetz, J., Kolko, J., & Meltzer, R. (2012). Are poor neighborhoods "retail deserts"? *Regional Science and Urban Economics*, *42* (1-2), 269–285. https://doi.org/10.1016/j.regsciurbeco.2011.09.005

Shen, Q. (1998). Spatial technologies, accessibility, and the social construction of urban space. *Computers, Environment and Urban Systems, 22*(5), 447–464. https://doi.org/10.1016/S0198-9715(98)00039-8

Shen, Q. (2000). New telecommunications and residential location flexibility. *Environment & Planning. A, 32*(8), 1445–1463. https://doi.org/10.1068/a3292

Visser, E., & Lanzendorf, M. (2004). Mobility and accessibility effects of b2c e-commerce: a literature review. *Tijdschrift Voor Economische En Sociale Geografie*, *95* (2), 189–205. https://doi.org/10.1111/j.0040-747X.2004.00300.x

Walker, R., & Cude, B. (1983). In-store shopping strategies: Time and money costs in the supermarket. *Journal of Consumer Affairs, 17* (2), 356–369. https://doi.org/10.1111/j.1745-6606.1983.tb00308.x

Walker, R. R., Keane, C., & Burke, J. G. (2010). Disparities and access to healthy food in the United States: A review of food deserts literature. *Health & Place, 16*(5), 876–884. https://doi.org/10.1016/j.healthplace.2010.04.013

Wang, F., & Luo, W. (2005). Assessing spatial and nonspatial factors for healthcare access: towards an integrated approach to defining health professional shortage areas. *Health & Place, 11*(2), 131-146. https://doi.org/10.1016/j.healthplace.2004.02.003

Woudsma, C., Jensen, J. F., Kanaroglou, P., & Maoh, H. (2008). Logistics land use and the city: A spatial–temporal modeling approach. *Transportation Research. Part E, Logistics and Transportation Review, 44*(2), 277–297. https://doi.org/10.1016/j.tre.2007.07.006

Zhang, Y., Chen, J., Li, X., & Zhong, M. (2019). Exploring logistics dispatcher's preference in electric tricycle related policies: The case of China. *Journal of Cleaner Production, 230*, 835–843. https://doi.org/10.1016/j.jclepro.2019.05.117

Image Sources

Fig.1: Schematic of computing physical and virtual shopping accessibility;

Fig.2: Grocery and delivery store densities in Wuhan City (number/km2);

Fig.3: Physical access to 4 items in Wuhan;

Fig.4: Virtual access for shopping in Wuhan City;

Fig.5: Difference Map: Physical access minus virtual access;

Fig.6: Physical access with the value of travel time increased by 25% to 100%;

Fig.7: Physical access with the value of in-store shopping time increased by 25% to 100%;

Fig.8: Virtual access with the value of waiting time increased by 25% to 100%;

Fig.9: Virtual access with the value of online shopping time increased by 25% to 100%.

Author's profile

Jing Chen

She is a lecturer in the School of Engineering Audit, Nanjing Audit University, Nanjing, China. She earned her PhD degree in Transportation Engineering from the School of Transportation, Southeast University in 2022. Currently, her research concerns the topic of urban mobility, accessibility, optimization of multimodal transportation network.

Mengying Cui

She joined Chang'an University, China, in 2020 as an Associate Professor at the College of Transportation Engineering. Prior to this appointment, she worked as a postdoctoral research associate at TransportLab at the University of Sydney for more than two years. She earned her PhD degree in Civil Engineering from the University of Minnesota in 2018. Her dissertation, "Full Cost Accessibility", provides a theoretical basis combines temporal, monetary, and non-monetary travel costs into accessibility evaluations, which fill the gap of the traditional time-based accessibility measures that ignore other cost factors,

especially the external cost, of travel. Her main interests of research include accessibility, transport networks, and transportation economics and she has co-authored several papers in top peer reviewed journals in transport and land use, including Transportation, Transportation Research Part D, Cities and so on. She currently serves as an editorial advisory board member for the Journal of Transport and Land Use.

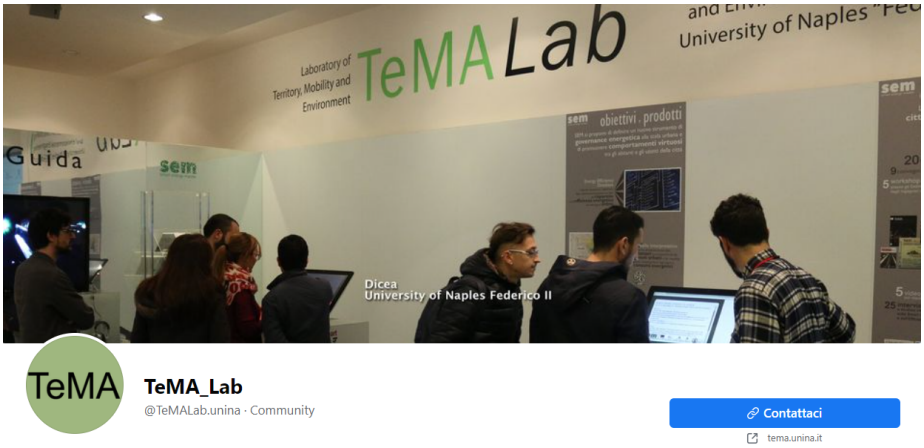
David Levinson

David Levinson joined the School of Civil Engineering at the University of Sydney in 2017 as Foundation Professor in Transport Engineering. He was a Professor at the Department of Civil, Environmental, and Geo- Engineering at the University of Minnesota, from 1999 to 2016. He conducts research on Accessibility, Transport Economics, Transport Network Evolution, and Transport and Land Use Interaction. He is the Founding Editor of *Findings* and the *Journal of Transport and Land Use*. He is the author of several books including: *The Transportation Experience, Planning for Place and Plexus, A Political Economy of Access, Elements of Access,* and *The End of Traffic and the Future of Access*. He blogs at https://www.transportist.net.

We are online!

TeMA_Lab

Follow us on Facebook



TeMA Lab and our Journal are on Facebook!
TeMA Lab is the Laboratory of Land Use, Mobility and Environment of the Department of Civil, Building and Environmental Engineering, at Università degli Studi di Napoli Federico II. Our field of expertise relates to urban systems, their complexity and the challenges that they will face in near future: adaptation to climate change, ageing population, energy consumptions, development of sustainable mobility and so on. Follow us to be constanly updated!.

www.facebook.com/TeMALab.unina

TeMA Journal of Land Use, Mobility and Environment

TeMA 1 (2024) 147-153
print ISSN 1970-9889, e-ISSN 1970-9870
10.6093/1970-9870/10772
Received 15th February 2024, Available online 30th April 2024 (by Editor)

Licensed under the Creative Commons Attribution – Non Commercial License 4.0
http://www.serena.unina.it/index.php/tema

REVIEW NOTES – International Regulation and Legislation for the Energy Transition

New trends in energy transition policies: citizens' involvement in the European energy market

Valerio Martinelli

Department of Civil, Building and
Environmental Engineering
University of Naples Federico II, Naples, Italy
e-mail: valerio.martinelli@unina.it
ORCID: https://orcid.org/0009-0007-8703-6573

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, 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. In this direction, the contribution of this review note examines the role of the European Union in promoting the energy transition through citizen participation. The crucial role of cities in achieving the environmental and climate objectives of European energy policy is underlined.

Keywords
Energy transition; Energy communities; European regulations

How to cite an item in APA format
Martinelli, V. (2024). New trends in energy transition policies: citizens' involvement in the European energy market. *TeMA - Journal of Land Use, Mobility and Environment*, *17* (1), 147-153. http://dx.doi.org/10.6093/1970-9870/10772

1. Introduction

Currently, 55% of the world's population resides in urban areas, a percentage set to grow to 68% by 2050 (UN, 2018). With a projected 30% increase in world population, climate change will have a significant impact on global ecosystems and land use. In Europe, urbanization reaches nearly 74% of the population. Therefore, the European Commission has adopted a long-term strategy that sees cities as ideal laboratories for transformative and sustainable solutions (EC, 2018). Cities account for 60% of global energy consumption and 78% of total global greenhouse gas emissions (UN-Habitat, 2020). As the main driver of economic development and energy consumption, cities play a crucial role in defining strategies to achieve sustainable development goals. A key strategy for pursuing this goal is to reduce dependence on fossil fuels and promote a renewable and sustainable energy system at the urban level. Accordingly, it is imperative to conduct timely assessments of city-scale renewable energy use to identify best practices and opportunities for improvement (Yuan, 2018). The energy transition is one of the main solutions to mitigate the impact of human activities on the environment. The transition from fossil fuels to renewable energy promises to reduce carbon emissions; however, it involves specific challenges and problems that require attention and appropriate solutions. Therefore, the energy transition is commonly recognized as a multidimensional, complex, nonlinear, nondeterministic, and uncertain phenomenon (Blazquez et al., 2020). The complexity of the energy transition phenomenon requires a holistic approach, including objectives and measures of instruments at different levels, as well as the establishment and implementation of public-private partnerships (Capasso & Mazzeo, 2020). Therefore, energy transition is the main solution to reduce the negative impact of human activities on the environment, bringing with it new approaches to energy production and consumption (Usman & Balsalobre-Lorente, 2022). In addition to have a real transition to low-carbon technologies, it is critical that behavioral changes by individuals and companies support this evolution. Achieving the transformation to a zero-carbon economy is not only about technologies and jobs, but also about people, their daily lives, and their behaviors. EU energy policy focuses on three main objectives: security of supply, sustainability, and competitiveness of the energy system.

Therefore, the main challenge is to strike a balance between these three objectives, often described as "the energy trilemma" (Mersinia et al., 2017). This term refers to the contradiction in EU energy policies arising from the need to ensure security of supply, increase competitiveness and promote sustainability simultaneously.

The energy transition is a challenge that, although technically and politically feasible, raises significant questions about economic viability. The key issue concerns access to adequate financing methods and the profitability of investment projects in renewable energy sources. Companies and citizens need solid financial instruments to bear the high costs and risks associated with investments in this sector. Currently, the state is confirmed as the main investor in the renewables market, given the complexity and uncertainty of projects. However, there is growing interest from private parties, driven by the potential offered by renewables and the regulatory policies of the European Union (Ji et al., 2021).

Internationally, the most important steps in the energy transition process have been taken within the European Union, which has established concrete measures over the years such as the EU Infrastructure Investment Plan, Clean Energy for All Europeans Package, or European Green Deal, and the establishment of the Energy Union. The progress made by EU member countries testifies to the importance of legal regulations, as the EU is a leader in managing climate change (Apostu, 2022).

However, much remains to be done. We must continue to develop and implement technological, economic and social policies that can facilitate a gradual transition to a more sustainable and resilient energy system. Only through a joint international effort can we successfully address the challenges of climate change and ensure a secure and sustainable energy future for future generations (Petrović et al., 2021).

2. The Clean Energy for all Europeans Package

The current energy system, based on fossil fuels, has a negative impact on the environment, society and the economy. To address this challenge, the European Union has set targets to reduce CO_2 emissions using renewable energy, aiming for carbon neutrality. Cities play a key role in this transformation, as they must adapt to ensure the development and well-being of the world's population within planetary limits. It is essential to consider the role and responsibilities of citizens in redefining the energy market during this transition. The redefinition is driven by three fundamental processes, referred to as the 3Ds of the transition: decarbonization, decentralization, and democratization. First, the transition to a low-carbon energy system, based on the replacement of fossil fuels with renewable energy sources. Second, there is the transformation of monopolistic and vertically integrated systems into competitive markets. Finally, the shift from a centralized to a decentralized system, where consumers are activated through the development of renewable energy (Huhta, 2019). To achieve these goals, several ambitious initiatives have been taken over the past three decades, including the Kyoto Protocol, the European Union's Climate and Energy Package, and the 2015 Paris Agreement. In addition, in 2019, the European Commission published the Clean Energy Package for all Europeans, a set of legislative acts that revolutionize the energy sector through measures for energy efficiency, renewables and security of supply. Agreement on this new energy regulation was a significant step toward implementing the EU's Energy Union strategy, published in 2015.

The Clean Energy Package for all Europeans targets include reducing greenhouse gases by 40%, covering 32% of European electricity consumption from renewable sources and improving energy efficiency by 32.5% by 2030. By coordinating these changes at the European level, this legislation underscores the EU's leadership role in combating global warming and contributes significantly to the EU's long-term strategy to achieve carbon neutrality by 2050. The package focuses on several key issues. For example, improving the energy performance of buildings is considered crucial, as they account for 40% of energy consumption and 36% of CO_2 emissions in the EU. The EU has also set ambitious targets for renewable energy and energy efficiency, which are considered essential for meeting climate goals.

In addition, the package includes governance regulations to ensure that each EU country develops integrated 10-year energy and climate plans. These plans are key to achieving the EU's energy union goals. Taken together, the Clean Energy Package for all Europeans represents a massive EU initiative to address the energy and climate challenges of the 21st century, with the goal of driving a transition to a more sustainable and resilient future. This package is central to the EU's long-term strategy to achieve carbon neutrality by 2050, based on three pillars: putting energy efficiency first, achieving global leadership in renewable energy, and ensuring a level playing field for consumers. Finally, a crucial part of the Clean Energy Package for all Europeans aims to make the EU electricity market fit for the transition to clean energy, with a new set-up to integrate renewable energy sources and new technologies in a flexible and secure way.

The decarbonisation of the national energy system and the consequent shift to an energy mix largely based on Renewable Energy Sources (RES) is a crucial environmental and economic goal. This change is not only substantially called for by European policies but is also actively supported by directives and policy documents. However, a transformation of this magnitude has significant consequences for the electricity system and the energy market, which must be properly managed to ensure security of energy supply.

The Clean Energy Package for all Europeans also proposes changes in the structure of the electricity market, moving from a centralized model to decentralized, smart and interconnected markets. To facilitate this, it establishes a legal framework for the concept of self-consumption, formally recognizing energy communities in EU legislation for the first time (Horstink, 2021). The Clean Energy Package for all Europeans represents the boldest effort to harmonize EU energy and climate policy, seeking to balance the needs of national sovereignty in the energy sector with European cooperation on the internal energy market, energy security and climate change.

3. Learning from Energy Communities towards a possible transition

The CEP's most relevant legislative acts concerning the energy transition, include the Directive on the Promotion of the Use of Energy from Renewable Sources 2018/2001 EU (RED II) and the Directive on Common rules for the Internal Market for Electricity 2019/944 (IEM). These acts give consumers and their communities the right to consume, store, and sell self-generated energy, enabling them to actively participate in the energy market. The CEP legal framework allows consumers to participate in the market either individually, as "self-consumers of renewable sources," or collectively through "City Energy Communities" or "Renewable Energy Communities".

The RED II Directive was created to promote the production of energy from renewable sources within the European Union by encouraging the active participation of citizens in the energy market.

This directive continues the path set by RED I by raising the collective EU target from 20% to 32% for renewable energy by 2030. However, the means to achieve these targets are left to the discretion of individual Member States. The continued growth in energy production from Renewable Energy Sources (RES) has led to a significant change in the structure of the energy system, influencing business models in the energy sector and leading to the definition of new configurations for energy production.

This includes the introduction of Renewable Energy Communities (RECs), defined as autonomous, member-controlled legal entities that are primarily located near renewable energy production facilities. The shareholders or members of RECs can be individuals, small and medium-sized enterprises or local authorities, and the main objective of RECs is to provide environmental, economic and social benefits to local communities rather than to pursue financial profits. On the other hand, the Internal Market for Electricity Directive focuses on the energy market and establishes rules for electricity generation, transmission, supply and storage.

In particular, it focuses on the role of consumers within the electricity market, with the aim of establishing a more competitive, customer-oriented, flexible and non-discriminatory EU electricity market with free market-based supply prices. The objective stated in the directive is to ensure affordable and transparent energy prices and costs for consumers, as well as to guarantee a high degree of security in energy supply and to facilitate a gradual transition to a sustainable, low-carbon energy system.

It also introduces Citizen Energy Communities (CECs), which manage both renewable and non-renewable energy, while RECs focus only on renewable energy.

The transposition of these global standards, especially those concerning energy communities, requires the development, implementation and dissemination of business models that foster greater consumer participation in all 28 Member States, while enabling co-investment by different actors. Among other necessary actions, Member States must adopt an 'enabling framework' for prosumership, especially for Renewable Energy Communities (RECs). By defining the rights and obligations of citizens, the directive links the concept of prosumership to issues such as combating energy poverty, increasing social acceptance, promoting local development and encouraging energy demand flexibility.

These Directives offer citizens a leading role in the energy market, accelerating the energy transition to a more sustainable and decarbonized system by fostering decentralization and energy sustainability on a local scale. In particular, the RED II Directive clearly highlights, regarding RECs, that their primary foundation lies in the decentralization and territorialization of energy production.

The purpose of these Directives is to specifically support the deployment of renewable energy sources (RES) for energy production, including electricity, and to promote the acceptance of renewable energy among Europeans (Martinelli, 2023).

The creation of energy communities is influenced by a wide range of governance models, including different combinations of innovative organisational and contractual arrangements, local identities and common interests (Baigorrotegui & Lowitzsch, 2019).

4. Urban challenges and opportunities for energy transition

In this regulatory context outlined by the EU, CERs present themselves as new local configurations of energy production and distribution, decentralised and democratic, which are strategic for fostering the integration of renewable energy sources in urban areas and as a new organisational form to promote positive environmental, economic and social returns. It is a transversal sustainability that encompasses technological aspects, the social dimension, regulatory aspects, planning and economic returns, not only of the individual but especially in terms of territorial governance (Cutore et al., 2023).

Energy communities provide an opportunity for consumers to participate directly in the production, consumption, and sharing of energy, especially for those who would otherwise be unable to do so. Regulating these innovative relationships poses a significant challenge for governments as they increase the complexity of the energy system. Cities play a crucial role in achieving RED II goals, contributing to the decarbonization of the energy system and promoting a sustainable energy future. However, the energy transition in cities offers several opportunities and challenges that deserve attention and joint action (Lowitzsch et al., 2020). Achieving Europe's energy goals must ultimately translate into action at the city level. Numerous initiatives around the world are accompanying cities in their efforts toward clean and renewable energy, such as the EU Mission: 100 Climate-Neutral and Smart Cities, launched in 2021 by the European Commission. The goal is to implement at least 100 such cities by 2030 and help them serve as experimental and innovation hubs from which other cities could benefit (EC, 2021). Within ci cities there are numerous opportunities, such as generating clean energy through solar panels and wind farms, reducing greenhouse gas emissions and improving air quality. The energy efficiency of buildings can be enhanced with heat pumps and district heating powered by renewable sources. The use of electric and hybrid vehicles can further reduce emissions and improve sustainability in urban transportation. These initiatives can also stimulate economic development by creating new job opportunities and fostering innovation in the renewable energy sector (Errichiello & Demarco). However, the availability of space for the installation of renewable plants may be limited in densely populated urban areas, and initial investment costs may be high. Integrating these energy sources into the existing power grid requires infrastructural upgrades and retrofits, while the establishment of appropriate policies and regulations is essential to facilitate the adoption and integration of renewable energy in cities (Gaglione & Ayiine-Etigo, 2021). In addition, cities face critical regulatory risks due to limited leeway in renewable energy projects due to conflicting regulations, such as those related to biodiversity and land protection. Often, cities must obtain consensus from other levels of government to implement energy efficiency measures, improve renewable capacity, and promote sustainable energy policies. The geographic, technological, demographic and cultural diversity of renewable projects adds further complications, making it difficult to adopt standardized solutions. Urbanization is a crucial factor to consider, as it will influence energy demand centers and transportation electrification. Energy demand will be closely linked to spatial planning, including the location, shape, and density of industrial, commercial, and residential developments (Hoicka & MacArthur, 2021). Renewable and distributed energy generation presents new challenges in the use of space, requiring closer integration between spatial and energy planning. Cities are exploring new business models, regulations, and technologies and have identified measures in energy communities that could be expanded in the future. The implementation of energy communities is a complex process influenced by a wide range of governance models that include innovative organizational and contractual arrangements, local identities, and common interests (Ulpiani, 2023). Energy communities offer an opportunity to connect the energy sector to a local perspective, where citizens play a crucial role in addressing global challenges through local solutions. The goal of the European Union is to establish an energy market that not only aims to reduce environmental impacts, but also can increase opportunities for economic and social development by taking a long-term perspective for greater sustainability. In sum, successfully addressing the transition to a greater share of renewable energy will require an integrated approach that considers various governance models, the

complexity of renewable projects, spatial reorganization, and urbanization. To achieve the ambitious goal of climate neutrality, it is imperative to intensify efforts, overcome barriers, and effectively implement multi-governance approaches (Gargiulo & Papa, 2021). Addressing these challenges and fully seizing the opportunities presented by the energy transition requires integrated collaboration at the local, national and international levels. We need to work together to develop innovative solutions, promote effective policies and regulations, and ensure equitable and sustainable access to energy for all citizens. Only through a shared commitment can we create greener, more resilient and habitable communities for future generations.

References

Apostu, S. A., Panait, M., & Vasile, V. (2022). The energy transition in Europe—A solution for net zero carbon*? Environmental Science and Pollution Research, 29* (47), 71358-71379. https://doi.org/10.1007/s11356-022-20730-z

Baigorrotegui, G., & Lowitzsch, J. (2019). Institutional aspects of consumer (co-) ownership in RE energy communities. Energy Transition: Financing Consumer Co-Ownership in Renewables, 663-701. https://doi.org/10.1007/978-3-319-93518-8_28.

Blazquez, J., Fuentes, R., & Manzano, B. (2020). On some economic principles of the energy transition*. Energy Policy, 147*, 111807. https://doi.org/10.1016/j.enpol.2020.111807

Capasso, S., & Mazzeo, G. (2020). Health emergency and economic and territorial implications. First considerations. *TeMA-Journal of Land Use, Mobility and Environment*, 45-58. https://doi.org/10.6092/1970-9870/6866.

Cutore, E., Volpe, R., Sgroi, R., & Fichera, A. (2023). Energy management and sustainability assessment of renewable energy communities: The Italian context. *Energy Conversion and Management*, 278, 116713. https://doi.org/ 10.1016/j.enconman.2023.116713.

Errichiello, L., & Demarco, D. (2020). From social distancing to virtual connections*. TeMA-Journal of Land Use, Mobility and Environment*, 151-164. https://doi.org/10.6092/1970-9870/6902

European Commission. (2019) Directorate-General for Energy, Clean energy for all Europeans, Publications Office. https://data.europa.eu/doi/10.2833/9937

European Commission. (2021). European Missions: 100 Climate-Neutral and Smart Cities by 2030-Info Kit for Cities

Gaglione, F., & Ayiine-Etigo, D. A. (2021). Resilience as an urban strategy: The role of green interventions in recovery plans. *TeMA-Journal of Land Use, Mobility and Environment, 14* (2), 279-284. https://doi.org/10.6093/1970-9870/8054

Gargiulo, C., & Papa, R. (2021). Chaos and chaos: the city as a complex phenomenon. *TeMA-Journal of Land Use, Mobility and Environment, 14* (2), 261-270. https://doi.org/10.6093/1970-9870/8273.

Habitat, U. N. (2020). World cities report 2020. *The Value of Sustainable Urbanization*. Available online: https://unhabitat. org/sites/default/files/2020/10/wcr_2020_report. pdf.

Hoicka, C. E., & MacArthur, J. (2021). The infrastructure for electricity. *In The Oxford Handbook of Energy Politics*. Oxford University Press.

Horstink, L., Wittmayer, J. M., & Ng, K. (2021). Pluralising the European energy landscape: Collective renewable energy prosumers and the EU's clean energy vision. *Energy Policy,* 153, 112262. https://doi.org/10.1016/j.enpol.2021.112262

Huhta, K. (2019). Unleashing Consumer Potential in the Energy Transition: A Reflection of the Transforming Role of the EU Consumer*. Oil, Gas & Energy Law, 17* (3). www.ogel.org URL: www.ogel.org/article.asp?key=3832

Ji, X., Chen, X., Mirza, N., & Umar, M. (2021). Sustainable energy goals and investment premium: Evidence from renewable and conventional equity mutual funds in the Euro zone. *Resources Policy, 74*, 102387. https://doi.org/10.1016 /j.resourpol.2021.102387

Lowitzsch, J., Hoicka, C. E., & van Tulder, F. J. (2020). Renewable energy communities under the 2019 European Clean Energy Package–Governance model for the energy clusters of the future?. *Renewable and Sustainable Energy Reviews*, 122, 109489.

Martinelli, V. (2023). Energy transition: digital (t) win? *TeMA - Journal of Land Use, Mobility and Environment, 16* (3), 653-659. http://dx.doi.org/10.6093/1970-9870/10321

Mersinia, I., Penttinen, S. L., & Aalto, P. (2017). Energy transitions: regulatory and policy trends.

Petrović, P., Arsić, M., & Nojković, A. (2021). Increasing public investment can be an effective policy in bad times: Evidence from emerging EU economies. *Economic modelling, 94*, 580-597. https://doi.org/10.1016/j.econmod.2020.02.004.

United Nations (2018). World Economic and Social Survey 2018: Frontier Technologies for Sustainable Development. New York.

Ulpiani, G., Vetters, N., Shtjefni, D., Kakoulaki, G., & Taylor, N. (2023). Let's hear it from the cities: On the role of renewable energy in reaching climate neutrality in urban Europe. *Renewable and Sustainable Energy Reviews*, 183, 113444. https://doi.org/10.1016/j.rser.2023.113444

Usman, M., & Balsalobre-Lorente, D. (2022). Environmental concern in the era of industrialization: can financial development, renewable energy and natural resources alleviate some load?. *Energy Policy*, 162, 112780. https://doi.org/10.1016/j.enpol.2022.112780

Yuan, X. C., Lyu, Y. J., Wang, B., Liu, Q. H., & Wu, Q. (2018). China's energy transition strategy at the city level: The role of renewable energy. *Journal of Cleaner Production*, 205, 980-986. https://doi.org/10.1016/j.jclepro.2018.09.162

Author's profile

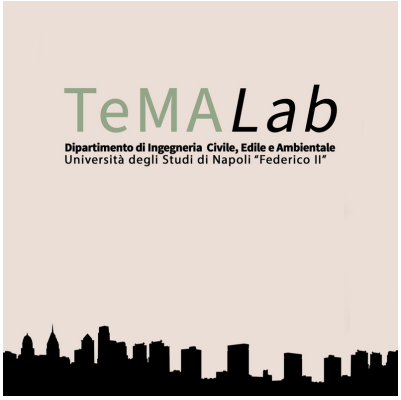
Valerio Martinelli

He is an engineer, with a master's degree in building Engineering-Architecture at the Department of Civil, Building and Environmental Engineering of the University of Naples Federico II. He is currently a first year Ph.D. student in Civil Systems Engineering at the same department. His research activity focuses on the study of Renewable Energy Communities.

We are online!

TeMA Lab

Follow us on Instagram



TeMA Lab and our Journal are on Instagram!
TeMA Lab is the Laboratory of Land Use, Mobility and Environment of the Department of Civil, Building and Environmental Engineering, at Università degli Studi di Napoli Federico II. Our field of expertise relates to urban systems, their complexity and the challenges that they will face in near future: adaptation to climate change, ageing population, energy consumptions, development of sustainable mobility and so on. Follow us to be constanly updated!.

www.instagram.com/temalab.unina/

TeMA Journal of Land Use, Mobility and Environment

TeMA 1 (2024) 155-167
print ISSN 1970-9889, e-ISSN 1970-9870
DOI: 10.6093/1970-9870/10771
Received 12th February 2024, Available online 30th April 2024

Licensed under the Creative Commons Attribution – Non Commercial License 4.0
http://www.serena.unina.it/index.php/tema

REVIEW NOTES – Urban strategies, programmes and tools

Strategies and instruments for active mobility: comparison of international experiences

Annunziata D'Amico

Department of Civil, Building and Environmental Engineering
University of Naples Federico II, Naples, Italy
e-mail: annunziata.damico@unina.it
ORCID: https://orcid.org/0009-0005-5481-8064

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, programmes and tools section presents the different strategies and tools for active mobility implemented internationally.
The contribution aims to address the issue of active mobility in the context of sustainable urban planning on a global scale. In this direction, this review provides an overview of strategies and tools that promote active mobility options in urban areas and identify best practices from cities around the world. In recent sustainable urban mobility policies, at all levels of governance, the focus has been on active mobility identified as one of the key components for the transition to a neutral climate and an inclusive urban future, more resilient and safer.

Keywords
Walking; Cycling; Urban strategies; Urban tool

How to cite item in APA format
D'Amico, A. (2024). Strategies and instruments for active mobility: comparison of international experiences. *TeMA - Journal of Land Use, Mobility and Environment*, *17* (1), 155-167. http://dx.doi.org/10.6093/1970-9870/10771

1. Active mobility in the international agendas

By the 1960s and 1970s, the car-oriented urban development radically changed the way cities were built and functioned. Modern cities face a series of challenges that have their roots in their past and in the ever-changing models of urban development. A striking example is the clear functional separation within urban areas, which implies the need to travel considerable distances to move from one area to another, making car use a mandatory choice rather than an optional option.

In modern cities, the car reigns supreme. Much of the urban space is devoted to roads, car parks and car related infrastructure, while pedestrians and cyclists are relegated to the margins. Urban expansion, driven by the logic of private mobility, has contributed to increasing traffic and pollution, creating an inhospitable and uninhabitable urban environment (D'Amico, 2023; Cecchini, 2023).

In addition to depriving people of space, urban car-oriented mobility has generated a number of other negative effects such as the expensive use of energy, excess GHG (greenhouse gas emissions) and air pollution, high social costs and harmful health consequences (Walk'n'Roll Cities Guidebook, 2022).

The pandemic and other recent events have strongly highlighted the importance of decarbonized, resilient and sustainable transport and mobility systems. These are significant elements to reduce the impact of shocks, accelerate recovery and represent added value for the community (SLOCAT, 2023).

Cities are significant hubs of economic and social activity. The synergy between the quality infrastructural system and the correct planning and design of urban space is the pillar on which to build resilient and sustainable cities (Carra et al., 2022). The urgent need to make cities more sustainable has also fueled a line of studies on "urban transformation", which investigates possible strategies to achieve this objective (Gargiulo & Zucaro, 2023).

In the urban context, mobility takes on a role of primary importance, influencing multiple aspects of daily life. Mobility fulfils a basic need in enabling people to integrate into society and the labour market, encouraging for example tourism and commerce.

Urban mobility represents a fundamental enabling factor for economic growth, social inclusion and urban sustainability. However, although it offers many advantages, mobility is not without costs for our society. Among the negative effects are greenhouse gas emissions, air, noise and water pollution, but also accidents and road crashes, congestion, and biodiversity loss. This has significant effects on health, well-being and quality of life. For these reasons, considerable efforts have been made in recent years and international political measures have been taken to address and resolve the problems of cities connected to mobility.

Greenhouse gas emissions from the transport sector have increased over time and are now the biggest challenge facing cities around the world and have become a central factor in international urban agendas.

The 28th United Nations Climate Change Conference (COP28) drew the spotlight on the implementation of international climate commitments, "signalling the beginning of the end of the fossil fuel era" (UN Climate Change Quarterly Report, 2024). Promoting active mobility can be one of the strategies that cities can encourage to reduce emissions and adapt to climate change. Enabling more people to walk and cycle safely is a fast, economical and reliable way to reduce transport-related emissions, with a potential reduction of up to 50% (PATH-UNFCCC, 2023).

Urban mobility is one of the dimensions covered by Sustainable Development Goal 11 on sustainable cities and communities and the New Urban Agenda. These global framework documents stress the importance of shifting to more sustainable and healthy means of transport, including active travel and they are a key reference for multi-level governance of decision-makers and stakeholders to guide urban policy and the promotion of decarbonized mobility, resilient, and sustainable.

The practice of walking and cycling fits perfectly into several points of the Global Agenda (Agenda 2030), although the concept of active travel and its benefits are not explicitly mentioned. The connection between the benefits of active mobility and its impact on health objectives (SDG Goal 3: Ensure healthy lives and

promote well-being for all at all ages) is clear, since, in a community, as the adoption of active mobility, an improvement in public health is observed, both in terms of increased physical activity and reduction of air pollution. Walking and cycling also have a clear link with SDGS 9 and 13: the first, (SDG Goal 9: Building resilient infrastructure, promoting inclusive and sustainable industrialization and promoting innovation) connects to active mobility in creating better accessibility to opportunities and services for all, exploiting technological innovations; the second (SDG Goal 13: Taking urgent action to combat climate change and its impacts) sees active mobility as a driver to encourage car use and negative externalities caused to environmental damage.

Urban mobility can significantly improve life in cities, not only by reducing the considerable greenhouse gas emissions it produces, but also by making it cleaner, less congested and safer. The World Health Organization and the United Nations Regional Commissions have developed the "Global Plan for the Decade of Action for Road Safety 2021-2030" (Global Plan, 2021), as a guidance document supporting the implementation of road safety objectives, including the promotion of active and safe transport modes. The Global Plan stresses that land use planning must create infrastructure and services that favor the choice of alternative and sustainable transport modes, particularly the healthiest and cleanest modes of transport but often most neglected: walking, cycling and public transport.

In line with recent related international agreements signed by the EU, the Partnership for Urban Mobility (PUM), which delves into one of the fourteen priority themes agreed by The Urban Agenda for the EU (2016), has developed the Final Action Plan of the Urban Mobility Partnership (EC Action Plan, 2018) which proposes actions to address the challenges of urban mobility and related urban development issues. "Soft mobility" is proposed in the Action Plan in two of the nine priority actions (ACTION n° 5 – Developing guidelines on infrastructure for active mobility supported by relevant funding; ACTION n° 6 – Promoting sustainable and active mobility behaviour) to encourage sustainable and resilient urban mobility, in which cycling and walking must be taken seriously into account in urban mobility policies, also considering the needs of vulnerable users and citizens with reduced mobility (children, elderly, citizens with disabilities, etc.).

Active mobility can be a driver for building urban transport systems that are economically sound, environmentally friendly, and socially inclusive. Indeed, in recent years efforts to integrate transport, health and environment activities are evident and, in the field of public health promotion, active travel modes are recognised as a promising strategy for increasing physical activity levels and for preventing noncommunicable diseases (WHO Regional Office for Europe, 2022). This positive trend is in line with the growing scientific consensus on the benefits of walking and cycling for health and the environment (Gerike et al., 2019; Cirianni et al., 2022).

2. What cities can do?

Active travel modes have, for too long and in most countries around the world, received little recognition in official policy and planning practice. Fortunately, this is no longer the case today, and walking and cycling are modes of transport integrated into planning frameworks and adopted for the advantages they bring to the urban context and to community.

Transport decisions are the responsibility of most cities, and city leaders now have a wider range of mobility options than in the past. A future in which most citizens travel on foot, by bicycle or by public transport is within reach of all cities that can learn from the lessons and experience of others.

In cities, an antidote to the car-oriented urban vision can be created by combining a series of actions and interventions, adapting them to specific local circumstances. EU Urban Mobility Observatory promoted the "Walk'n'Roll initiative" where 28 European cities of different sizes (from towns to metropolises), together with the URBACT Knowledge Hub, explore common visions and practical interventions through different workshops

and events. As part of the project, the "Walk'n'Roll Cities Guidebook" (Walk'n'Roll Cities Guidebook, 2022) was drawn up which provides an overview of solutions and actions that cities can undertake, including:

- creating pedestrian-only zones, co-existence streets and allocating at least 50% of the street space to people, not cars, with wide sidewalks, narrow lanes, and physical traffic calming;
- introduce partial or total restrictions on car circulation in some urban areas, recognizing occasional limitations (delivery, loading-unloading, transport of people with mobility difficulties, etc.);
- use strategic parking management to regulate traffic flow and dissuade people from traveling to certain neighborhoods;
- apply speed limits, to make walking and cycling trips more time-competitive with driving and brake the exclusive use of the car.

The creation of a network of "quiet spaces", i.e. a coherent system of squares and streets with pedestrian priority that spreads throughout the city, makes it possible to promote active mobility and transform the image of the city, for the benefit of the environment and public health. This requires the construction or adaptation of existing infrastructure and investments aimed at integrating "soft mobility" with micromobility and other sustainable transport modes, such as shared bicycles, electric mobility and public transport services.

Achieving a transition towards sustainable transport and mobility systems requires collective and synergistic action that sees the involvement of all stakeholders, both public and private, also actively involving citizens and associations. The participatory planning approach is a first step that can be implemented.

C40 Cities Climate Leadership Group, a global network of mayors of the world's leading cities that are united in action to confront the climate crisis, state that a priority action that cities must take today is "to implement transit-oriented development".

These are human-scale urban planning policies that aim to reduce travel distances, encouraging dense and mixed-use development (C40, 2019). The aim is to transform public space for the benefit of citizens, making it easier for them to access everything they need with a short walk or bike ride from home.

Walkability goes beyond the simple sidewalk, just as cyclability is not just a cycle path, it is in fact a complex infrastructural system that requires adequate, efficient and attentive urban planning in all aspects.

To encourage people to travel by foot or bike, cities need to rebalance the distribution towards people walking and cycling, for example, to make walking an attractive option, accessible and comfortable, footpaths need to be in "good condition and sufficiently wide" (ITDP, 2018). Intersections should be designed to maximize people's safety with adequate traffic signals that give priority to those traveling on foot or by bicycle. To improve cyclability, there should be an exclusive cycle structure, separated from car traffic with visible and adequate racks for the rental and parking of bicycles.

3. Best practices and initiatives around the world

Today, planning practice has accumulated a rich portfolio of measures ready to be considered for inspiration, adaptation and possible application in every city.

Concrete experience shows that the transition to more active mobility triggers positive effects and a number of benefits also in terms of resilience, social and environmental. Resilience to climate scenarios should be integrated right from the design phase of new infrastructures and programs for active mobility, but can also be implemented in existing ones.

In a growing number of cities, strategies adopted at the local level to promote sustainable transport modes and reduce the negative impacts of urban mobility have been encapsulated and expanded into Sustainable Urban Mobility Plans (SUMPs). This measure, introduced in Europe with "The urban mobility package of 2013" (EU, 2023), is conceived as a strategic framework designed to improve the quality of life by addressing the main challenges related to urban transport. Similarly, Sustainable Urban Logistics Plans (SULP) integrate city-level logistics into urban mobility planning, aiming for a more sustainable freight transport system. At the

national scale, National Urban Mobility Policies and Investment Programmes (NUMP) represent the strategic frameworks adopted to respond to the country's sustainable mobility needs (SLOCAT, 2023).
Policies relating to walking and cycling are increasingly difficult because active mobility is also recognized as a solution to mitigate climate change, reduce emissions, bring benefits to public health and create vibrant and inclusive societies.
The Partnership for Active Travel and Health (PATH, 2023) coordinated an analysis of Nationally Determined Contributions (NDCs) - result of the 2015 Paris Agreement - and other national walking and cycling policies and strategies in the 197 countries of the "UN Framework Convention on Climate Change" (UNFCCC) from February to September 2023. The report highlighted that 111 UNFCCC countries (57%) have a national policy that addresses walking and that 44 UNFCCC countries (22%) have a national policy that supports cycling. However, only 8 countries have connected their commitments to active travel in their NDCs and national policies for walking and cycling: apart from Singapore the others are all low- or middle-income countries and include Bangladesh, Bhutan, Colombia, Costa Rica, Ethiopia, Rwanda and Uganda.
The choices made by decision-makers influence the use of urban spaces in cities and can promote large-scale changes that lead to a clean transportation revolution with fewer cars, more electric vehicle fleets and bike lanes. Several cities around the world have taken bold and ambitious actions on active mobility and this contribution aims to highlight and share some of the best policies, projects and approaches implemented in various urban contexts, on a global scale.

3.1 Africa overview

The Africa region comprises 54 countries spanning from Northern Africa to Sub-Saharan Africa. The region is the world's least urbanised, yet it has the highest rate of urbanisation globally, at 3.5% per year (APC, 2020). The continent's urban population share is projected to grow from 47% in 2022 to 60% in 2050 (SSATP, 2022), when african cities are projected to be home to an additional 300 million urban residents, of which the vast majority are expected to rely on walking, cycling and public transport for their daily journeys.
Transport is key for promoting sustainable economic growth in the region and for addressing a complex set of challenges related to climate change and the demand for mobility. The main challenges facing the transport sector in Africa include a lack of integrated planning across various transport modes, insufficient data on public transport systems, poor transport infrastructure and access, and the highest road fatality rates globally.
Actually in Africa, many residents depend on walking and cycling as their primary means of transport. Up to 78% of people walk for travel every day to access healthcare, education, shops, jobs and public transport – often because they have no other choice (UNEP & UN-Habitat, 2022).
The lack of adequate infrastructure has a significant impact on people's choice of mode. As many as 95% of Africa's roads fail to provide an acceptable level of service for pedestrians, and 93% fail to provide an acceptable level of service for cyclists (SLOCAT, 2023).
However, in 2019, 19 (35%) of the 54 countries in Africa were reported to have a walking and cycling policy (UNEP & UN-Habitat, 2022). For example, in 2020, Addis Ababa (Ethiopia) launched a 10-year Non Motorised Transport (NMT) Strategy aimed at developing a comprehensive network of high-quality walking and cycling facilities to address the growing demand for better access to the city and has drawn up a three-year NMT implementation plan outlining immediate actions, objectives, indicators and key objectives to improve the active transport environment from 2022 to 2024 (SLOCAT, 2023).
In 2021, the African Network for Walking and Cycling (ANWAC) was created as a space for organisations and experts to convene and collaborate under the auspices of a common goal: making the life of people who walk and cycle in African countries safer, healthier, and more comfortable through combined action, expertise and influence (UNEP & UN-Habitat, 2022). Rapidly rising urbanisation and motorisation rates have prompted an

urgent response to Africa's growing transport needs, including through the development of sustainable urban mobility plans (SUMPs) and National Urban Mobility Plans (NUMPs), as for the cities of Cameroon and Tunisia. Several African countries and cities have prioritised active mobility in their policy strategies, for example:

- Kenya: in 2021, the city of Kisumu (Kenya) launched the Kisumu Sustainable Mobility Plan, a 10-year roadmap that aims to foster increased access for city residents by prioritising active mobility;
- Rwanda: Institute for Transportation and Development Policy (ITDP), in partnership with the City of Kigali (Rwanda), is developing a "Non-Motorised Transport Master Plan", slated for completion in mid-2023, that identifies priority corridors for greenways and active transport in the city (ITDP, 2021);
- Ethiopia: "The Non-Motorised Transport Strategy 2020-2029" targets building 430 km of pedestrian infrastructure and more than 300 km of cycling track in secondary cities, as well as 600 km of walkways and 200 km of cycling lanes in Addis Ababa, by the year 2029 (ITDP, 2021);
- Kenya: "The Non-Motorized Transport Policy of Nairobi City County" allocates 20% of the existing and future transport budget to infrastructure and services for walking and cycling (Nairobi NTP, 2015).

Dar es Salam – TANZANIA

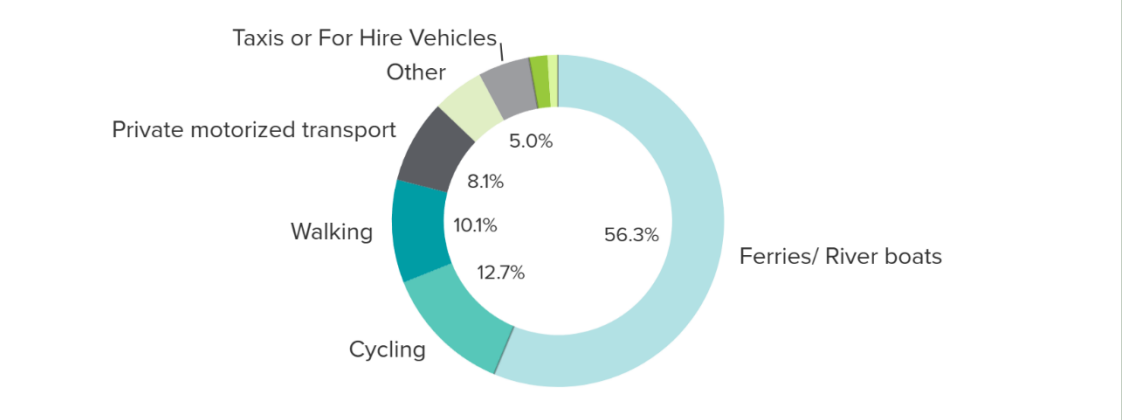


Fig.1 Dar es Salam 's transport mode share (CDP, 2019)

Tanzania is urbanizing rapidly and Dar es Salaam is the largest city in Tanzania, one of the fastest-growing cities in the world. As Dar es Salaam and other African cities continue to develop, there is a critical need to design efficient transport systems. A lack of formal public transport, growing sprawl, and massive traffic congestion, compounded by the challenges of complex and fragmented institutional structures, have kept Dar s Salaam, as well as other African cities, from attaining higher levels of investment and development (Magnusson et al., 2018).
For these reasons, the Government of Tanzania established the Dar Rapid Transit Agency (DART). The aim was to create an agency that would establish and operate a Bus Rapid Transit (BRT) system in Dar es Salaam City to improve the city's efforts in mobility, safety, comfort and clean environment (ADBG, 2015).
Plans for the BRT system indicated that sidewalk and bicycle lanes would be provided in both directions whenever possible, with 2.5 m minimum width for sidewalks and 1.5 m wide bicycle lanes. The high-quality bicycle lanes that run parallel to the BRT corridor, as well as safe sidewalks and at-grade pedestrian crossings have provided a safe space for cyclists and pedestrians (ITDP, 2020).
Dar es Salaam won the Sustainable Transport Award in 2018 and hosted the Institute for Transportation and Development Policy's MOBILIZE summit (UNEP & UN-Habitat, 2022).

3.2 Asia overview

Some Asian countries have adopted sweeping measures towards low-carbon mobility and reductions in vehicle travel, while cities have increasingly created sustainable urban mobility plans (SUMPs), often to decongest urban areas.
Some cities, such as in China (Wang et al., 2014) and Singapore (Diao, 2019), also have adopted strict rules on vehicle permitting and licences to reduce the number of vehicles. Measures to support active mobility are

on the rise in Asian cities, with governments such as India, Indonesia and the Philippines launching initiatives since 2020 to support walking and cycling.

Among the initiatives implemented in India are those of the cities of Chandigarh, the Pune Municipal Corporation and Navi Mumbai which have successfully implemented transit-oriented development in their urban planning master plans (SLOCAT, 2023).

In 2022, the ASEAN (Association of Southeast Asian Nations) region released guidelines for developing SUMPs in metropolitan areas. There have been various actions and tools undertaken by various Asian countries and cities to encourage active mobility, among these initiatives the following stand out:

- in 2020, India launched the India Cycles4Change Challenge to inspire more than 100 cities to become cycling havens, resulting in pilot cycling-friendly solutions along 400 km of main roads and 3,500 km of neighbourhood streets (ITDP India, 2022);
- with the support of "MobiliseYourCity", launched at COP21 in Paris in 2015, some countries, such as India and the Philippines, have implemented sustainable urban mobility plans (SUMPs) and national urban mobility plans (NUMPs).

Singapore – SINGAPORE

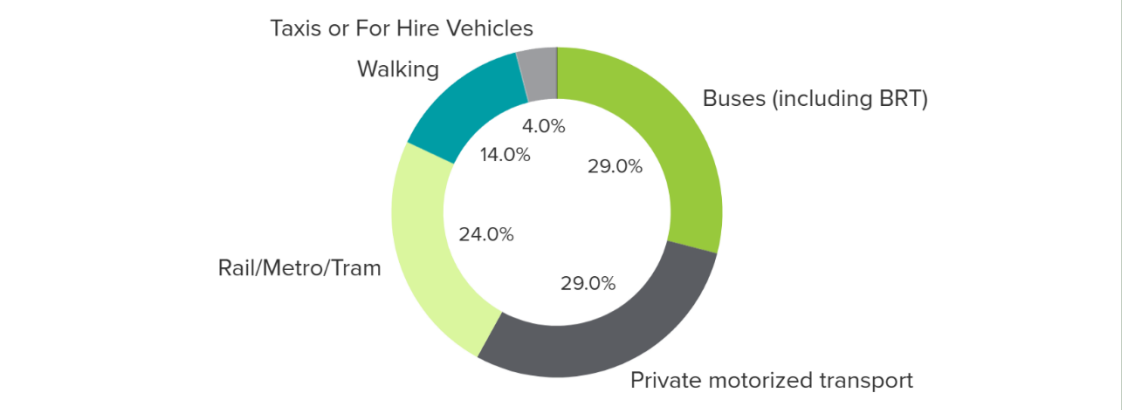


Fig.2 Singapore 's transport mode share (CDP, 2019)

Road and public transportation planning in Singapore is primarily within the purview of the Land Transport Authority (LTA). In 2018, they released the "Land Transport Master Plan 2040", which aims to achieve the following core objectives by 2040:

- "20-Minute Towns" – all intra-town journeys should be at maximum 20 minutes;
- "45-Minute City" – 90% of all inter-town journeys to be completed within 45 minutes;
- 90% of all journeys, both intra- and inter-town, to utilise modes of transportation other than personal vehicles, termed as "Walk-Cycle-Ride" journeys.

In 2022, the Urban Redevelopment Authority (URA) released the Long-Term Plan Review (LTPR) that aims to chart Singapore's infrastructural development for the next 50 years.

Cognisant of the overlap between future land use plans and land transport plans on active mobility, LTA and URA collaborated in 2018 to develop the "Walking and Cycling Design Guide" to guide private developers on installing active mobility infrastructure in their premises. WCDG provides comprehensive specifications to developers on active mobility infrastructure, such as cycling lanes, park connectors, pedestrian/bicycle crossings and bicycle parking designs. The guide also states the bicycle parking provision requirements that developers must meet as part of their Walking and Cycling Plan submissions. Additionally, developers are also incentivised to incorporate other end-of-trip facilities like bicycle servicing, lockers and showers (Lee, 2023).

3.3 Europe overview

As part of the EU's Efficient and Green Mobility Package, the EU Urban Mobility Framework was released in December 2021 to guide cities to reduce emissions, improve public health, and make urban mobility smarter

and more sustainable. The framework foresees that all major cities in the network develop a Sustainable Urban Mobility Plan (SUMP) by 2025, for planning and implementing responses to urban mobility policy challenges in the entire functional urban area.

Since then, the European Commission (EC) has been encouraging the widespread uptake of SUMPs as a cornerstone of European urban mobility policy. In fact, in early 2023, the EC released a Recommendation to Member States to establish national programmes to support cities in developing SUMPs, as "a strategic plan designed to satisfy the mobility needs of people and businesses in cities and their surroundings for a better quality of life" (EU, 2023). The implementation of SUMP, which started in Europe, has now extended to cities all over the world, with the aim of promoting more sustainable mobility (SLOCAT, 2023). An emblematic case is the city of Istanbul (Turkey) which, in 2022, developed the first SUMP in a global megalopolis, covering a population of almost 16 million inhabitants (EU Urban Mobility Observatory, 2022).

The COVID-19 pandemic resulted in key changes in Europe's urban areas, and several cities reconfigured streets to enable greater walking and cycling. In 2021, european countries adopted the Vienna Declaration to spur the transformation towards clean, safe, healthy and inclusive transport and mobility, with a strong focus on promoting cycling across the pan-European region. Ministers and representatives of the European countries also adopted the Pan-European Master Plan for Cycling Promotion, a first-of-its-kind initiative that extends across the region (WHO, 2021).

More and more European governments, as well as regional and city institutions, are developing pedestrian and cycling policies. "Proximity planning – such as the "15-minute city" in Paris, "super blocks" in Barcelona and "low-traffic neighbourhoods" in London – is experiencing reinvigorated momentum" (SLOCAT, 2023).

Since 2020, Brussels (Belgium) implemented the "Good Move", the Regional Mobility Plan, outlining its mobility ambitions, to increase walkability significantly, and reduce car use. In planning for cycling, the Netherlands remains the European leader: in 2015, the country's Tour de Force plan brought together various government and non-governmental entities, as well as businesses and academia, to promote cycling.

Barcelona – SPAIN

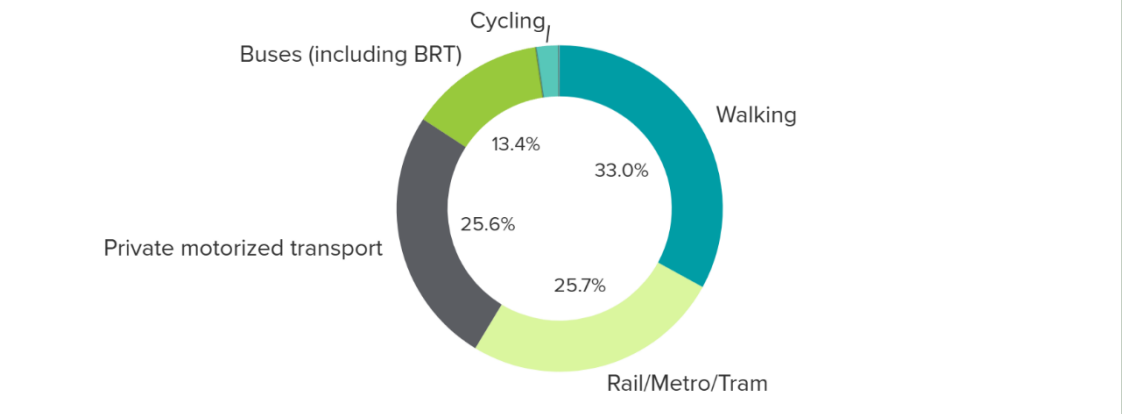


Fig.3 Barcellona's transport mode share (CDP, 2019)

Improving the health and wellbeing of its citizens, while simultaneously reducing the environmental impact of car pollution, have been the driving forces of Barcelona's innovative urban and transport programme of "superblocks".

With the "superblock" project at its heart, the "Barcelona Urban Mobility Plan 2013-2018" is a key element of Barcelona's climate action strategy that plans to transform car-occupied streets into large-scale public green spaces, creating cycle paths inside and around the superblocks, thus promoting alternative and clean mobility.

The city of Barcelona plans to radically transform its mobility, public space, and environmental impact by constructing over 500 superblocks that cover all areas within its boundaries. Physically, a superblock is a traffic-regulated cell of city blocks approximately 400m x 400m, which consists of nine smaller blocks in a three-block by three-block mesh (Zografos et al., 2020). Within the superblocks, pacified interior roads will provide a local road network that is accessible primarily to active transport (i.e. walking and cycling) and secondarily to residential traffic with a maximum speed of 20 km/h (Mueller et al., 2020).

The Superblocks are a new innovative model in urban and transport planning that reframe the current mobility paradigm and places people and well-being at the center. Three Superblock areas have already proved a success, with six more under construction, and long term plans for the blocks to be expanded to serve all of the city's 1.6 million residents (C40, 2019). Active mobility in Barcelona is also encouraged by an important cycling infrastructure, the "Bicivia", a metropolitan cycling network that connects the entire metropolis of Barcelona, with a primary and secondary network for a total of 414 km.

3.4 Latin America overview

Latin America and the Caribbean is the second most urbanised region in the world after North America, with 84% of the population living in cities in 2022 (UN, 2022). Walking remained a major mode of transport in Latin American cities in 2021 and 2022. Cycling was less prevalent, but countries and cities continued to expand their cycling infrastructure, boosted by measures taken during the pandemic such as Chile and Mexico, and cities such as Bogotá (Colombia), Buenos Aires (Argentina), Lima (Peru) and Rio de Janeiro (Brazil) (SLOCAT, 2023).

Local sustainable urban mobility plans (SUMPS) continued to expand in the region highlighting the role of cities as climate action leaders. Among the countries that have adopted tools or programs in favor of active mobility, there are:

- Mexico: in 2020, a constitutional amendment in Mexico, the General Law of Mobility and Road Safety, declared the universal right to safe, accessible, efficient, sustainable, inclusive and equitable mobility, to promote equitable and sustainable access to transport services, and harmonise subnational actions (PAHO, 2022);
- Chile: in 2021, Chile launched its National Sustainable Mobility Strategy, establishing a vision and objectives for urban mobility by 2050 and recommending measures for cities to generate their own locally aligned strategies;
- Uruguay: in 2022, launched the Guide for Sustainable Urban Mobility Planning to provide sub-national governments with tools for planning and implementing sustainable urban mobility strategies;
- Colombia: in 2022, Colombia developed the National Active Mobility Strategy with a Gender and Differential Approach, which provides guidelines for local governments to promote walking and cycling, and also adopts a gender and differential approach to ensure that "no one is left behind", one of the postulates of the Paris Agreement.

Bogotá – COLOMBIA

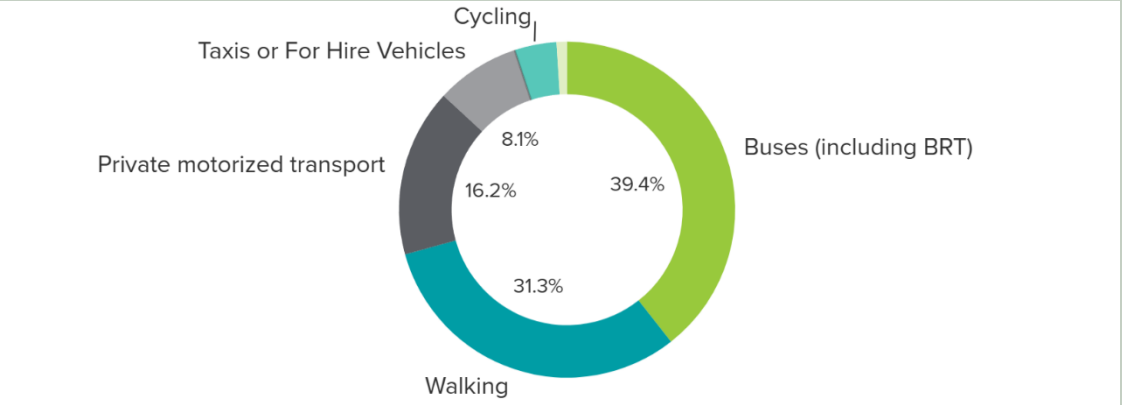


Fig.4 Bogotá's transport mode share (CDP, 2019)

Bogotá is the capital and largest city of Colombia. In recent years the transformation of Bogotá's urban transport has had various components, one of which is the implementation of bicycle-related infrastructure, policies and promotion strategies.

The city's experimentation with cycling began many decades before. In 1974, the city became the first city in South America and one of the first in the world to introduce Ciclovía, an event which sees major thoroughfares closed to vehicle

traffic in order to make way for pedestrians and cyclists. In 1998, construction began on a cycling network known as the "Red de Ciclorrutas" (also known as "The Bike Path Master Plan") that created safe bicycling routes. Initially integrated into pedestrian sidewalks, the project grew from 8 kilometers of bike lanes in 1998 to 240 kilometers two years later. The city also invested in integrating cycling with the public transport system, including creating secure and protected bike parking at terminals and stations of the newly opened bus rapid transit system, TransMilenio. Today, the cycling network includes more than 593 kilometers of permanent cycle paths, 162 kilometers in the roadway, 299 integrated within sidewalks, 124 as shared, low-speed spaces, and 5 kilometers of cycle bridges and tunnels (Mobilize, 2023).
Bogotá won the first Sustainable Transport Award in 2005 and then again in 2022.

3.5 Nord America overview

National governments in Nord America - comprising the large economies of Canada and the United States - have increasingly recognised the need to support city and local governments in planning and implementing sustainable urban mobility strategies – including through the development of national plans, policies and guidelines.

In recent years, there have been several strategies implemented by the North American countries for active mobility. Among these, there is the Canada that released its first national active transport strategy in 2021 and in 2022, British Columbia (Canada) announced new funding for "Vision Zero", a strategy that supports climate goals by shifting people to walking, cycling and micromobility. In February 2023, Fayetteville, Arkansas (USA) updated its Active Transportation Plan with a vision to "develop and promote an interconnected and universally accessible network of sidewalks, trails and on-street bicycle facilities that encourage citizens to use active/non-automotive modes of transportation to safely and efficiently reach any destination" (Fayetteville ATP, 2023).

Vancouver – CANADA

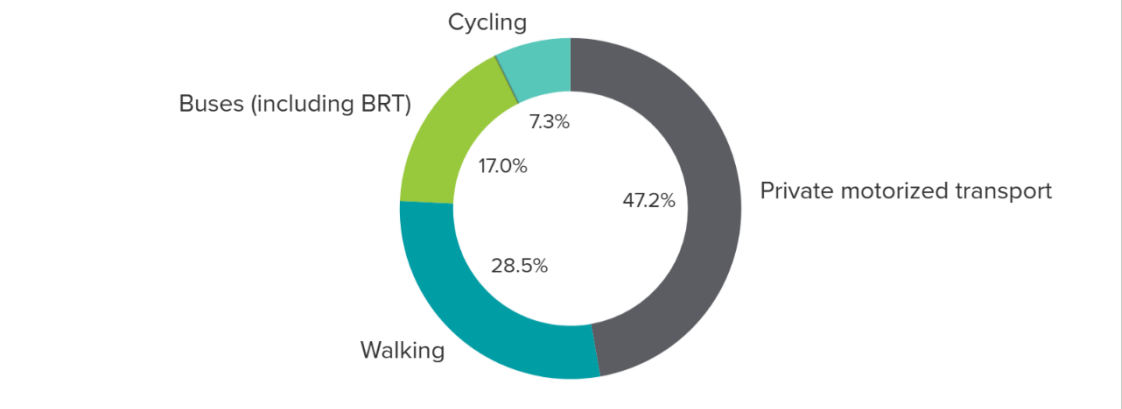


Fig.5 Vancouver 's transport mode share (CDP, 2019)

"Transportation 2040" is the plan adopted by Vancouver City Council in 2012 and represents the long-term strategic vision for the city that will help guide decisions about transportation, land use and public investment for years to come.
In January 2019 Vancouver became the first city in Canada to declare a climate emergency, which was accompanied by ambitious plans to reduce carbon pollution, improve energy efficiency, and transition to renewable energy.
"The Vancouver Climate Emergency Action Plan" (2020) sets out as one of its objectives to ensure that two thirds of Vancouver's travel is on foot, by bicycle or by public transport by 2030, and that 50% of the kilometers traveled on the roads of Vancouver must be achieved with zero emission vehicles.
The city's active transport network will also be extended, e-bikes will be introduced to the city's public bike share system, and an electric vehicle charging network will be introduced to encourage people to make the switch. Proposals for a new zero emission zone are also underway (C40, 2019).

3.6 Oceania overview

In Oceania, which includes the large economies of Australia and New Zealand, private car use has continued to dominate passenger transport. Car trips dominated in Australia and New Zealand even though these countries had the world's highest share of the urban population with access to public transport in 2021, at

82.8%, compared to a global average of 56.2% (SLOCAT, 2023).
In 2020, Wollongong (Australia) developed a comprehensive 2030 cycling strategy; within 10 years, the city aims to make cycling the primary choice for urban mobility, buildingNew Zealand's Decarbonising Transport Action Plan 2022-2025 sets out four transport targets to support the goal of reducing transport emissions 41% below 2019 levels by 2035. In 2022, the city of Wellington (New Zealand) approves a new long-term cycling plan, Paneke Pōneke Bike Network, aimed at expanding cycling networks to connect the suburbs the city centre (New Zealand Government, 2022).

Wellington – NEW ZEALAND

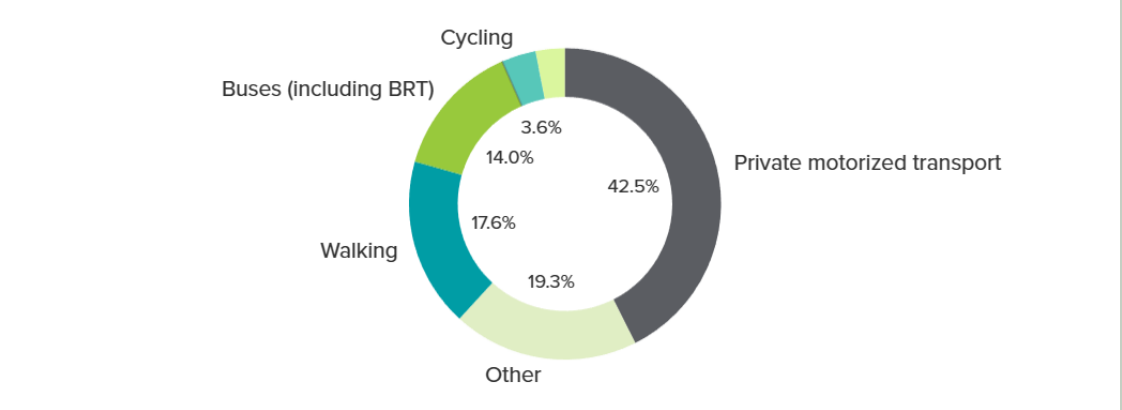


Fig.6 Wellington 's transport mode share (CDP, 2019)

As New Zealand's capital and third-largest city, Wellington has a strong business and commercial hub. A large portion of the number of people cycling in Wellington is made up of those who cycle to work.
In 2022, Wellington City Council approved a new long-term cycling plan, "Paneke Pōneke Bike network plan", aimed at expanding cycling networks to connect suburbs to the city centre.
The goal of the plan is to make Wellington a city where it is easy for people of all ages and abilities to choose low or zero carbon transport options, using a safe network. Cycling and other options such as scooters and e-scooters can make a significant contribution to a change in the way we get around. To enable this change, the city proposes the construction of a safe, connected, and high-quality network for bicycles and scooters.
The future network, 166 km long, made up of 74km of primary connections and 92km of secondary connections, will include the main commuter routes, neighborhood streets and residential streets. The plan also includes consideration of connections to key off-road mountain biking trails that are used by some riders as part of their commute (Paneke Pōneke Bike network plan, 2022).

4. Conclusion

Considering the Paris Agreement goal of keeping global temperatures below 1.5 degrees Celsius (°C) by 2050, policy makers play a crucial role in breaking the link between transport demand and emissions. They must use the tools at their disposal to ensure zero- and low-carbon technologies, and will be essential to integrate and to potentiate a mixture of transport modes: including public transport, ridesharing, shared vehicles and infrastructure for walking and cycling.
To encourage active mobility as a means of transport, a multi-level effort, including awareness-raising campaigns, is needed to educate the population on the benefits that can be derived from more sustainable mobility, favourable territorial policies, to create more pedestrian-friendly urban spaces, with safe pedestrian zones and cycle paths, with adequate connections to stations and stops to facilitate intermodality with other sustainable transport services.
Spatial planning determines the use of city areas (for example, as services, public spaces, industrial districts, retail, and residential neighbourhoods) and how people move around these. It is therefore important to improve the quality of the built environment, ensure greater proximity and quality of access to everyday services on foot and to create viable and convenient options for public transport, so as to contribute to the

progressive abandonment of the use of polluting private vehicles and to encourage active mobility choices, for a more livable and sustainable urban environment.

References

APC (2020). Addressing the Challenges of Urbanization in Africa. African Policy Circle, 2020. https://www.kas.de/documents/252038/7995358/Addressing+the+Challenges+of+Urbanization+in+Africa.

C40 (2019). We have the power to move the world. C40 CitIes. Retrieved from: https://c40.my.salesforce.com/sfc/p/#36000001Enhz/a/1Q000000MfYW/39.r67AI_Yp_ZIgJUkaJEAEWxquuVoF4SJqkeWYlNVk

Carra, M., Rossetti, S., Tiboni, M., & Vetturi, D. (2022). Urban regeneration effects on walkability scenarios. *TeMA - Journal of Land Use, Mobility and Environment*, 101-114. https://doi.org/10.6093/1970-9870/8644

CDP (2019). Modal share data accessed via the C40 Knowledge Hub Transport Data Explorer.

Cecchini, A. (2023). Il divenire della disciplina urbanistica: il contributo di Arnaldo Cecchini. *TeMA - Journal of Land Use, Mobility and Environment*, (1), 37-59. https://doi.org/10.6093/1970-9870/9744

Cirianni, F. M. M., Comi, A., & Luongo, A. S. (2022). A sustainable approach for planning of urban pedestrian routes and footpaths in a pandemic scenario. *TeMA - Journal of Land Use, Mobility and Environment, 15* (1), 125-140. https://doi.org/10.6093/1970-9870/8629

D'Amico, A. (2023). Urban spaces and pedestrian mobility: the role of urban design for enhancing walkability. *TeMA - Journal of Land Use, Mobility and Environment, 16* (3), 639-644. http://dx.doi.org/10.6093/1970-9870/10327

Diao, M. (2019). Towards sustainable urban transport in Singapore: Policy instruments and mobility trends. *Transport policy, 81*, 320-330. https://doi.org/10.1016/j.tranpol.2018.05.005

EC Action Plan (2018). Partnership for Urban Mobility Final Action Plan. Retrieved from: https://futurium.ec.europa.eu/es/urban-agenda/urban-mobility/action-plan/final-action-plan-urban-mobility-partnership-available?language=es

EU Urban Mobility Observatory (2022). Istanbul's new Sustainable Urban Mobility Plan. Retrieved from: https://urban-mobility-observatory.transport.ec.europa.eu/resources/case-studies/istanbuls-new-sustainable-urban-mobility-plan_en

EU (2023). Commission Recommendation (EU) 2023/550 of 8 March 2023 on National Support Programmes for Sustainable Urban Mobility Planning (notified under document C(2023) 1524). Retrieved from: https://eur-lex.europa.eu/eli/reco/2023/550/oj

Fayetteville ATP (2023). Active Transportation Plan. Retrieved from: https://www.fayetteville-ar.gov/DocumentCenter/View/28276/Active-Transportation-Plan--- Update---2623-FINAL

Gargiulo, C., & Zucaro, F. (2023). A Method Proposal to Adapt Urban Open-Built and Green Spaces to Climate Change. *Sustainability*, *15* (10), 8111. https://doi.org/10.3390/su15108111

Gerike, R., de Nazelle, A., Wittwer, R., & Parkin, J. (2019). Special issue "walking and cycling for better transport, health and the environment". *Transportation research Part A: Policy and practice, 123*, 1-6. https://doi.org/10.1016/j.tra.2019.02.010

Global Plan (2021). Global Plan for the Decade of Action for Road Safety 2021-2030. World Health Organization and the United Nations Regional Commissions. Retrieved from: https://www.who.int/publications/m/item/global-plan-for-the-decade-of-action-for-road-safety-2021-2030

ITDP (2018). Pedestrians First, Tools For a Walkable City. 1st ed. New York: ITDP (Institute for Transportation and Development Policy). https://www.itdp.org/publication/walkability-tool/

ITDP (2020). Dar es Salaam: 1985 and Today. Retrieved from: https://africa.itdp.org/dar-es-salaam-1985-and-today/

ITDP (2021). Rwanda. Retrieved from: https://africa.itdp.org/%20where-we-work/rwanda/

ITDP India (2022). The Dawn of a Cycling Revolution. Retrieved from: https://smartnet.niua. org/indiacyclechallenge/wp-content/uploads/2022/01/A-Dawn-of-a-Cycling-Revolution-Publication.pdf.

Lee, C. (2023). How Is Singapore Planning For Active Mobility?.Maju. https://www.maju.sg/post/how-is-singapore-planning-for-active-mobility

Mueller, N., Rojas-Rueda, D., Khreis, H., Cirach, M., Andrés, D., Ballester, J., Bartoll, X., Daher, C., Deluca, A., Echave, C., Milà, C., Márquez, S., Palou, J., Pérez., K., Tonne, C., Stevenson, M., Rueda, S., Nieuwenhuijsen, M. (2020). Changing the urban design of cities for health: The superblock model. *Environment international, 134*, 105132. https://doi.org/10.1016/j.envint.2019.105132

Nairobi NTP (2015). Non motorized transport policy. Towards nmt as the mode of choice. Nairobi City County Government. Retrieved from: https://kara.or.ke/wp-content/uploads/2023/09/Nairobi-City-County-Non-Motorized-Transport-Policy.pdf

New Zealand Government (2022). Aotearoa New Zealand's first emissions reduction plan, Chapter 10: Transport. Retrieved from: https://environment.govt.nz/publications/aotearoa-new-zealands-first-emissions-reduction-plan/

Paneke Pōneke Bike network plan (2022). Retrieved from: https://www.transportprojects.org.nz/assets/Modules/DocumentGrid/Bike-Network-Plan-Final-June-2022.pdf

PAHO (2022). Mexico's New Mobility and Road Safety Law Could Be a Game-changer, Pan American Health Organization. Retrieved from: https://www.paho.org/en/news/1-5-2022-mexicos-new-mobility-and-road-safety-lawcould-be-game-changer

PATH (2023). PATH's 2023 UNFCCC Report: National Policies for Walking and Cycling in all 197 UNFCCC countries. Retrieved from: PATH-UNFCCC-policies-report-FINAL.pdf (pathforwalkingcycling.com)

SLOCAT (2023). Global Status Report on Transport, Climate and Sustainability – 3rd edition. Retrieved from: www.tcc-gsr.com.

SSATP (2022). African Transport Policy Program (SSATP), Annual Report 2022, Retrieved from: https://www.ssatp.org/publication/annual-report-2022

Magnusson, J., ITDP, & Kost, K. (2018). Dar es Salaam. Leads a Breakthrough for African Cities. Sustainable Transport. Retrieved from: https://itdpdotorg.wpengine.com/wp-content/uploads/2018/02/DES-Leads-a-Breakthrough-for-African-Cities.pdf

Mobilize (2023). From Transmilenio to Cycle NetworksLessons Learned from Bogotá's Comprehensive Urban Mobility Planning. Retrieved from: https://www.itdp.org/wp-content/uploads/2023/05/From-Transmilenio-to-Cycle-Networks-Lessons-Learned-from-Bogotas-Comprehensive-Urban-Mobility-Planning-MAY4.pdf

UN Climate Change Quarterly Report (2024). Message to Parties and observers - UN Climate Change Quarterly Report: Q4 2023. Retrieved from: https://unfccc.int/documents/637577

UN (2022). "World Population Prospects 2022". Retrieved from: https://population.un.org/wpp/

UNEP & UN-Habitat (2022). Walking and Cycling in Africa: Evidence and Good Practice to Inspire Action. Nairobi. https://wedocs.unep.org/20.500.11822/40071

WHO (2021). European countries adopt Vienna Declaration on clean, safe and healthy transport and first-ever Pan-European Master Plan for Cycling Promotion. Retrieved from: https://www.who.int/europe/news/item/18-05-2021-european-countries-adopt-vienna-declaration-on-clean-safe-and-healthy-transport-and-first-ever-pan-european-master-plan-for-cycling-promotion#Vienna,%20Austria,%2018%20May%202021

WHO Regional Office for Europe (2022). Walking and cycling: latest evidence to support policy-making and practice. Copenhagen: WHO Regional Office for Europe. Retrieved from: https://www.who.int/europe/publications/i/item/9789289057882

Walk'n'Roll Cities Guidebook (2022). Walk'n'Roll Cities Guidebook. Innovations in mobility and public space. Retrieved from: walknroll.pdf (urbact.eu)

Wang, L., Xu, J., & Qin, P. (2014). Will a driving restriction policy reduce car trips? The case study of Beijing, China. *Transportation Research Part A: Policy and Practice, 67*, 279-290. https://doi.org/10.1016/j.tra.2014.07.014

Zografos, C., Klause, K. A., Connolly, J. J., & Anguelovski, I. (2020). The everyday politics of urban transformational adaptation: Struggles for authority and the Barcelona superblock project. *Cities, 99*, 102613. https://doi.org/10.1016/j.cities.2020.102613

Author's profile

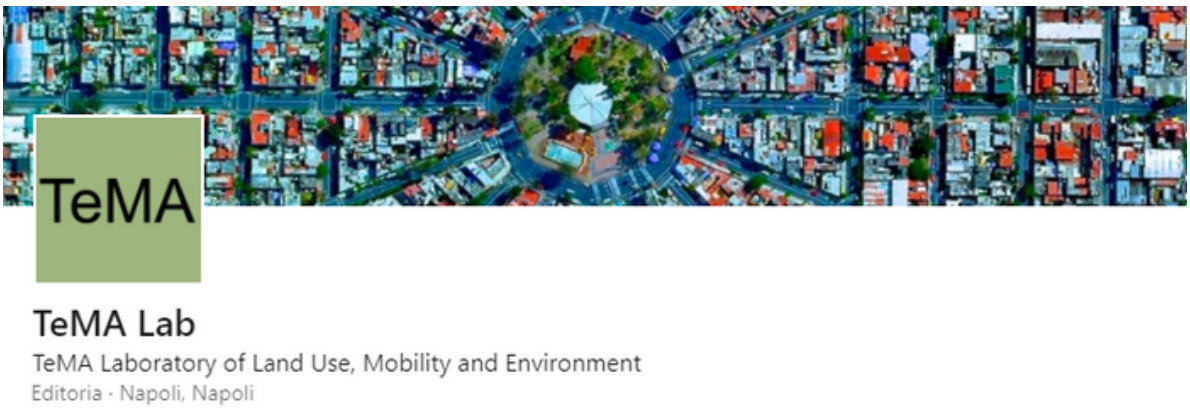
Annunziata D'Amico

She is an engineer, Ph.D. student in Civil Systems Engineering at Department of Civil, Building and Environmental Engineering of University of Naples Federico II. Currently, her Ph.D. research concerns the topic of urban mobility.

We are online!

TeMA Lab

Follow us on LinkedIn



TeMA Lab and our Journal are on LinkedIn!
TeMA Lab is the Laboratory of Land Use, Mobility and Environment of the Department of Civil, Building and Environmental Engineering, at Università degli Studi di Napoli Federico II. Our field of expertise relates to urban systems, their complexity and the challenges that they will face in near future: adaptation to climate change, ageing population, energy consumptions, development of sustainable mobility and so on. Follow us to be constanly updated!.

www.linkedin.com/company/tema-journal/

TeMA Journal of Land Use, Mobility and Environment

TeMA 1 (2024) 169-177
print ISSN 1970-9889, e-ISSN 1970-9870
DOI: 10.6093/1970-9870/10784
Received 19th February 2024, Available online 30th April 2024

Licensed under the Creative Commons Attribution – Non Commercial License 4.0
http://www.serena.unina.it/index.php/tema

REVIEW NOTES – Urban Practices

Global warming or global warning? A review of urban practices for climate change adaptation in Europe

Stella Pennino

Department of Civil, Building and
Environmental Engineering
University of Naples Federico II, Naples, Italy
e-mail: stella.pennino@unina.it
ORCID: https://orcid.org/0009-0008-4439-0078

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 Practices section aims at presenting recent advancements on relevant topics that underline the challenges that the cities have to face. This note provides an overview of the challenges that global warming poses and the risks in terms of climate change that it generates for territories and cities. The challenges that adaptation to climate change commonly faces are outlined, and a brief review of European case studies is carried out. Finally, the results of the review are discussed highlighting some key threads of climate adaptation practices and three significant examples of climate change adaptation in urban areas are reported, within a perspective of integration and sharing of know-how on the topic.

Keywords
Climate Change; Adaptation; Urban practices; Case studies; Europe

How to cite an item in APA format
Pennino, S. (2024). Global warming or global warning? A review of urban practices for climate change adaptation in Europe. *TeMA – Journal of Land Use, Mobility and Environment*, *17* (1), 169-177. http://dx.doi.org/10.6093/1970-9870/10784

1. Introduction

The year 2023 was the warmest year on record in global temperature since 1850. In the 12-month period between February 2023 and January 2024 the average global temperature exceeded pre-industrial levels by 1.5°C and the world air and ocean temperature has dangerously increased as well (Climate Copernicus, 2024). The rising temperature trend is gradually altering ocean and winds currents, precipitation patterns, and the internal dynamics of ecosystems: a phenomenon commonly referred to as climate change. This series of gradual alterations generates an increase in the frequency and severity of climatic extreme events that cause significant damage to the environment, people and the economy. Climate change also acts as a risk multiplier, worsening and exacerbating the condition of social groups that are already vulnerable or in a previous state of crisis due to other factors (European Climate Risk Assessment, EEA, 2024).

According to the official UN definition "since the 19th century, human activities have been the main factor behind climate change, which is mainly attributable to the combustion of fossil fuels (such as coal, oil and gas) that produces heat-trapping gases" (UNRIC, 2024). Reducing greenhouse gas emissions is indeed key to slowing and limiting global warming. However, even under the most optimistic scenarios of complete decarbonization of anthropogenic activities – as agreed by International Parties within the Paris Agreement – the effects of global warming, including climatic changes, will not stop immediately, and the effects will continue to develop and manifest themselves for several more years. It therefore emerges as a pressing necessity to adapt the built environment and the human society in order to cope with the disruptive effects of climate change in the short term, preserving crucial ecosystems and protecting human lives, while implementing mitigation long-term measures.

Europe is the fastest-warming continent in the world, heating at about twice the global rate. The European Environment Agency report "European climate risk assessment 2024" identifies 36 climate risks with potentially severe consequences across Europe and highlights how the relative levels on the severity scale have already reached critical levels. This analysis shows how urgent and priority it is to adapt cities both in the built environment and in the social organisation in order to cope with these extreme climatic events, reducing the vulnerability of urban systems and the related climate risks. On this matter, aiming for a more sustainable city model supporting the ecological transition means putting in place a coordinated system of strategies, actions and interventions to overcome the great challenges that cities today are called to respond to for the reduction of the effects of climate change (Gaglione & Ayiine-Etigo, 2021).

2. Climate change adaptation

The UNFCCC (United Nation Framework Convention on Climate Change) definition of climate adaptation reads as follows: "Adaptation refers to adjustments in ecological, social or economic systems in response to actual or projected climate stimuli and their effects. It refers to changes in processes, practices and structures to moderate potential damages or to benefit from opportunities associated with climate change". This definition is aligned with those given by the IPCC and the EEA, and it configures this practice as a process of system variation, aimed at reducing its vulnerability or, similarly, increasing its resilience.

This concept began to take shape with the start of the scientific debate on climate change between the 1980s and 1990s. The general scientific output related to climate change has seen a slow and gradual increase with a significant acceleration after 2006, the year from which specific issues around mitigation, adaptation and resilience also began to feature in the climate change debate (Boulanger, 2023).

Over the last 15 years, the topic has become central to the scientific debate on climate change, although it has not yet assumed the centrality of mitigation, a topic that is at the core of major international agreements and forums, primarily COPs and the Paris Agreement. However, organisations and bodies dedicated to this key issue such as the Adaptation Committee (AC) and the Nairobi Working Programme (NWP) have been implemented at the international level under the coordination of the UNFCCC, and most importantly, the

Cancun Adaptation Framework established the process for the elaboration of National Adaptation Plans (NAPs), tools that each country is required to develop to reduce its vulnerability to the impacts of climate change, with the ultimate goal of integrating climate adaptation into existing and new policies.

With the increasing centrality given to the topic of climate adaptation in scientific production and the development of NAPs for several countries, there are numerous climate adaptation actions and measures that have been developed and just as many that are continuously being developed and put into practice. Since urban systems are complex due to the multitude of physical and functional elements upon which climate change has effect, it is crucial to design integrated plans and strategies to mitigate and adapt (Guida & Pennino, 2022). Moreover, given the importance of the climate change phenomenon at the global level, collaboration at the academic and institutional level is strongly needed and encouraged in order to share best adaptation practices to enable their replication in other similar contexts. To this end, several repositories exist that collect climate adaptation best practices and make them open access for all scholars, policy makers, and other interested users. In this series of review notes, some of the aforementioned repositories will be analysed and a few case studies extracted from the collection will be reported.

At the European level, there is an official European Union website: the European Climate Adaptation Platform Climate-ADAPT.

3. A review of Climate-ADAPT case studies

Given its above-average rate of warming, Europe is one of the continents that is already experiencing noticeable effects of climate change. Climate risks threaten energy and food security, ecosystems, infrastructure, water resources, financial stability and people's health (European Climate Risk Assessment, EEA, 2024). On the other hand, Europe is one of the countries most committed to the ecological and energy transition, and is at the forefront of climate change standards, practices and studies, both in terms of mitigation and adaptation.

Since 2020, all EU Member States (MS) have a national adaptation policy framework officially adopted (e.g. National Adaptation Strategy (NAS), mostly followed by a National Adaptation Plan (NAP) or Sectoral Adaptation Plans (SAP)) covering a broad range of climate change adaptation options and measures (Medri, 2020). Moreover, in February 2021, the European Commission adopted the European Strategy on Adaptation to Climate Change, with which it put in place a strategy to adapt to the inevitable impacts of the phenomenon and become climate resilient by 2050 (Directorate-General for Climate Action of the European Commission, 2021). In addition to the legal implications and European strategies, the European Union has numerous tools for collecting and sharing data on the phenomenon, including the European Climate and Health Observatory and the European Climate Data Explorer.

Among these valuable tools is the European Climate Adaptation Platform: Climate-ADAPT. This platform was created in cooperation between the European Commission and the European Environment Agency (EEA) with the aim of supporting European countries in adapting to climate change and is managed with the support of the European Topic Centre on Climate Change Impacts, Vulnerability and Adaptation (ETC/CCA). The platform enables organisations and stakeholders involved in climate change adaptation to share and consult information and data on climate change, vulnerability of different regions, and climate change adaptation strategies, actions and tools, including a collection of case studies from several European cities.

For the selection of the case studies to be presented in this review note, the English-language case studies uploaded on the platform in the last 5 years were analysed, for a total of 48 case studies. Case studies covering all adaptation sectors and climate impacts were analysed for all European countries.

For the selected sample of case studies, we report graphs of some of the most relevant indicators: country where the intervention took place, scale of the intervention (administrative level at which the intervention was carried out), climate impacts addressed and/or sectors affected.

The graph in Fig.1a shows that the majority of cases has taken place in Spain, Italy and Germany. There are no cases at all for Bulgaria, Croatia, Estonia, Ireland, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, Poland and Romania.

Concerning the administrative level at which the interventions were implemented, as visible in the graph in Fig.1b, the majority were carried on at the local level, followed by national and sub-national strategies (the latter refer to sub-national administrative entities or geographical regions, such as river basins). In addition, there are 4 supranational cases, identified as "Transnational Region" measures, which are implemented across different nations for reasons of geographical or climatic continuity, as in the case of large transnational river basins. Then there are 10 actions that were developed in cooperation between several administrative levels, generally at local level in collaboration with regional or national authorities.

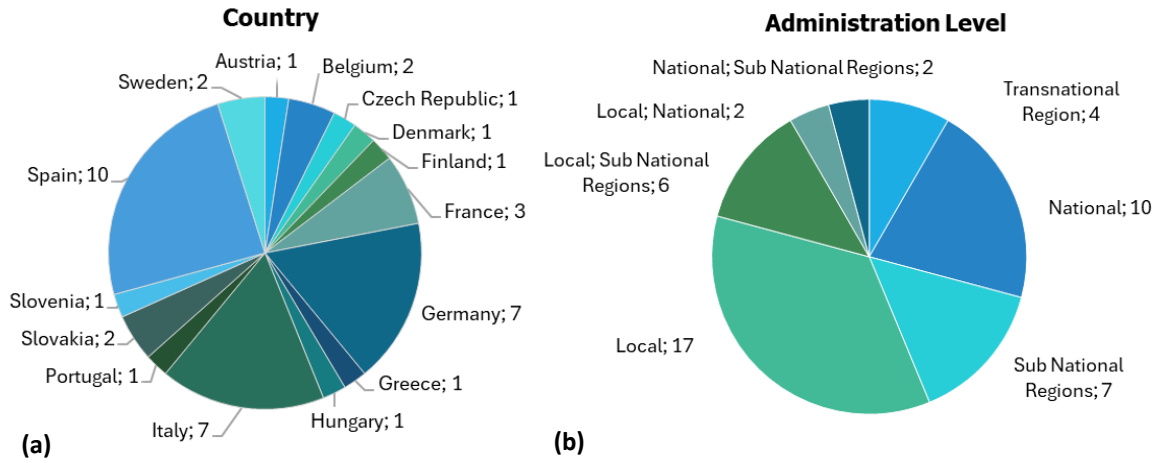


Fig.1 (a) Country of implementation; (b) Administration level where the case study of the selected sample was implemented

As stated in the ETC/CCA Technical Report on Key Type of Measures for adaptation to climate change, while often targeting the same vulnerable systems and problems, climate change options and measures are highly heterogeneous in the way they are organised, labelled and described across EU Member States (Medri, 2020). For this reason, a pool of experts from the ETC/CCA and the EEA drew up the above-mentioned report "Rationale, approach and added value of Key Type of Measures for adaptation to climate change" in 2020, which describes how the labelling system of climate change adaptation measures for the EU was developed from the category system defined in the IPCC Fifth Annual Report, a system also used in the cataloguing of the case studies on the Climate-ADAPT platform.

For the realisation of this review note, a great deal of information was collected for each case study, including KTM, Sub-KTM and their specifications. However, as pointed out by the researchers who prepared the report, many of the measures present a strong heterogeneity and are difficult to place in a single category. For this reason, in this review, it was decided to categorise the measures into 5 qualitative categories, which simplify the identification of some common trends among the adaptation measures analysed in the sample. The categories refer to the climate impact in question or the sector affected by the phenomenon, and are:

- Extreme Temperatures: this category includes all measures to combat the effects of climate change on people and/or the built environment caused by rising temperatures, extreme heat and heat waves;
- Water: this category includes all adaptation measures affecting watercourses and precipitation, including causes and effects of flooding, runoff, salinisation of river deltas, river water pollution, etc.;
- Extreme Temperatures/Water: this category includes measures that act on the effects of climate change on ecosystems that are highly dependent on water, such as forests, farms, agricultural areas, and thus

includes all phenomena such as droughts, water scarcity, alteration of ecosystems and reduction of biodiversity in natural environments caused by temperature increase;

- Health: this category includes all measures that are exclusively related to the effects of climate change on human health, directly or indirectly. These include the spread of viruses, invasive species carrying viruses or substances harmful to humans, and the effects of climate change on the mental health of the population;
- Governance: in this last category, we find all measures, generally national or supranational, aimed at fostering cooperation, information sharing, more effective organisational structures for adaptation to climate change through staff training, information provision and academic cooperation.

As can be seen from the graph in Fig.3 regarding the analysed sample of cases, this categorisation shows that there are clearly predominant trends in climate change adaptation measures. Indeed, the interventions are almost equally distributed among the five categories, highlighting how the identified sectors, in relation to specific climate impacts, are those of greatest interest and pressure in the current European framework.

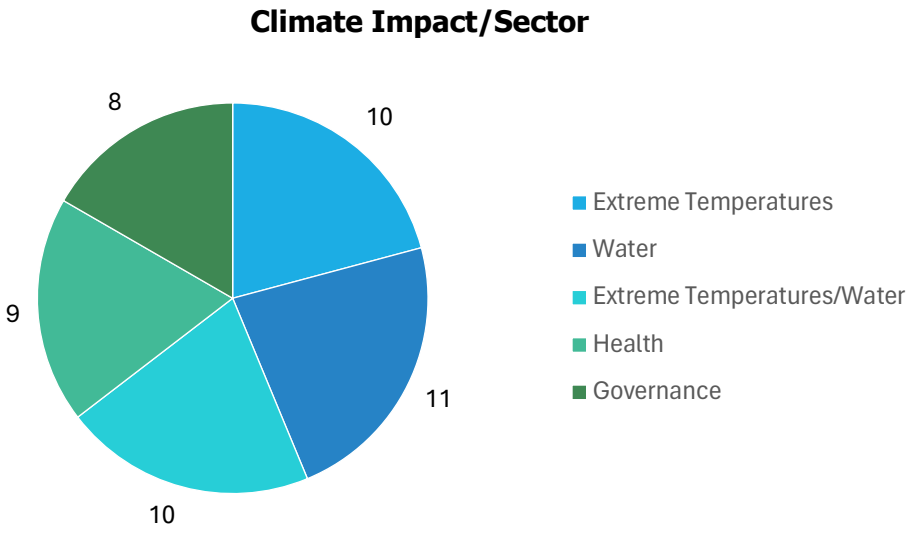


Fig.2 Categories of the climate change adaptation case studies analysed in this review note

4. Considerations from case studies

The review of the case studies reveals a great deal of information about the spread and location of the case studies, the types and climate impacts of greatest concern.

In terms of dissemination, it appears that most of the case studies were implemented in the largest and most populous countries in Europe, with Spain in first place, followed by Germany and Italy, and France. A number of smaller and less populous but committed European countries then emerge, including Sweden, Belgium and Slovakia. By contrast, countries in the Balkans and Eastern Europe are almost completely absent.

With regard to the type of interventions, there is a considerable multiplicity. Interventions implemented at local or regional level are generally more focused on the physical, built or natural environment and include actual interventions, monitoring tools or strategies, or interaction with the users of the places in question. Strategies at the national or transnational level, on the other hand, are generally at the technological, organisational, or governance level, and focus on sharing practices, training personnel, early warning systems, coordinating interventions, and improving cooperation between different administrative bodies affected by the phenomena addressed.

The data on trends in climate impacts dealt with/sectors affected is significant, as they clearly show predominant sectors for climate change adaptation.

The predominant category, albeit by only one case, is Water. This is not surprising, as one of the most evident phenomena of climate change is the variation in rainfall patterns, which has significant effects on rivers and streams in terms of flooding and runoff, which in turn have serious consequences on the natural and built environment, significant fallout and economic losses, as well as constituting a risk to people, and a very strong cause of anxiety, post-disaster shock, and threat to the mental health of people impacted or threatened by these phenomena. In fact, the case studies on watercourses include both physical interventions on them, protection and management through nature-based-solutions, monitoring interventions and early warning systems, but also financial instruments for reducing the vulnerability of the threatened population and psychological support programmes for people affected by the aforementioned phenomena.

Among the most prevalent categories, tied for second, is that concerning all phenomena due to extreme temperatures, which includes all actions aimed at adapting the built environment to mitigate the effects of increasingly frequent extreme temperatures. These include new construction or renovation of existing buildings by significantly increasing green areas, integrating trees and plants, nature-based systems for cooling and lowering temperatures. An interesting aspect of this category of interventions is that they often involve public facilities, managing to reach a large part of the population and especially some of the most vulnerable groups, including children and the elderly.

Then there is a third predominant category, which is the one that encompasses all phenomena related to water resource management in agricultural, river or forestry contexts. Phenomena such as droughts, water scarcity, and impoverishment of biodiversity due to high temperatures are a major threat to crops, forests and mountain habitats, but also to tourism in some areas. This type of climatic impact is confirmed as one of the most widespread. The interesting aspect is precisely the location of the interventions, since they are not located exclusively in the Mediterranean area, where the phenomenon of heatwaves is most keenly felt, but there are also relevant cases in Germany, Belgium and Sweden, countries generally considered less affected due to their different climate and geographical position.

A surprisingly present category is the health sector. Nine actions concern the development of new risks to human health caused by rising temperatures, of which one is related to the treatment of eco-anxiety, two to the invasion of invasive marine species harmful to humans, and no less than six actions to study, monitor or counter the spread of new viruses from tropical areas generally transmitted by mosquitoes, including dengue, West Nile Virus or tick-borne encephalitis. The risk of the spread of new and more infectious viruses from tropical areas is an issue that emerged strongly in late 2023 and early 2024 due to the increased spread of dengue in South America, and also due to the increased sensitivity of the topic following the Covid-19 pandemic. However, these case studies show that the phenomenon is far from recent and is already receiving attention at European level, as some of them were implemented almost 20 years ago.

The last category, slightly lower with eight case studies, is governance measures. This category of interventions includes numerous projects implemented at the regional or transnational level to coordinate the study, monitoring and cooperation actions in climate adaptation of administrative or geographical regions. Among these initiatives, two significant trends emerge, the first being the integration of adaptation measures into policies or interventions already in place or being implemented, making adaptation a necessary and integrated requirement throughout the development process of the interventions themselves. The second concerns the training of professionals most affected by the issue, including two interventions entirely dedicated to health professionals, who play a key role in addressing the effects of climate change.

As relevant examples three case studies were identified for their readiness and replicability, for the multiplicity of aspects they deal with, and for the possibilities that the integrated actions they indicate concern several urban levels simultaneously. The three cases refer to three different categories defined previously: Extreme Temperatures, Governance and Water, and were implemented in three different countries. The first one, belonging to the "Water" category, refers to a "Grey" intervention, i.e. the realisation of a physical

infrastructure, in particular a hydraulic infrastructure system to limit the effect of contaminated water spilling into the sea following extreme rainfall phenomena, carried out in Rimini, Italy. The second , belonging to the "Governance" category, shows an example of mainstreaming climate adaptation, integrating this practice into the design and implementation of public infrastructure on city territory, through an example in the city of Jena, Germany. The third intervention, belonging to the "Extreme Temperatures" category, refers to a complex adaptation system at the urban scale for the crescendo phenomenon of heat stress, including a heat prediction and warning system, integrated with targeted actions at the urban level and awareness and involvement interventions implemented in the city of Antwerp, Belgium. They are illustrated in the following data sheets.

1.1 Protecting bathing water quality from sewage overflow in Rimini, Italy

During heavy rainfall events, Rimini frequently experienced combined sewage system overflows which caused local surface flooding in the city and direct discharge of untreated, diluted wastewater into the sea. The resultant contamination of sea water was posing health risks and necessitated frequent implementation of bathing bans on the city's beaches, with negative impacts on tourism.
The Municipality of Rimini set up and continues to implement an Optimized Seawater Protection Plan (*Piano di Salvaguardia della Balneazione Ottimizzato – PSBO*), which included the creation of a separated sewage collection system, improvement of the sewage treatment system and construction of storage tanks for overflow water. After the finalization of the sewerage system works on Rimini's northern coast in 2020, the discharges of untreated wastewater into the sea have been drastically reduced. Despite continuing occurrence of heavy rainfall events, the number of bathing bans implemented has decreased.
Public works on the street surfaces, necessary during renovation of the sewage system, provided an opportunity to transform streets and parking areas on the waterfront into an urban park ("*parco del mare*") with green areas and space for recreational activity that simultaneously functions as a barrier against coastal flooding.

Source: Climate-ADAPT; Feb 27, 2024

Retrieved from: https://climate-adapt.eea.europa.eu/en/metadata/case-studies/protecting-bathing-water-quality-from-sewage-overflow-in-rimini-italy

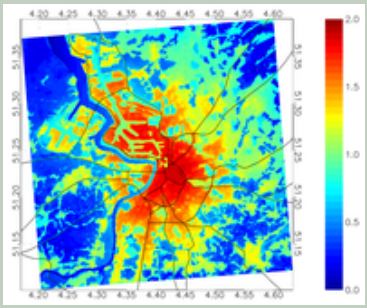
1.2 Mainstreaming climate change adaptation into urban planning: greyfield land redevelopment in Jena, Germany

In Jena, adaptation has been integrated in urban planning thanks to public awareness, public institutional support, and investments in collaboration and research. Detailed cost-benefit analyses inform decision-making for interventions such as the greyfield land redevelopment.
Jena is a city of about 108,000 inhabitants and – due to its specific geographic location – is exposed to various climate change-related risks, whereas heatwaves are the most relevant. Climate projections for Jena expect a substantial increase of this risk in the future. Under the frame of "JenKAS - Jena Climate Adaptation Strategy", a concept for adapting the city to climate change impacts was developed between 2009 and 2012 as part of a project funded by the Federal Ministry of Transport, Building and Urban Development and the Federal Institute for Research on Building, Urban Affairs and Spatial Development. The overall goal of the project was to lay the ground for mainstreaming climate change adaptation into urban planning.
The redevelopment of the Inselplatz – a 3 hectares inner city square mainly used as parking area – into a new campus of the Friedrich Schiller University was one of the first practical interventions for which the JenKAS approach was applied. As part of the planning process economic assessments were conducted to determine the most suitable bundle of adaptation measures to reduce local heat risk and to improve the local climate of this specific area in the medium and long-term perspective.

Source: Climate-ADAPT; May 08, 2020

Retrieved from: https://climate-adapt.eea.europa.eu/en/metadata/case-studies/mainstreaming-climate-change-adaptation-into-urban-planning-greyfield-land-redevelopment-in-jena-germany

1.3 Adapting to heat stress in Antwerp (Belgium) based on detailed thermal mapping



The city of Antwerp, facing increasing heat stress, has adopted adaptation measures at the city-wide, local and citizen scale. This includes the development of a heat forecast and warning system, which has raised awareness at the political level. However, challenges remain for communication and technical integration.

The city of Antwerp, in order to better understand the problem of heat stress, commissioned the research organization VITO to map the current and future temperatures and thermal comfort in the city. The research results indicate that the urban heat island of Antwerp exacerbates the impact of climate change on the urban population as the amount of heatwave days in the city raises twice as fast as in the rural surroundings. To tackle the problem of heat stress in the city, adaptation measures at three different scales (city-wide, local and the individual citizen) are put forth. At the city-wide scale, the installation of green roofs is made mandatory for new or renovated buildings with a suitable roof, as are permeable and green parking lots. The regulations also aim to increase albedo of public buildings. At the local scale, the thermal comfort is improved by installing fountains and ponds, planting trees and creating parks in public spaces that are renovated, while involving inhabitants through citizen science measurement campaigns. Finally, a dedicated heat forecast and warning system is put in place to minimize the health impacts to individual citizens.

Source: Climate-ADAPT; Apr 07, 2020

Retrieved from: https://climate-adapt.eea.europa.eu/en/metadata/case-studies/adapting-to-heat-stress-in-antwerp-belgium-based-on-detailed-thermal-mapping

References

About Climate-ADAPT — Discover the key services, thematic features and tools of Climate-ADAPT. (n.d.). Climate-ADAPT. https://climate-adapt.eea.europa.eu/en/about

Adapting to heat stress in Antwerp (Belgium) based on detailed thermal mapping — Discover the key services, thematic features and tools of Climate-ADAPT. (n.d.). Climate-ADAPT. https://climate-adapt.eea.europa.eu/en/metadata/case-studies/adapting-to-heat-stress-in-antwerp-belgium-based-on-detailed-thermal-mapping

Boulanger, S. O. M. (2023). Urban Adaptation to Climate Change State of the Art: Evaluating the Role of Adaptation Assessment Frameworks through a Systematic and Bibliometric Analysis. *Sustainability*, *15* (13), 10134. https://doi.org/10.3390/su151310134

Copernicus: 2023 is the hottest year on record, with global temperatures close to the 1.5°C limit. (n.d.). Copernicus. https://climate.copernicus.eu/copernicus-2023-hottest-year-record

EU Adaptation Strategy. (n.d.). Climate Action. https://climate.ec.europa.eu/eu-action/adaptation-climate-change/eu-adaptation-strategy_en#:~:text=The%20European%20Commission%20adopted%20its,become%20climate%20resilient%20by%202050.

European Environment Agency. (2024). European Climate Risk Assessment: Executive Summary. In *eea.europa.eu*. Publications Office of the European Union. https://doi.org/10.2800/204249

Gaglione, F., & Ania, A. E. D. (2021). Resilience as an urban strategy: The role of green interventions in recovery plans. *TeMA – Journal of Land Use, Mobility and Environment, 14* (2), 279-284. http://dx.doi.org/10.6092/1970-9870/8054

Guida, C., & Pennino, S. (2022). Climate adaptation in the Mediterranean: storms and droughts. *TeMA – Journal of Land Use, Mobility and Environment, 15* (3), 543-547. http://dx.doi.org/10.6092/1970-9870/9410

Introduction | *UNFCCC*. (n.d.). https://unfccc.int/topics/adaptation-and-resilience/the-big-picture/introduction

Leitner M., Dworak T., Capela Lourenço T., Lexer W., Prutsch A, Vanneuville W. (2020) "Rationale, approach and added value of Key Type of Measures for adaptation to climate change": European Topic Centre on Climate Change Impacts, Vulnerability and Adaptation (ETC/CCA) Technical Paper 2020/2. http://dx.doi.org/10.25424/cmcc/key_type_of_measures_for_adaptation_to_climate_change_2020

Mainstreaming climate change adaptation into urban planning: greyfield land redevelopment in Jena (Germany) — Discover the key services, thematic features and tools of Climate-ADAPT. (n.d.). Climate-ADAPT. https://climate-adapt.eea.europa.eu/en/metadata/case-studies/mainstreaming-climate-change-adaptation-into-urban-planning-greyfield-land-redevelopment-in-jena-germany

Nazioni Unite. (2022, October 26). *Che cosa sono i cambiamenti climatici? - ONU Italia*. ONU Italia. https://unric.org/it/che-cosa-sono-i-cambiamenti-climatici/

Protecting bathing water quality from sewage overflow in Rimini, Italy — Discover the key services, thematic features and tools of Climate-ADAPT. (n.d.). Climate-ADAPT. https://climate-adapt.eea.europa.eu/en/metadata/case-studies/protecting-bathing-water-quality-from-sewage-overflow-in-rimini-italy

Rationale, approach and added value of Key Type of Measures for adaptation to climate change. (n.d.). Eionet Portal. https://www.eionet.europa.eu/etcs/etc-cca/products/etc-cca-reports/rationale-approach-and-added-value-of-key-type-of-measures-for-adaptation-to-climate-change

United Nations. (n.d.). *Climate change | United Nations*. https://www.un.org/en/global-issues/climate-change

Author's profile

Stella Pennino

She is an engineer and Ph.D. student in Civil Systems Engineering at the Department of Civil, Building and Environmental Engineering of the University of Naples Federico II. Her research activities concern adaptation of the urban environment to climate change-related hazards and vulnerability measures, with the aim of mainstreaming sustainability in urban planning decision-making.

We are online!

TeMA Lab

Follow us on Twitter

TeMA Lab and our Journal are on Twitter!
TeMA Lab is the Laboratory of Land Use, Mobility and Environment of the Department of Civil, Building and Environmental Engineering, at Università degli Studi di Napoli Federico II. Our field of expertise relates to urban systems, their complexity and the challenges that they will face in near future: adaptation to climate change, ageing population, energy consumptions, development of sustainable mobility and so on. Follow us to be constanly updated!.

www.twitter.com/TeMALab_unina

TeMA Journal of Land Use, Mobility and Environment

TeMA 1 (2024) 179-186
print ISSN 1970-9889, e-ISSN 1970-9870
DOI: 10.6093/1970-9870/10778
Received 15th February 2024, Available online 30th April2024

Licensed under the Creative Commons Attribution – Non Commercial License 4.0
http://www.serena.unina.it/index.php/tema

REVIEW NOTES – Urban planning literature review

Exploring approaches and solutions for urban safety: a focus on women

Tonia Stiuso

Department of Civil, Building and
Environmental Engineering
University of Naples Federico II, Naples, Italy
e-mail: tonia.stiuso@unina.it
ORCID: https://orcid.org/0009-0006-2474-8138

Abstract
Starting from the relationship between urban planning and mobility management, TeMA has gradually expanded the view of the covered topics, always remaining in the groove of rigorous scientific in-depth analysis. This section of the Journal, Review Notes, is the expression of continuously updating emerging topics concerning relationships between urban planning, mobility, and environment, through a collection of short scientific papers written by young researchers. The Review Notes are made of five parts. Each section examines a specific aspect of the broader information storage within the main interests of TeMA Journal. In particular, the Urban planning literature review section presents recent books and journals on selected topics and issues within the global scientific panorama.
For the first issue of TeMA Journal volume no. 17, this section provides a comprehensive overview of the challenges and solutions related to women's safety in urban areas, using a variety of scientific sources and practical resources to illustrate effective approaches and innovative strategies. This contribution aims to examine these challenges and the solutions proposed in the scientific literature, specifically in books, journals, and reports.

Keywords
Urban safety; Urban planning; Literature review; Women

How to cite an item in APA format
Stiuso, T. (2024). Exploring approaches and solutions for urban safety: a focus on women. *TeMA - Journal of Land Use, Mobility and Environment*, *17* (1), 179-186. http://dx.doi.org/10.6092/1970-9870/10778

1. Introduction

Today, 55% of the world's population lives in urban areas, equivalent to approximately 4.5 billion people. This percentage is expected to rise to 68% by 2050 (Rainmaking, 2020), generating opportunities for these territorial contexts but also enormous challenges in terms of social, environmental, and economic sustainability (Gaglione, 2023). Over half of the global urban population is composed of women (Ritchie & Roser, 2024), yet cities are not designed to meet their needs (Carpentieri et al., 2023). The built environment significantly impacts the quality of life of women; it can greatly limit their ability to move, be economically active, or simply enjoy the spaces in which they live (How Can Lighting Make Our Cities More Inclusive?, n.d.; Cardiracci, 2022). The women of diverse ages, gender identities, expressions, and socioeconomic conditions face numerous barriers and challenges throughout their lives in cities (UN-Habitat, 2021). Some of these stems from gender-based discrimination, resulting in higher levels of poverty, unemployment, unpaid care duties, difficulties in continuing education, experiences of violence and harassment, and ultimately exclusion or non-participation in decision-making processes in both public and private sectors. These issues are a global reality and are repeatedly highlighted by numerous studies and the media; it is enough to recall that according to an Engender analysis from 2022, women do not use outdoor public space as freely as men. So far, territorial governance has operated on the assumption of neutrality, but the historical and social context has inevitably led these strategies to have discriminatory or non-protective solutions for the most vulnerable members of society. The importance of designing with consideration for the diverse characteristics of users of urban spaces has been neglected; consequently, these spaces are not equally accessible to all, particularly to women. For example, since women are more likely to travel outside peak hours and since the infrastructure system is based on office hours, this makes them more dependent on low-frequency transport services (Cardiracci, 2022). Urban development undertaken within a framework of social inclusion involving all stakeholders and adopting approaches to participatory and inclusive urban planning provides approaches capable of ensuring walkability (Carra et al., 2022; D'Amico, 2023), sustainability, equality, and improvement of human rights (Andersdotter, 2021). On the other hand, it is important to emphasize that besides social and environmental factors, there are other factors to consider in an initial contextual analysis. In Italy, approximately 4,000 sexual assaults are reported each year. According to an ISTAT survey from 2015, six million 788 thousand women have experienced some form of physical or sexual violence in their lifetime, 31.5% of women between the ages of 16 and 70: 20.2% have experienced physical violence, 21% sexual violence, 5.4% more severe forms of sexual violence such as rape and attempted rape. Unfortunately, this number does not reflect reality; indeed, incidents of violence are much more numerous. In 88% of cases, women who have experienced sexual violence did not report it (the percentage rises to 95.6% if the perpetrator is Italian and drops to 75.3% if the perpetrator is foreign). Globally, it has emerged that in the United Kingdom, 97% of young women have experienced sexual harassment in public (UN Women, 2021); in Ireland, 55% of women feel unsafe traveling on public transport after dark (Cahill, 2020); in Brazil, 12% of transgender women have been attacked in public bathrooms (James et al., 2016).

2. Agreements and strategies developed at international level

Many authorities and global organizations are actively addressing the issue of gender inequalities within the context of sustainable development in urban settings. Across various locales, municipal administrations have crafted comprehensive blueprints aimed at fostering inclusivity and safety in urban landscapes (Sgambati & Stiuso, 2023), particularly ensuring women's security. In response to this imperative, extensive research and analysis has examined key agreements and methodologies formulated on a global scale to combat social inequalities, particularly in urban environments. These efforts emphasise a concerted effort to create equitable, safe and empowering urban environments that prioritise the well-being and dignity of all inhabitants, regardless of gender.

2.1 CEDAW (1979)

The CEDAW (Convention on the Elimination of all forms of Discrimination Against Women) is the most important legally binding international instrument regarding women's rights. The Convention outlines numerous measures to eliminate discrimination, and states that ratify the CEDAW commit not only to aligning their legislation with it, but also to eliminating any discrimination practiced by "individuals, entities, and organizations of any kind," as well as taking every appropriate measure to change discriminatory customary practices and traditions.

2.3 Sustainable Development Goals (2015)

In 2015, the United Nations promoted 17 goals for sustainable development, known as the Sustainable Development Goals (SDGs). These aim to safeguard the planet and the well-being of its inhabitants. They leverage a novel economic approach. The SDGs concerning gender equality and citizens' safety are three, specifically referring to their sub-goals:

- Goal 5: Achieve gender equality and empower all women:
  - Target 5c calls for adopting policies and legislation that promote gender equality;
- Goal 10: Reduce inequalities:
  - Target 10.3 is a sub-goal to ensure equal opportunities and reduce inequalities;
- Goal 11: Sustainable cities and communities:
  - Target 11.2 entails ensuring accessibility to transportation and safety on streets;
  - Target 11.7 aims to provide universal access to green and public spaces, making them accessible and safe for women, children, and the elderly.

For all sustainable development goals (SDGs), gender equality is both an enabling factor and an accelerator. Moreover, despite specifically addressing gender in the implementation of the 2030 Agenda for Sustainable Development, women's empowerment and gender equality are prerequisites underlying each of the 17 goals. Until we succeed in defending the rights of women and girls, we will never achieve justice and inclusion, as well as economies that work for all (Andersdotter, 2021).

2.4 New Urban Agenda (2016)

The New Urban Agenda (NUA) advocates for gender equality and the empowerment of all women and girls, emphasizing the need for a gender-sensitive approach in all aspects of sustainable urban development. The NUA also strategically supports the 2030 Agenda, ensuring that gender equality and women's empowerment are integrated into all social development goals. The NUA contributes to integrating a gender perspective into urban development and urbanization, recognizing women as important decision-makers and committing politically to addressing the specific gender challenges faced by women in urban settings (Andersdotter, 2021).

2.6 EU Gender Equality Strategy (2020-2025)

The Gender Equality Strategy 2022-2025 guides countries to accelerate advancements in gender equality and the empowerment of women over five years. It aims to surpass fragmented efforts and instead assist countries in decentralizing power and reforming economic, social, and political systems rooted in discrimination (EU Action for Equal Pay, 2021).

3. Best practices

To date, some countries around the world are developing and adopting solutions to enhance the safety and protection of women in their cities. However, it is crucial to focus on the outcomes and benefits these initiatives

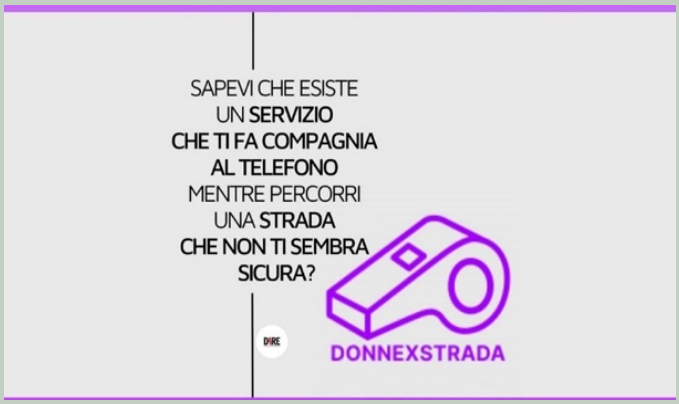
are yielding to support their implementation, even though most ongoing projects lack a set of Key Performance Indicators (KPIs), which are indicators that allow monitoring and quantifying successes or failures. For instance, it is essential to highlight how cities that consider aspects of women's safety and protection within urban transformation governance enhance women's experiences and mobility within spaces, thereby improving their mental and physical well-being (Pelliccelli, 2022). Improving lighting and pedestrian mobility and creating multifunctional and multigenerational spaces can make cities safer, more accessible, and livable for all (United Nations Development Programme, 2016). This also boosts economic activity and creates new opportunities to generate income. The main solutions involve creating safer streets and public spaces based on physical characteristics; integrating and considering gender diversity in urban system strategies and plans; and preventing violence through law enforcement and increased awareness campaigns. Indeed, many campaigns encourage victims to report harassment through user-friendly mobile apps and online platforms, such as the campaign launched in London, 'Report it, stop it!'. Other solutions that deserve detailed description are outlined below.

Wher – Mappe e città a misura di donna

'Wher' – is a safety reporting navigation app operated by Walk21 Foundation. Created in 2016 but actively on the market since January 2018, it is the first application that allows women to feel safer in unfamiliar cities by suggesting the best routes. It provides reviews on major Italian and European cities thanks to an all-female community. Once the app is downloaded, available for free on Google Android and iOS, users simply log in via their social networks. They input their mobility habits and select a city to start reading comments and descriptions posted by other women.

Each street is divided into three time frames (day, evening, and night), and already mapped streets are colored differently depending on the evaluation: green for safe areas, yellow for those to be traversed with caution, and magenta if they are best avoided. User judgments are based on perceived parameters such as lighting, crowd density, and personal feelings. The map also indicates useful services for women, such as public transport stops or pink parking spaces. To date, there are 20 mapped cities, including Turin, which was the starting city, Milan, Bologna, Rome, Palermo, Naples, and London (Lorenzini & Lorenzini, 2024).

Donnexstrada



Retrieved from: https://donnexstrada.org/

'Donnexstrada' is an Italian Association dedicated to addressing gender-based violence, particularly focusing on women's safety on the streets. Presently, the Association operates several services with the help of 80 volunteers and 100 professionals: "direttexstrada," which offers a 24-hour accompaniment service for individuals who feel unsafe on the streets, a counseling center providing specialized psychological support for women and gender-related issues, a platform for collecting testimonies to listen to and give voice to those who have experienced harassment, abuse, or negative experiences on the streets or elsewhere, and a legal consultancy service for victims of gender-based violence. Additionally, through the so-called "Punti Viola" (Purple

Points), the Association aims to establish safe spaces for women in various commercial establishments (such as bars, restaurants, pharmacies, nightclubs, hair salons, and beauty centers), where staff will be sensitized and trained. Currently, the Instagram page has 165,000 followers.

'Safe City and Safe Public Spaces Report'

Authors/Editors: UN Women
Publisher: Nuria Felipe Soria and Andere Nieva, in collaboration with Laura Capobianco and Lizzette Soria, UN Women
Publication year: 2021
Retrieved from: https://www.unwomen.org/sites/default/files/Headquarters/Attachments/Sections/Library/Publications/2021/Safe-Cities and-Safe-Public-Spaces-global-results-report-2017-2020-en.pdf

Women's Global Flagship Programme Initiative Safe Cities and Safe Public Spaces, supported by over 15 donors from public and private sectors, is helping to increase the number of cities and public settings that have safe and empowering spaces for women and girls. The Initiative currently spans 27 cities from developed and developing countries. It focuses on the development of locally-owned human rights and evidence-based initiatives ending violence against women and girls, and supporting women's political participation and economic empowerment. The inaugural global report presents results across the initiative's "champion" cities – from Cairo to Kigali, Winnipeg to Quito, and New Delhi to Sakai. It stresses the need for comprehensive laws and policies that prevent and respond to sexual violence in public spaces, and highlights some of the encouraging initiatives that are already yielding results. The Safer Cities program is investing $30 million over two years to help improve the perception of safety in our cities and countries, particularly for women, girls, and gender-diverse individuals. The program has three objectives, aligned with the UN's Safer Cities for Girls program:

- Enhancing the safety of women and girls and their access to public spaces.
- Allowing women and girls to move freely and independently within their communities.
- Increasing the involvement of women and girls in how the spaces around them are designed and managed.

The program engages women, girls, and gender-diverse individuals to understand their perspectives and co-design placed-based approaches to enhance the perception of safety while walking to, through, and within public spaces, including our streets.

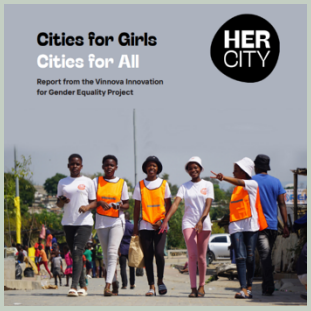
'Whose City? - An evaluation of urban safety for women in 10 countries' ActionAid 2017

Retrieved from: https://www.unwomen.org/sites/default/files/Headquarters/Attachments/Sections/Library/Publications/2021/Safe-Cities-and-Safe-Public-Spaces-global-results-report-2017-2020-en.pdf

The report "Whose City?", released by ActionAid, reveals that women in several countries, including Bangladesh, Brazil, the Democratic Republic of Congo (DRC), Jordan, Liberia, Nepal, Nigeria, Senegal, South Africa, and Zimbabwe, continue to experience high levels of violence, harassment, and intimidation. The study employs a scoring system to evaluate countries based on the prevalence of physical and sexual violence against women, the existence of national legal frameworks and plans to address gender-based violence, and the integration of gender perspectives in urban planning, particularly concerning public transportation design.
While the scorecard does not cover all aspects of women's safety in cities, such as public services beyond transportation, it provides a preliminary assessment of key issues and challenges. The aim is to assist governments in recognizing areas where they fall short and prioritizing actions to enhance urban safety for women. Despite government commitments to ending gender-based violence through various rights instruments, national legislation, policy frameworks, and gender equality mainstreaming structures, the report underscores that women still do not fully enjoy their right to the city. Overall, women across these countries remain vulnerable to violence, harassment, and intimidation.

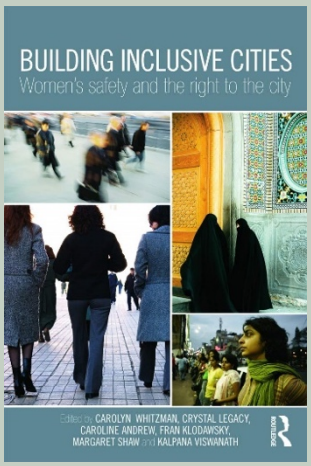
'Cities for Girls Cities for All - Report from the Vinnova Innovation for Gender Equality Project'
Her City – UN Habitat (2022)

Retrieved from: https://unhabitat.org/sites/default/files/2021/03/02032021_her_city_publication_low. pdf



'Her City' is a report published by UN-Habitat in collaboration with Vinnova Innovation for Gender Equality Project. The report focuses on promoting gender equality and inclusivity in urban environments. It likely includes research findings, case studies, and recommendations for creating cities that are safe, accessible, and accommodating for all residents, with a particular emphasis on the needs and experiences of women and girls. The report likely addresses issues such as transportation, urban planning, public spaces, and economic opportunities, aiming to inform policymakers and urban planners about the importance of gender-sensitive approaches in city development. Research shows that urban development, undertaken within a social inclusion framework involving all stakeholders and adopting inclusive urban planning approaches, provides the dynamics to deliver the pre-conditions for such shared urban prosperity: sustainability, equality, and improvements of human rights.

'Building Inclusive Cities: Women's Safety and the Right to the City' 1st Edition (Whitzman et al. 2013)



Editor: Carolyn Whitzman, Crystal Legacy, Caroline Andrew, Fran Klodawsky, Margaret Shaw, Kalpana Viswanath
Publisher: Routledge
Pubblication year: 2013
ISBN code: 978-0415628167

Expanding upon a growing movement across various regions, including Latin America, Africa, Asia-Pacific, Europe, and North America, this book explores advanced practices and constructs theories regarding a rights-based approach to ensuring women's safety amidst efforts for poverty reduction and social inclusion. Drawing from twenty years of research and grassroots initiatives focused on creating safer urban environments for women and all individuals, the book advocates for the right to inhabit an inclusive city.
The initial segment of the book outlines the myriad challenges women encounter concerning their access to vital services, housing stability, quality of life, and freedom of movement within urban spaces. In the subsequent section, the book critically evaluates initiatives, projects, and concepts that aim to enhance urban safety.
"Building Inclusive Cities" adopts a cross-cultural learning perspective derived from action-oriented research conducted worldwide. It then translates these findings into theoretical frameworks to enrich the discourse on urban planning and management, applicable to both developing and developed nations. Ultimately, the book seeks to stimulate both contemplation and tangible efforts towards creating more inclusive urban environments.

'STEPUP – Walkability for women in Milan'

Retrieved from: https://transformtransport.org/research/inclusive-mobility/step-up/

The research project "STEP UP - Walkability for Women in Milan," which was submitted under the call for proposals "INEQUALITIES RESEARCH - Generating new knowledge to reduce inequalities" and funded by Fondazione Cariplo (Grant No. 2022-1643), concentrates on evaluating the walkability level for women in Milan, specifically focusing on their perceived safety at night. Transform Transport led the coordination of STEP UP from March 2023 to the end of February 2024, in collaboration with TeMA Lab - Università degli Studi di Napoli Federico II, Sex and the City, and Walk21 Foundation.

The objective of STEP UP is to assess the walkability level for women in Milan, with a particular emphasis on factors influencing their perception of safety while walking (refer to Figure 2). Initially, a thorough review of relevant literature was conducted to gather insights from scientific studies and policy guidelines on the subject. The findings of this literature review were then utilized to develop two main lines of analysis: (a) conducting surveys and focus group discussions in specific neighborhoods of Milan to gather additional insights from residents and city users, validating the results of the literature review and extending upon them; and (b) performing a GIS mapping analysis to examine how these findings manifest spatially. For constructing the GIS model, the outputs of the literature review were utilized to select pertinent geolocated datasets, which were sourced, organized, and refined from open data repositories and geoportals. This process aimed to investigate the relationship between factors influencing the perception of safety and women's reported perceptions of safety. Data pertaining to women's reported perceptions of safety while walking were gathered through 'Wher' - a safety reporting navigation app operated by the Walk21 Foundation. Subsequently, this data was analyzed via GIS techniques to develop a multi-layered map of Milan, focusing on areas that could be improved based on the most significant safety factors identified through a spatial regression model.

'Digital Data in Support of Innovation for Urban Practice: Women-Inclusive Walkable Cities–Naples, a Case Study.' (Carpentieri et al., 2023)

The present study advocates for increased investment in both qualitative and quantitative analysis. It proposes the utilization of Geographic Information System (GIS) methodology to gather data directly from women in urban areas, alongside other freely available location-based data. This approach aims to generate analyses that can assist policymakers in formulating policies related to walkability in urban settings, with a specific focus on gender inclusivity in urban planning. The contribution outlines the initial outcomes of a novel and replicable methodology applied to urban planning in Naples, Italy.

References

ActionAid (2017) Whose city? In: ActionAid International. Retrieved April 4, 2024, from: https://actionaid.org/publications/2017/whose-city

Alvazzi del Frate, A., & van Kesteren, J. N. (2004). Criminal victimisation in urban Europe: Key findings of the 2000 International Crime Victims Survey. UNICRI.

Andersdotter Fabre, E., Julin, T., Lahoud, C., & Martinuzzi, C. (2021). Her City. A guide for cities to sustainable and inclusive urban planning and design together with girls. United Nations Human Settlements Programme (UN-Habitat), Kenya. https://unhabitat. org/sites/default/files/2021/03/02032021_her_city_publication_low. pdf.

Cahill, R. (2020). Travelling in a Woman's Shoes: Understanding Women's Travel Needs in Ireland to Inform the Future of Sustainable Transport Policy and Design. Transport Infrastructure Ireland. Retrieved April 4, 2024, from https://www. tii. ie/technical-services/research/TII-Travelling-in-a-Womans-Shoes-Report_Issue. pdf

Candiracci, S., Power, K., Batbayar, I., Chakraborty, R., Jones, J., Robinson, S., & Williams, R. (2022). Cities Alive: Designing Cities that Work for Women. Cities Alive, Arup, University of Liverpool

Carpentieri G., Guida C., Gorrini A., Messa F., Abdelfattah L., & Büttner B. (2023). Digital data to support urban planning processes to develop women safety cities: an application to the city of Naples. *TeMA - Journal of Land Use, Mobility and Environment*, *16*(3), 595-608. https://doi.org/10.6093/1970-9870/10272.

Carra, M., Rossetti, S., Tiboni, M., & Vetturi, D. (2022). Can Urban Regeneration improve Walkability? A space-time assessment for the Tintoretto area in Brescia. Transportation Research Procedia (Print), 60, 394–401. https://doi.org/10.1016/j.trpro.2021.12.051

D'Amico A. (2023). Urban spaces and pedestrian mobility: the role of urban design for enhancing walkability. *TeMA - Journal of Land Use, Mobility and Environment*, *16*(3), 639-644. https://doi.org/10.6093/1970-9870/10327

DONNEXSTRADA. (2024). DONNEXSTRADA. https://donnexstrada.org/

EU action for equal pay. (2021). European Commission. Retrieved April 4, 2024, from: https://commission.europa.eu/strategy-and-policy/policies/justice-and-fundamental-rights/gender-equality/equal-pay/eu-action-equal-pay_en#:~:text=The%20Commission%20therefore%20presented%20on,(3)%20of%20the%20TFEU

Gaglione, F. (2023). Urban planning and GeoAI in smart city policies. TeMA - Journal of Land Use, Mobility and Environment, 16 (3), 631-637. http://dx.doi.org/10.6092/1970-9870/10317

Gorrini, A., Presicce, D., Choubassi, R., & Sener, I. N. (2021). Assessing the level of walkability for women using GIS and location-based open data: the case of New York City. *Findings*. https://doi.org/10.32866/001c.30794

How can lighting make our cities more inclusive? (n.d.). Arup. Retrieved April 4, 2024, from https://www.arup.com/perspectives/how-can-lighting-make-our-cities-more-inclusive

James, S. E., Herman, J. L., Rankin, S., Keisling, M., Mottet, L., & Anafi, M. (2016). The Report of the 2015 U.S. Transgender Survey. Washington, DC: National Center for Transgender Equality.

Lorenzini, L., & Lorenzini, L. (2024). Wher, la app che rende le città a misura di donna. StartupItalia. https://startupitalia.eu/lifestyle/wher-la-app-che-rende-le-citta-a-misura-di-donna/

Pellicelli G., Rossetti S., Caselli B., & Zazzi M. (2022). Urban regeneration to enhance sustainable mobility. *TeMA - Journal of Land Use, Mobility and Environment*, 57-70. https://doi.org/10.6093/1970-9870/8646

Rainmaking. (2020). 55% of the world's population currently lives in urban areas - Rainmaking. Rainmaking - We Unleash the Power of Entrepreneurship to Solve Big Problems With the World's Leading Companies. https://rainmaking.io/article/55-of-the-worlds-population-currently-lives-in-urban-areas/

Ritchie, H., & Roser, M. (2024). Gender ratio. Our World in Data. https://ourworldindata.org/gender-ratio

Scarponi, L., Abdelfattah, L., Gorrini, A., Valenzuela Cortés, C., Carpentieri, G., Guida, C., ... & Choubassi, R. (2023). Thematic Review on Women's Perception of Safety While Walking in Public Space: The STEP UP Project. *Sustainability,* 15(21), 15636. https://doi.org/10.3390/su152115636

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

STEP UP – Walkability for Women in Milan - Transform Transport. (2024, February 14). *Transform Transport.* https://transformtransport.org/research/inclusive-mobility/step-up/

Töppel, M., & Reichel, C. (2021). Qualitative Methods and Hybrid Maps for Spatial Perception with an Example of Security Perception. *Urban Planning, 6* (1), 105–119. https://doi.org/10.17645/up.v6i1.3614

UN Women. (2021). Safe Cities and Safe Public Spaces GLOBAL RESULTS REPORT. Retrieved from: https://www.unwomen.org/sites/default/files/Headquarters/Attachments/Sections/Library/Publications/2017/Safe-Cities-and-Safe-Public-Spaces-Global-results-report-en.pdf

United Nations Development Programme. (2016). Sustainable Urbanization Strategy: UNDP's Support to Sustainable, Inclusive and Resilient Cities in the Developing World. Retrieved from: https://www.undp.org/sites/g/files/zskgke326/files/publications/UNDP_Urban-Strategy.pdf

Uteng, T. P., Singh, Y., & Lam, T. F. (2019). Safety and daily mobilities of urban women—Methodolgies to confront the policy of "invisibility." In Elsevier eBooks (pp. 187–202). https://doi.org/10.1016/b978-0-12-814818-1.00012-3

Whitzman, C., Legacy, C., & Andrew, C. (2013). Building inclusive cities: Women's Safety and the Right to the City.

Author's profile

Tonia Stiuso

She is an engineer and research fellow at the Department of Civil, Building and Environmental Engineering at the University of Naples Federico II. Her research currently focuses on the theme of urban sustainability, in particular the study of gender inequalities and adaptation to climate change.