TeMA

Journal of Land Use, Mobility and Environment

The climatic, social, economic and health phenomena that have increasingly affected our cities in recent years require the identification and implementation of adaptation actions to improve the resilience of urban systems. The three issues of the 16th volume will collect articles concerning the challenges that the complexity of the phenomena in progress imposes on cities through the adoption of mitigation measures and the commitment to transforming cities into resilient and competitive urban systems.

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. From 2015, the articles published on TeMA are included in the Core Collection of Web of Science. It is included in Sparc Europe Seal of Open Access Journals, and the Directory of Open Access Journals.

THE CITY CHALLENGES AND EXTERNAL AGENTS. METHODS, TOOLS AND BEST PRACTICES

Vol.16 n.1 April 2023

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

TeMA Journal of
Land Use, Mobility and Environment

THE CITY CHALLENGES AND EXTERNAL AGENTS. METHODS, TOOLS AND BEST PRACTICES

1 (2023)

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 | on line 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, Architectural and Environmental Engineering
University of Naples "Federico II"
Piazzale Tecchio, 80
80125 Naples
web: www.tema.unina.it
e-mail: redazione.tema@unina.it

The cover image shows the building of Kharkiv National University of Civil Engineering and Architecture, destroyed as a result of a missile and bomb attack. March 2022 (Source: STRINGER/Reuters/Forum. https://www.pism.pl/publications/sweden-on-the-russian-aggression-against-ukraine)

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. From 2015, the articles published on TeMA are included in the Core Collection of Web of Science. TeMA Journal has also received the *Sparc Europe Seal* for Open Access Journals released by *Scholarly Publishing and Academic Resources Coalition* (SPARC Europe) and the *Directory of Open Access Journals* (DOAJ). 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.

TeMA Journal of Land Use, Mobility and Environment

THE CITY CHALLENGES AND EXTERNAL AGENTS. METHODS, TOOLS AND BEST PRACTICES

1 (2023)

Contents

REVIEW NOTES

EDITORIAL PREFACE: TEMA JOURNAL OF LAND USE MOBILITY AND ENVIRONMENT

The city challenges and external agents. Methods, tools and best practices 1 (2023)

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

The relentless march of time has become the real enemy of our cities hit by unexpected (?) and environmental, economic, and social events necessitating prompt and, most importantly, effective action to mitigate the impacts caused by associated factors such as global warming, migration, conflict, famine, and others - with cities being especially vulnerable.

In this issue, TeMA journal, for the first time, includes a scientific article addressing the topic of war. This article titled "Urban space at the time of the war. Configuration and visual image of Kharkiv (Ukraine)" by Valerio Cutini (University of Pisa, Italy), Mykhaylo Averbakh, Oksana Demydiuk (Kharkiv National University, Ukraine) considers the changes in the surrounding artificially created environment under the influence of the tragic circumstances of the Russian military invasion in Ukraine and the peculiarities in the perception of the urban environment, resulting from the interaction between it and the people.

Three months after the publication of the last issue of TeMA journal (30th December 2022), we would like to repropose the appeal contained in the editorial: *"TeMA journal, since 2007, has supported the global exchange of academic knowledge and that Editorial decisions have never been affected by the origins of the manuscript, including the nationality, ethnicity, race, or religion of the authors. Thus, for the sake of knowledge and to improve understanding, cooperation, and relationship, our position is to continue considering papers for publication from worldwide authors and institutions. Our established editorial policies, of peer review and declaration of competing interests, will guarantee to avoid publication of inappropriate or propaganda contents".*

In the same way, we feel the need to underline that the complexity of the ongoing phenomena imposes on cities involves not only adopting mitigation measures aimed at reducing the adverse effects of these phenomena; this challenge requires scholars, researchers, technicians, and decision-makers to transform cities into resilient, competitive urban systems rapidly. The three issues of the 16th volume collect articles concerning the climatic, social, economic and health phenomena that have increasingly affected our cities in recent years and, hence, require the identification and implementation of adaptation actions to improve the resilience of urban systems.

For this issue, the section "Focus" contains four contributions. The issue of the first article is explained before. The second article, titled "The City Challenges and the New Frontiers of Urban Planning. Digital Twins as Tools of Urban Resilience: Research and Practices" by Gabriella Pultrone (University of Reggio Calabria, Italy), addresses the potential of new technologies, yet to be adequately explored in the fields of planning and design at different territorial scales, for better governance, sustainable development and quality habitats. It consists of three main sections, consistent with the methodology and the main steps of the ongoing research to which it refers.

The third article, titled "Nature-based solution for climate change adaptation and mitigation in urban areas with high natural risk. Proposals of possible measures for a municipality in the Vesuvius area" by Giuseppe Mazzeo (ISMed-CNR, Italy) e Salvatore Polverino (University of Genova, Italy), offers an analysis of the main NBSs applicable in an urban context and on different scales (from urban to building) and an applicative example related to their integration into territorial governance tools. In particular, the municipality of Cercola, a territorial context with a high natural risk in the Vesuvian area, has been analysed as a case study.

The last article of the section, titled "Social aspects in small ports tourism sustainability. Planning small ports and marinas through the lens of tourism and sustainability" by Alessandro Bove and Elena Mazzola (University of Pavia, Italy), focuses on small ports and marinas and investigates the real situation about services offered and the related possible tourism satisfaction for sustainable socio-cultural development. The paper has collected data from people connected to Italian and Croatian docks and analysed it with statistical methods and georeferenced maps.

The section "LUME" (Land Use, Mobility and Environment) contains seven contributions. The first is titled "Identifying spatial variation in the values of urban green at the city level. A case study in Thessaloniki, Greece" by Antonia Giannakidou and Dionysis Latinopoulos (Aristotle University of Thessaloniki, Greece), attempts to examine if the proximity to green spaces has a fixed/homogenous effect on residential property values across the city. A global regression analysis was first applied to explore which structural, locational and green/environmental characteristics likely have a statistically significant effect on housing prices.

The second article of the section, titled "Public perceptions of barriers to walk in urban areas: walkability insights from Lahore, Pakistan" by Muhammad Ahsan, Nabeel Shakeel and Farrukh Baig (University of Management and Technology Lahore, Pakistan), examines the public's perception of barriers to walking in Lahore, Pakistan. Surveys were conducted online using structured questionnaires. A valid sample of 277 responses was analysed using a weighted factor and regression analysis to investigate pedestrians' perceptions of walking constraints.

The third contribution, titled "Soil de-sealing for cities' adaptation to climate change. Planning of priority interventions in urban public space", by Marianna Ceci, Barbara Caselli, Michele Zazzi (University of Parma, Italy). The paper aims to outline a methodological approach, supported by GIS technology, to map in detail urban public soils and identify priority areas to be depaved. In particular, the method assesses the permeability of public land concerning hydraulic and heat island hazard exposure of potentially vulnerable urban systems.

The fourth article, titled "Usability and Accessibility of Urban Service Areas with Increasing Epidemics: The case of Bursa/Turkey. The Effect of Urban Service Areas on the Quality of Life in the Post-Pandemic Period" by Elvan Ender Altay and Diba Şenay (Bursa Uludag University, Türkiye), deepens the concept of urban life quality. It comes to the fore with urbanisation, and it is directly related to the quality, quantity, and sufficiency of the urban service areas of the cities. In the paper, cultural and open spaces and green areas in the central district of Bursa are classified and evaluated within the scope of pre- and post-pandemic conditions. Solution suggestions were developed to increase the quality of life.

The fifth paper, titled "Applying Delphi Method to Develop Sustainable City Indexes a case study of Chiang Mai, Thailand" by Wiwat Pongruengkiat, Korrakot Y. Tippayawong, Pruk Aggarangsi, Preda Pichayapan, Tossapon Katongtung and Nakorn Tippayawong (Chiang Mai University, Thailand), develops appropriate indicators for assessing the sustainability of Chiang Mai city using the Delphi method of panel surveys. At least 20 experts in various fields were selected for the Delphi surveys conducted in three rounds.

The sixth article, titled "The small smart city: renewable energy sources in the little town of Italy" by Romano Fistola (University of Naples Federico II, Italy), Federica Gaglione, Ida Zingariello (University of Sannio, Italy), deals with the topic of energy. The scientific community has concentrated its studies on optimisation models to support the energy organisation of territorial contexts and on identifying optimal strategies within complex management systems such as urban systems. Wind energy is a valid option to improve economic conditions and reduce the environmental impact. The work is inspired by a scientific-technical consultancy aimed at assisting the technical office of the municipality of Biccari (FG) in defining the guidelines for the General Urban Plan.

The last paper of the section, "Investigating the socio-spatial logic of historic urban areas through space syntax" by Chiara Garau, Alfonso Annunziata, Claudia Yamu (Oslo Metropolitan University, Norway), Dario D'Orlando, Marco Giuman (University of Cagliari, Italy), aims to address a gap in the existing literature by developing a method to analyse the configuration of historical urban sites to understand the social and cultural antecedents of the transformation and development of urban areas in the Roman era. The study builds on

Space Syntax theories and techniques to develop an analytical protocol that combines syntactical analysis and statistical analysis to measure and compare spatial, visual and social relationships in four urban Roman sites in the Mediterranean.

The Review Notes section proposes four insights on the themes of the TeMA Journal. The first section, "Urban Planning Literature", by Carmen Guida and Valerio Martinelli, is dedicated to books highlighting the role of new technologies in managing good-quality energy data, which is essential to support reliable decision-makers in reducing energy consumption in urban environments.

The second contribution, "Policies and practices of transition towards climate-neutral and smart cities", by Federica Gaglione, examines how current challenges, from climate change to energy consumption in urban areas, can find a valid foundation in adopting a "smart". In particular, the review focuses on the objectives of the smart city within the Europe 2020 strategy and the climate-neutral & smart cities mission. The third section, "European cities and e-scooters at the crossroad", by Gennaro Angiello, analyses the complex relationships between European cities and electric scooters and reports on the case study of Paris where, in a recent non-binding referendum, Parisians opted overwhelmingly to ban e-scooters in the French capital. The fourth contribution, "Circular economy in urban areas: evidence from global cities", by Stefano Franco, aims to address the issue of circular economy in urban contexts by describing theoretical approaches and identifying best practices from cities worldwide. Finally, "The interventions of the Italian Recovery and Resilience Plan: digitalisation in cities", by Sabrina Sgambati and Tonia Stiuso, deals with the topic of digitalisation in urban areas within the framework of the Italian National Recovery and Resilience Plan. It provides an overview of the proposed reforms, strategies and interventions to boost the digital economy and digitalise public services within the urban context.

TeMA Journal of Land Use, Mobility and Environment

Call for papers 2023

TeMA vol.16 (2023)

The climatic, social, economic, health and resources changes, that are increasingly challenging our cities, require the identification and implementation of strategies to increase the liveability, competitiveness and sustainable performance of urban systems and adaptation actions aimed at improving their resilience. Humanity's success in addressing such phenomena will be largely determined by what happens in cities. At the same time, the challenge that the complexity of the transformations and transitions in progress imposes on cities requires scholars, researchers, technicians and decision makers to rapidly commit to transforming cities into resilient, competitive urban systems and promoting sustainable communities. New technologies can support the innovation process towards multidisciplinary solutions to the above-mentioned challenges. For instance, big data, remote sensing offer unprecedented opportunities to know and interpret urban systems and their complexity. Thus, it is of primary importance to rethink the theories and methodologies underlying urban planning practice.

With these premises, TeMA Journal welcomes interdisciplinary work, with theoretical, methodological and empirical approaches concerning the following topics:

- Accessibility to urban services and places;
- Multidimensional resilience of cities to limit the impacts of climate change;
- Transitions to renewable resources and energy saving in cities;
- Definitions of planning tools, methods and techniques aimed at promoting city adaptation to current and foreseeable social, economic, innovation and energy transitions;
- Requalification of urban environments;
- Increasing urban competitiveness through sustainable and resilient solutions;
- Adaptation of urban systems to external (temporary and permanent) agents.

TeMA Journal of Land Use, Mobility and Environment

TeMA 1 (2023) 7-26
print ISSN 1970-9889, e-ISSN 1970-9870
DOI: 10.6093/1970-9870/9912
Received 8th March 2023, Accepted 20th March 2023, Available online 30th April 2023

www.tema.unina.it

Urban space at the time of the war. Configuration and visual image of Kharkiv (Ukraine)

Valerio Cutini [a]*, Mykhaylo Averbakh [b], Oksana Demydiuk [c]

[a] University of Pisa, Pisa, Italy
e-mail: valerio.cutini@ing.unipi.it
ORCID: https://orcid.org/0000-0003-4065-6226
* Corresponding author

[b] Kharkiv National University of Civil Engineering and Architecture, Kharkiv, Ukraine
e-mail: mikhailaverbakh1960@gmail.com
ORCID: https://orcid.org/0000-0001-6085-4145

[c] Kharkiv National University of Civil Engineering and Architecture, Kharkiv, Ukraine
e-mail: ok.demydyuk@gmail.com
ORCID: https://orcid.org/0000-0001-5787-5156

Abstract
This paper is devoted to consider the changes in the surrounding artificially created environment under the influence of the tragic circumstances of the Russian military invasion in Ukraine and the peculiarities in the perception of the urban environment, resulting from the interaction between it and the people.
The war has changed the usual visual image of Ukrainian cities: many cities suffer from shelling, many objects of architectural and cultural value have been destroyed. The ruins of Mariupol, Kharkiv, Mykolaiv, Izium will represent the new view of these cities for a long time, as a reminder of the terrible events and suffering of individuals and communities. A lot of visual-informational forms have appeared, accompanying on the mental, content and emotional levels the resistance of Ukrainians.
Visual forms capturing the destruction of streets and houses, household activities, suffering and pain of residents are shown focusing on the case study of Kharkiv, whose inner geography is considered within a configurational framework. The article, written under the storm that is still ravaging Ukraine, also displays a variety of "pictures" of people's living in the Kharkiv metro, whose intended use is transformed into a shelter. Fragments and knowledge elements that ought to be recollected and put together while discussing strategies and choices for reconstructing Kharkiv when the weapons are finally laid down.

Keywords
City image; Configuration analysis; Visual perception; Metro station; Bomb shelter; Destruction; Reconstruction.

How to cite item in APA format
Cutini, V., Averbakh, M. & Demydiuk, O. (2023). Urban space at the time of the war. Configuration and visual image of Kharkiv (Ukraine). *Tema. Journal of Land Use, Mobility and Environment*, *16* (1), 7-26. http://dx.doi.org/10.6093/1970-9870/9912

1. Introduction

The purpose of this paper is twofold. On the one side, it aims at reflecting on the genesis of the configurational state of Kharkiv throughout its modern development, briefly discussing the way the morphologic pattern of the urban grid matches and reproduces the inner geography and the socio-spatial logic of the settlement, as observed in the different phases of its growth as well as in its present form: so as to comprehend the context where the current war events are currently taking place. On the other hand, and in the light of this overall picture, the paper is devoted to consider the changes in the surrounding artificially created environment under the influence of the tragic circumstances of the Russian military invasion in Ukraine and the peculiarities in the perception of the urban environment, resulting from the interaction between it and the people.

The two issues are closely linked by the conceptual framework of space syntax, that assumes a city as a socio-spatial mechanism aimed at favouring social interaction in space:

"*Space syntax is built on two formal ideas (…) The first is that we should think of space not as the background to human activity, as we think of it as the background to objects, but as an intrinsic aspect of everything human beings do. (…) The second idea is that human space is not just about the properties of individual spaces, but about the inter-relations between the many spaces that make up the spatial layout of a building or a city*" (Hillier & Vaughan, 2007).

It is the assumption of a city as a socio-spatial system that suggested to analyse spatial grids using methods, computational tools and parameters that had long been used in social network analysis, and that sociologists had borrowed from graphs theory and network analysis when a relational mode of thought was introduced into social studies. And it is precisely the integration and complementarity of spatial and social issues in urban systems what allows observing in Kharkiv the social effects of war destructions on spatial perception and individual and collective behaviour.

It should also be observed that in a configurational view the spatial grid of a settlement, primary element of the phenomena that occur along the paths, was acknowledged (Rabino & Cutini, 2012; Cutini, 2022) as the material depository of its urban resilience, intended as its capacity to sustain perturbations, disruptions and local alterations under disasters or unpredictable events: and hardly there are disruptions more devastating and unpredictable that those caused by war and missiles.

Some cautions are needed, to be preliminary underlined in the current circumstances, so very difficult and sensitive. A first caution is practical and patently obvious: given the sensitive nature of the topics, no detailed information on the local situations and spatial circumstances of places affected by the current war events will here be provided. All the mentioned spatial references are taken from historic sources, or extracted from open access data, freely available in the web.

Another issue is the unavoidable temporariness of findings and observations. Today, at the very moment of writing these contribute, under the war that is still ravaging Ukraine, it is not possible to know the forthcoming events and when the weapons will be laid down, putting a definite end to the traumatic transformation of urban space, perception and behaviours. At this time of uncertainty, we can only detect and discuss aspects that cannot but be marked by temporariness and transience, as well as destined to be overtaken by unforeseeable events. Nevertheless, precisely in this time of war it appears important to give witness to the current spatial and social devastations while they are underway.

A further caution is more general, and far less obvious: it is out of the purpose of this paper to grasp for some correlation between tragic war events and configurational issues, what would not be allowed by the available information and, even if possible, would be unacceptably disrespectful to individuals and communities suffering from such a tragedy. On the contrary, it is aimed at opening a window to discreetly observe perceptions and behaviours within the devastated urban environment of Kharkiv, sketching fragments that ought to be recollected and put together, once this tragedy is finally all over.

2. The city of Kharkiv and its configuration

Grief and destructions seem to be written in the destiny of Kharkiv, as the city - like other cities of Sloboda Ukraine, such as Sumy, Akhtyrka, Ostroh - was founded in the XVII century as a fortress, built in a troubled period of disorder and conflicts due to persisting clashes between Cossacks, Crimean Tatars and the Polish–Lithuanian Commonwealth.

The fortress was built on the slopes of the hills that converge on the confluence of the rivers Kharkiv and Lopan, where the original urban area was enclosed within the triangular perimeter of the town-walls, roughly corresponding to the outline composed of the present Kvitky-Osnovianenka Street, Maidan Konstytutsii (Constitution Square), Pavlivsky Maidan, Serhiivskyi Maidan and Bursatskyi Uzviz. In the nineteenth century the first growth direction was addressed northward by the location of the new government centre, corresponding to the junction of the two radial roadways reaching the fortress, Klochkivska (from north-west) and Sumska (from north-east), imprinting on the growing settlement the pronounced Y pattern that for decades was to characterize the spatial development of the northern part of Kharkiv.

A strong impetus for urban growth was given early in the nineteenth century, when Kharkiv, under a process of intense industrialization, was appointed – from December 1919 to January 1934 - as the first capital of the Ukranian Soviet Socialist Republic, position that enhanced the pivot spatial role of the government centre, central node in Viktor Trotsenko's masterplan: here the government centre (hinging on what was later named Dzerzhynskyi Square and presently Freedom Square ('Maidan Svobody' in Ukrainian)) is shaped as a composition of two open spaces, a circular plaza and a rectangular square, geometrically arranged so as to enclose what at the time was claimed to be, with its 11.5 hectares, the largest open space in Europe. Five radial streets were drawn departing from the centre of the circular plaza, crossing Derzhprom architectural complex (see Fig.7) and addressing the external radial development of the city according to the overall urban scheme that was worked out by I. F. Voitkevych in 1924 (Hewryk, 1992).

In the years preceding the II world war the strong population growth and the housing problem were tackled by the construction of massive residential neighborhoods so as to make Kharkiv a living laboratory for proposing new housing and spatial patterns for the socialist city: the garden city concept, with mass low-rise housing construction, was initially implemented, soon replaced by the house-commune pattern and residential combines typologies (Didenko et al., 2016). The neighborhoods were located all around the inner core, along the streets departing from the original fortress site, so as to give rise to a powerful model of radiocentric growth.

In the Twenties and Thirties, the development of Kharkiv was under the influence of utopian ideas formed within the Soviet system, and revolved around reconstruction of the way of life, cultivation of the new socialist education, and improvement of cultural and consumer services. These ideas made a great impact on architectural and urban planning activity. The industrial district "New Kharkiv" and the new administrative center "Kharkiv-City" are city-forming structures that were innovative and soon became integral parts of the 20th century urban heritage (Shpara, 1967).

The post-war decades, with the increasing growth of the population up to the present 1,400,000 inhabitants, further fostered the scattering of neighborhoods in the suburban territory, located all over the wide area included within the highways ring-road, with a particularly high density in its north-eastern and south-eastern parts, along the present Akademika Pavlova Street and Heroes of Kharkiv Avenue (Heroiv Kharkova Avenue).

This is obviously not the place to enter the wide debate on Soviet urbanism or discussing the contribute that on such regard may arise from Kharkiv. A comprehensive overview on urban development and planning of Kharkiv in 1950s-1970s is provided by Alforov (1972) and Liubarskyi (1960), while the urban planning of Kharkiv residential areas is described by Tiulpa (1964). More in general, the volume "Soviet modernism, brutalism, post-modernism: buildings and structures in Ukraine 1955–1991" presents a comprehensive study of post-war Soviet architecture and a key for understanding the historical and political context of the

multifaceted modernist architectural movement in Ukraine (Gubkina, 2019), while an overview of the Kharkiv architectural heritage can be found in a collective monograph by Shkodovskyi et al. (2002).

The recent post-Soviet years are characterized by unsystematic urban growth, with the progressive saturation of the urban spaces left unused in the previous general plans, gradually bought out by investors and built up, mostly with commercial massive activities.

As a key for interpreting the genesis of Kharkiv spatial layout a configurational approach will be assumed, using the theoretical concepts and the analysis tools that, under the name of Space Syntax, were introduced at the end of the twentieth century by Bill Hillier (1984, 1996). The approach is based on the fundamental role of the urban grid as a primary element in the making of the phenomena occurring along its paths, in particular the distribution of movement flows and the location of economic activities. In order to appraise such role, several indices were introduced, depending on the topologic relationships between the spatial elements that form the grid (Hillier, 1996).

By means of these relations, the configurational state of the system – as well as the configurational value of each of its elements - can be defined (Hillier, Hanson, 1984) through the use of several selected indices, namely the connectivity value, the choice value and the integration value. We call these parameters configurational, meaning that they do not refer to the intrinsic features of a spatial element, but depend on the relations mutually connecting it to all the elements in the rest of the system. The connectivity value measures the number of elements directly connected with the observed one, the choice value measures the frequency an element is on the shortest paths connecting all the other couples of elements, and the integration value measures the mean depth of an element with respect to all the other elements in the system. Those three parameters are suitable for reproducing different kinds of centrality: connectivity reproduces the capability of an element to work as a hub, focal point of local connections, choice reproduces the capability of an element to work as an intermediate location, intercepting through movements, and integration, by far the most important configurational parameter, reproduces the capability of an element to work as a terminal, easily accessible from any other place in the settlement (Cutini, 2001).

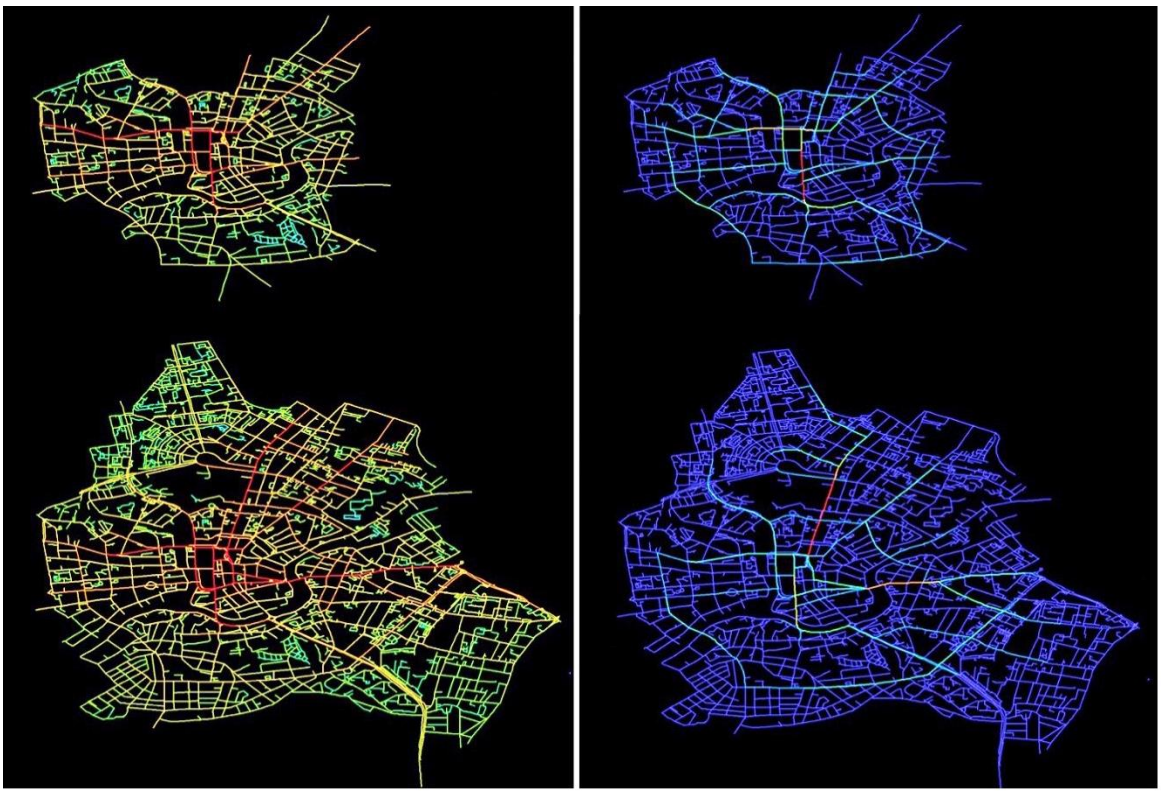


Fig.1 Global integration (left) and choice (right) values in the segment map of Kharkiv, at the end of nineteenth century (top) and in the '30s (below)

In order to analyse a grid configuration, several operational techniques have been so far introduced, distinguishing from one another for the different way to reduce the spatial grid into a system. In order to diachronically analyse the configuration of Kharkiv the so-called Angular Segment Analysis will here be used, "one of the most fundamental analyses in space syntax practice that helps understand movement, land-use and other socio-economic patterns" (Kolovou et al., 2017, p. 1); the system to analyse is the segment map of Kharkiv at different times, composed of the segments that result from the intersection of the lines of its axial map, that is the longest and fewest lines suitable for connecting all the spaces of the urban grid (Turner, 2000).

The angular segment analysis of Kharkiv was then carried out considering a sequence of five systems, corresponding to the urban grid at significant historical phases: the end of nineteenth century, the beginning of the '30s, the end of the '70s, the end of the twentieth century and the current date. The main results, referred to the centrality indices of integration and choice, are summarized in Figg.1-3.

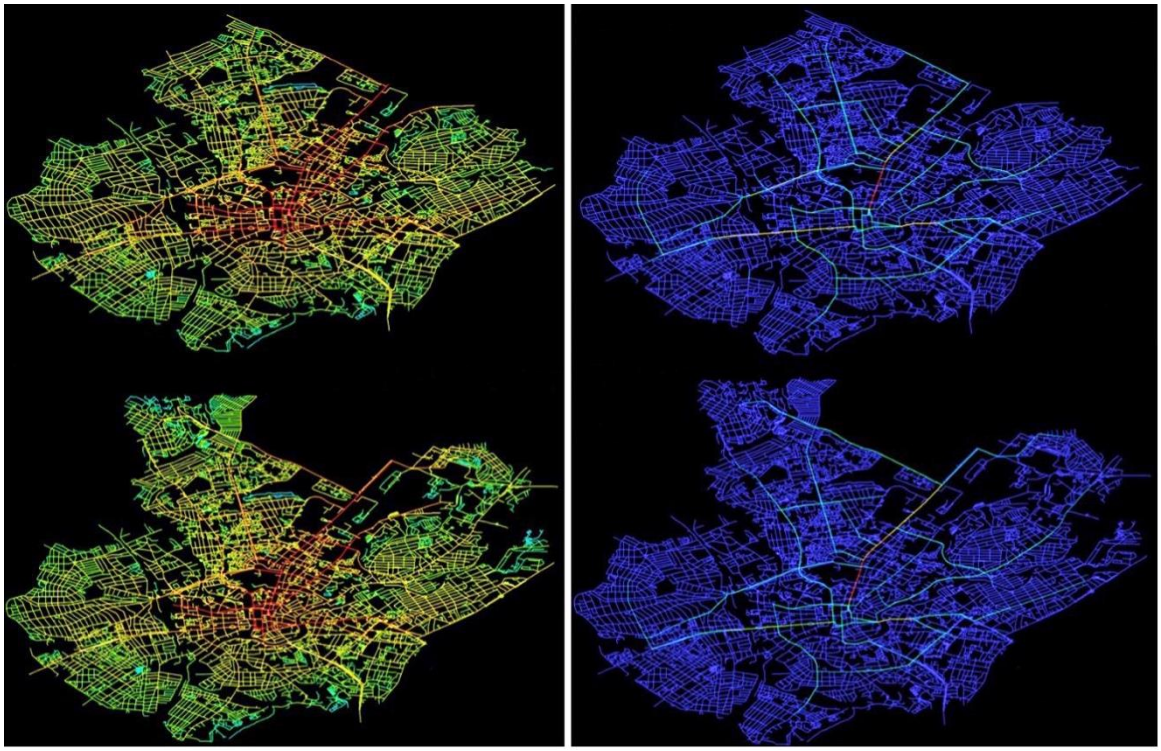


Fig.2 Global integration (left) and choice (right) values in the segment map of Kharkiv, in the '70s (top) and in the '90s (below)

Several information can be easily drawn out of these results. First, the layouts in Fig.1 (top left) point out the original integration core of the grid, clearly located within the meander of the river Kharkiv close to the confluence of Lopan. The bridges that respectively cross the two rivers also correspond (Fig.1, top right) to the two segments with highest choice values, pointing out them as the basic elements in the distribution of movement flows all over the inner core of the settlement. The two maps below show the effects of the first urban growth in the early 20th century, with the making of the northbound Y pattern centred in the government centre and the arising Sumska as a strong integrator (Fig.1, bottom left) as well as provided with the highest choice value (Fig.1, bottom right), what highlights it as the arising axis in the modern development of the city.

The images in Fig.2 represent the configurational effects of the growth of Kharkiv in the twentieth century, that can be summarized in a shifting of centrality heading north-east and in a clockwise rotation of its backbone axis, which appears completed in the current configurational state (Fig.3): here the integration core of the whole grid is oriented towards east, and the highest centrality levels pertain to the two radial axes of

Akademika Pavlova Street and Heroiv Kharkova Avenue and to the north-eastern sections of the highways ring road surrounding Kharkiv.

Figg. 2 and 3 allow to detect the making of the skeleton of the distribution of movement flows, characterized by the main roads radiating from the inner core of the settlement, provided with particularly high values of choice in their eastern sections. Indeed, it is a recurrent configurational pattern, that typically characterizes the cities that have experienced a similar mode of growth: as it was shown with reference to other contexts (Cutini, 2016; Cutini et al., 2020), a radial development around a compact inner core is likely to determine a strong polarization effect, with the radial arteries and the outer ring roads gaining the highest choice values all over the grid, at the expense of all the minor roads structuring the urban fabric.

In addition, it is also interesting to observe in Fig.4 the configurational features of the residential neighborhoods that were built in the course of the twentieth century, scattered all over the grid and highlighted by the attribution of remarkable values of local integration.

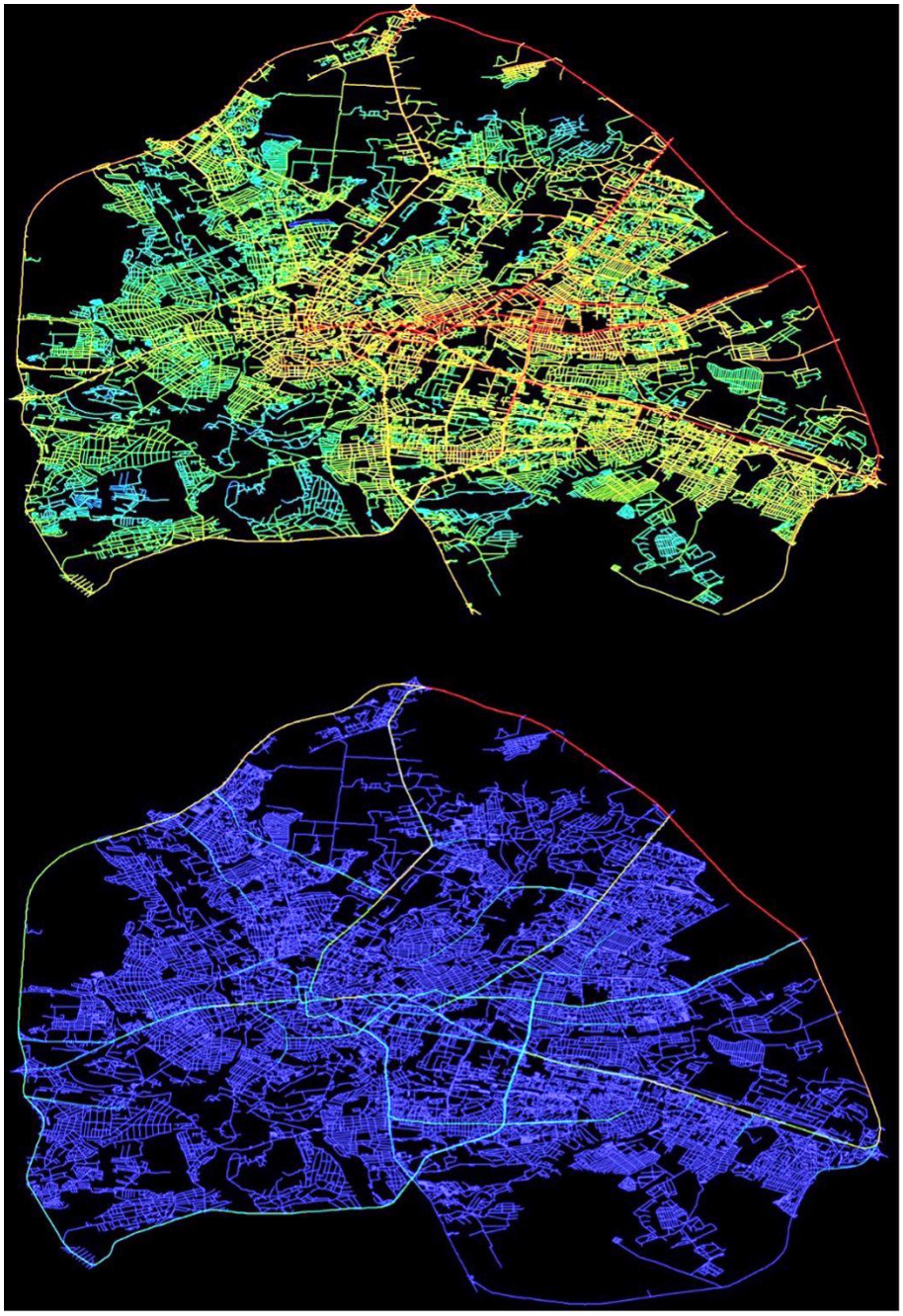


Fig.3 Global integration (top) and choice (below) values in the present segment map of Kharkiv

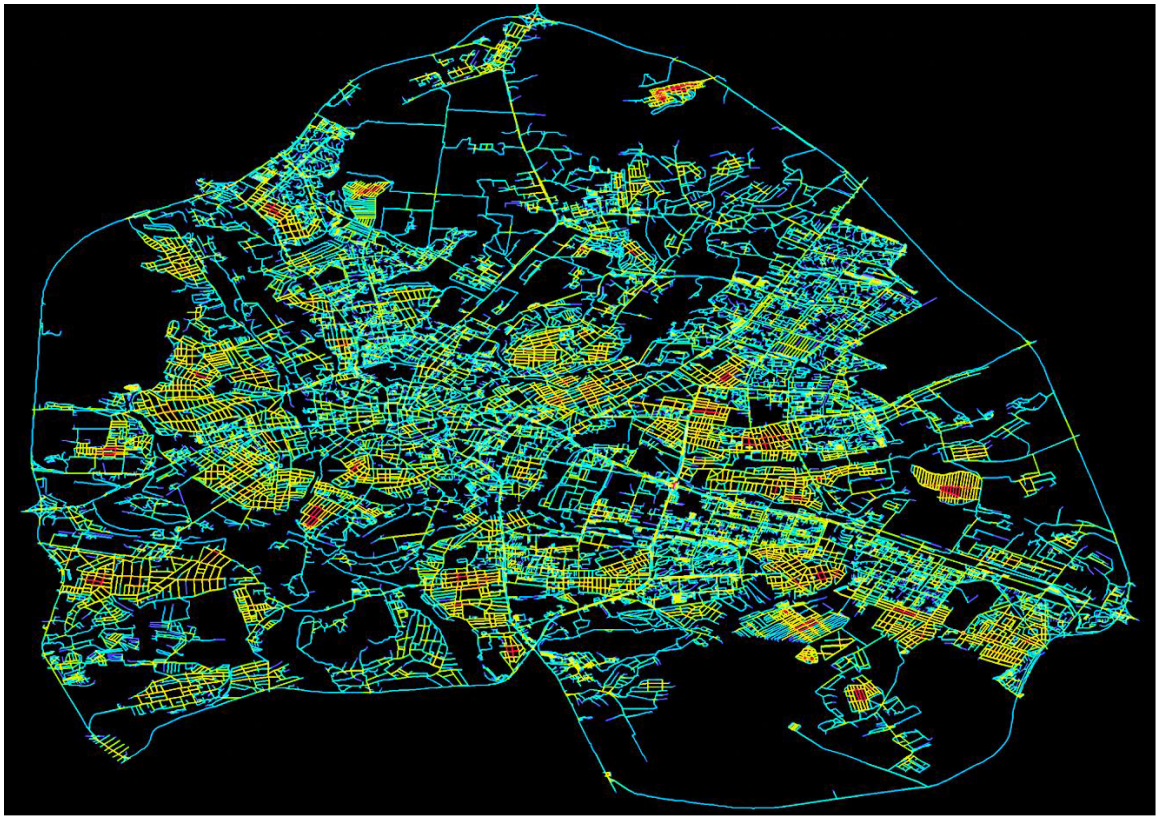


Fig.4 Local integration values in the segment map of Kharkiv

3. At the time of the war

At dawn on February 24, 2022, explosions were fired in many cities of Ukraine. Russia launched missile and air strikes on radars and air defense missile systems, air bases, ammunition depots of Army Field Forces brigades. Kharkiv is the city from which the Russia's full-scale war in Ukraine began, when the first explosions thundered there around five in the morning.

According to the Mayor of the city, during the six months of the war, as a result of shelling, more than 4 thousand residential buildings, 110 schools, more than 100 kindergartens, more than 50 healthcare institutions and hundreds of other administrative and non-residential buildings have been destroyed to various extents. A number of universities are among them, in particular those that train specialists in the field of civil engineering and architecture. Also, the invader purposefully destroys the energy supply system, transport and engineering infrastructure facilities (Mayor's Office, 2022).

The very first hours of the war radically transformed the image of a peaceful, colourful, cheerful city.

To protect against fragments, windows of the above-ground floors were scotch taped, as if they were crossed out, and windows of semi-basement floors and basements were covered with sandbags for protection. A few days later, as a result of bombing and missile attacks, many window openings were left gaping with ominous holes, and some of them were covered with hastily boarded-up plywood.

The city statues were protected with the same bags. The monument to Taras Shevchenko, the outstanding Ukrainian poet, writer, artist and thinker, one of the main national symbols of Ukraine, a multifaceted sculptural composition in the style of socialist realism with elements of the Stalinist empire style and art deco, a monument that was created in the '30s, when Kharkiv was the capital of Soviet Ukraine and is the most known monument to Shevchenko, was enclosed within a special structure with a protective net.

In Khakiv and elsewhere, the image of monuments, the main symbols of cities (Kyiv, Odesa, Dnipro, Zaporizhzhia, etc.), covered with sandbags for protection, is becoming a common, branded artistic technique for posters and patriotic leaflets.

Fig.5 The building of Kharkiv National University of Civil Engineering and Architecture, destroyed as a result of a missile and bomb attack. March 2022
(Source: STRINGER/Reuters/Forum. https://www.pism.pl/publications/sweden-on-the-russian-aggression-against-ukraine)

All over the city, signs of bomb shelters and protective constructions appeared on walls of buildings. Concrete block barriers were erected at many points along major highways and access roads to slow down passways and to control traffic, as well as checkpoints, structures for protection and the ability to fire. Road signs in all directions were dismantled or pasted all over in order to make wayfinding difficult to the invading army. But billboards and all kinds of posters with patriotic content appeared, they were addressed to defenders and residents, and, conversely, with reproaches and curses towards invaders.

Anton Gerashchenko, advisor to the Ukraine's Minister of Internal Affairs, made an appeal to owners of outdoor advertising objects (billboards, light boxes, advertising structures on walls of buildings) to place the appropriate inscriptions on their own, without any approval, without embarrassment in expressions.

The most common were signs explicitly addressed to the Russian troops. The most popular destination is the meme expression "Russian warship, go fuck yourself" from the defenders of Snake Island.

On other billboards, Ukrainians offer the occupiers to leave their lands, disobeying orders: "Russian soldier, stop! How will you be able to look your kids in the eyes? Go away! Stay human", "Russian soldiers are not welcome here. Instead of flowers, bullets are waiting for you. Go away, return to your family", "Ivan, has your mother already known that you are killing Ukrainians?", "Putin lost. The whole world stands with Ukraine". Most messages to Russian soldiers in Ukraine were urging them to leave "without blood on your hands" etc.

War has changed the face of the city. Photo and video reports on the life of cities, tourist posters, advertising banners on websites, in addition to architectural sights and natural landscapes, always show their inhabitants (laughing, joyfully walking or skipping, or lying on green grass, or inhaling the smell of flowers, squinting in the sun, breathing aroma of coffee).

Now the faces, captured by photojournalists, have become grim visaged, gloomy, tired, showing pain, horror, despair. People fuss, hurry, carry belongings in their backpacks and in their hands, drag children behind them. Silent queues stretched to those shops and pharmacies that were not closed. The fear of being under shelling has not yet appeared and strengthened, and people do not scatter even under the sounds of shell explosions rumbling in the distance.

A view of city streets packed with cars, slowly flowing and stretching towards the exit out of the city, should be added to these shots. As it was shown above, Kharkiv has a radial planning structure with elements of a ring structure. From the very first days, the city was caught in a semicircle of encircling.

The northern (Oleksiivka, Piatykhatky), north-eastern and eastern (Saltivka, the largest residential district of the country, with population as Mariupol, about half a million), southeastern (industrial territories, districts of Kharkiv Tractor Plant and Rogan residential area) radial roads were under the control of advancing troops. There was only one free evacuation vector – the western one, the direction to Poltava – Kremenchuk – Kropyvnytskyi – Vinnytsia and further to the western Ukraine or abroad to Poland, Slovakia, Hungary. This radial road corresponds to the Poltavskyi Shliakh highway, on which all streets and avenues merge and converge. Behind the city exit, other cars try to join this stream, moving from two sides along the external ring road.

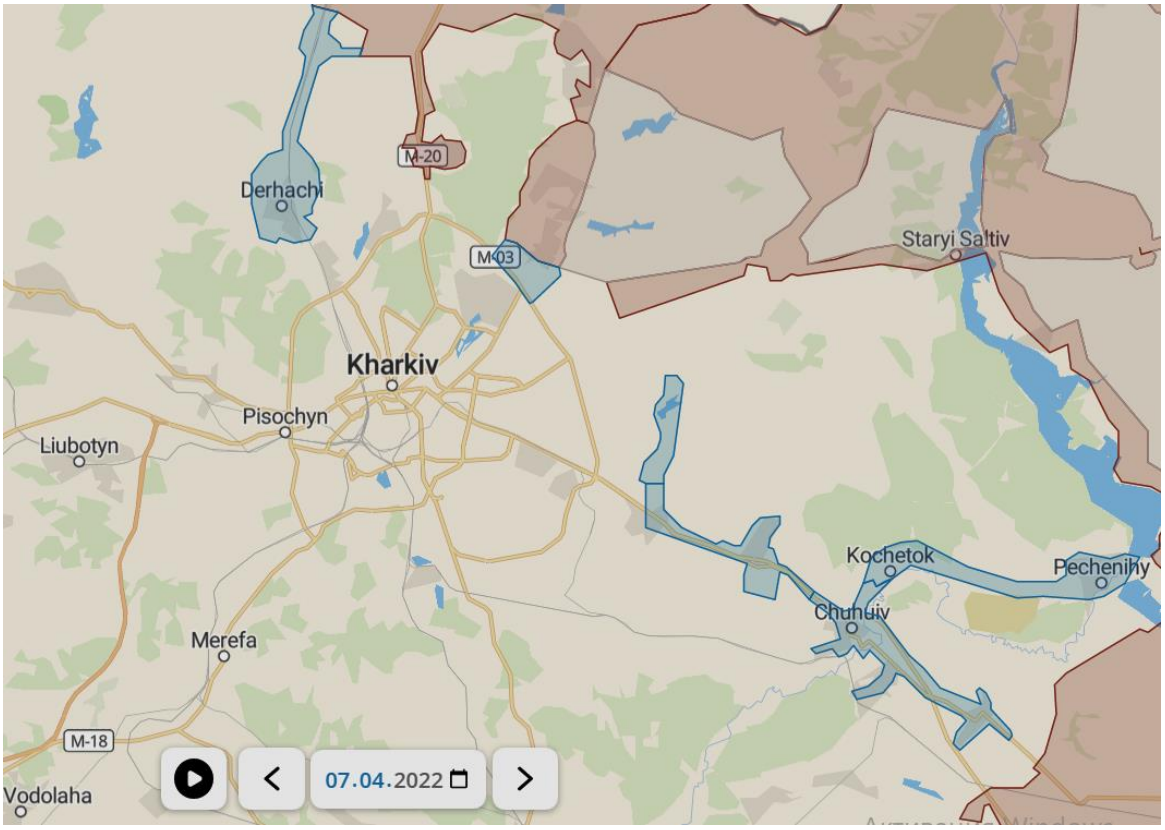


Fig.6 Map of the Kharkiv encirclement by Russian troops at 07/04/2022 (Source: https://deepstatemap.live/en#9.75/49.9346/36.1983)

The evacuation of Kharkiv and the region inhabitants had an unprecedented, never before experienced scale. Some data: in 2020 the population of the Kharkiv region was 2.6 million people. Since then, almost half of the inhabitants were forced to leave because of the war: at September 2022, 672 thousand people left the Kharkiv region abandoning their destroyed dwelling or the combat zone, while almost 300 thousand people left their homes, still remaining in the region.

From 7,000 to 8,000 people are registered as migrants every week in the Kharkiv region; only in Kharkiv more than 150 thousand residents lost their homes.

Many people were evacuated from the northern part of the Kharkiv region, which was substantially destroyed by the occupiers (Kharkiv Today, 2022). Property damages affecting only multi-storey buildings are estimated 103 billion hryvnias.

In order to consider the scope and effects of war destructions on the inner geography of Kharkiv, it can be interesting to compare (Fig.7) the distribution of global integration values all over its grid (suitable for

reproducing the levels of urban centrality) with a building damage assessment based on satellite imagery collected on June 15th, 2022.

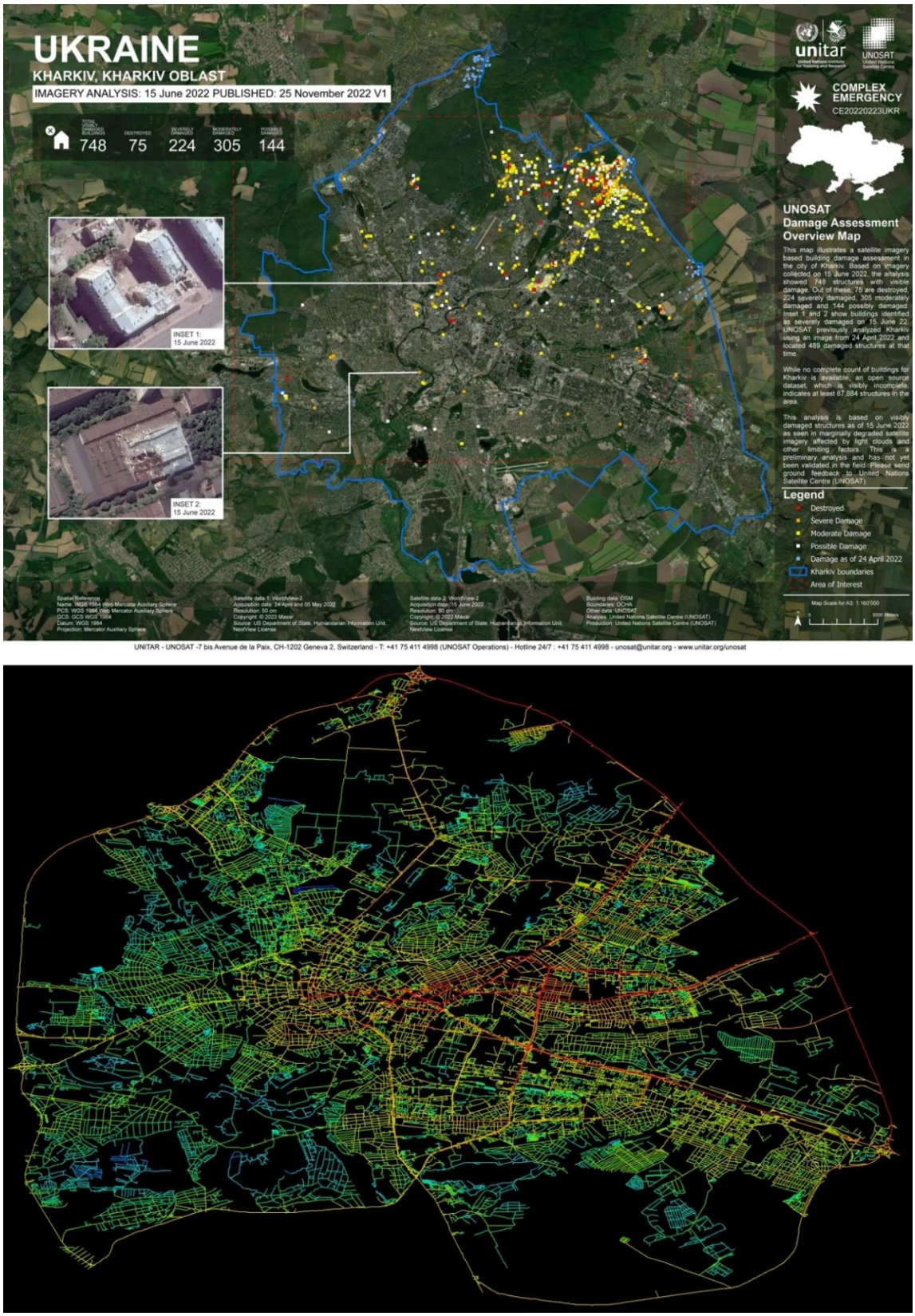


Fig.7 Satellite imagery, at June 15th 2022[1], based building war damage assessment (above) and global integration values

[1] Source: https://reliefweb.int/updates?view=maps

The image, published by Reliefweb, a service provided by the United Nations Office for the Coordination of Humanitarian Affairs, shows 748 structures visibly damaged in the city of Kharkiv (Reliefweb, 2022).
It is noticeable in Fig.7 that the location of a large proportion of the damaged structures (at June 15th, 2022) corresponds to some of the most integrated segments all over the grid, both in the inner core and in the outskirts, in particular the north-eastern, along Akademika Pavlova Street, where high values of urban attractiveness stand for a remarkable concentration of economic activities and interaction places.
If this correspondence is anything but surprising, since major economic activities are usually targeted objectives of any war bombing, yet researches so far (Cutini, 2013) attest the heavy effects of disruptions on the whole settlement when they affect its integration core.
It is also to be pointed out that the radial structure of the city, described and discussed above, actually represents a vulnerability element in the global system configuration, due to the marked polarization in the distribution of movement flows, channelled into a limited number of spatial elements, as reproduced by the distribution of choice values and confirmed by the high value of the frequency index (Cutini, 2013).
The few segments that are provided with the highest choice values (namely, as it was said, the main arteries radiating from the inner core and the outer ring road) (Fig.3), represent Achilles' heels of the settlement, as their disruption could easily determine the breaking of the system (Rabino & Cutini, 2012).
Even if the issue of massive war damage sadly runs throughout millennia of history, from Chartago and Jerusalem to Mosul, as it was to be expected the current tragic events have recently drawn the attention of the scientific debate on the issues regarding the matter post-war planning of destroyed cities (Alvanides, Ludwig, 2023), mostly based on the re-interpretation of the reconstruction processes after World War II (Knauer, 2023; Szczepańska, 2023; West, 2023) and discussing the legacies of planning decisions on the social and urban fabric of today's cities.
Moreover, even before the present war space syntax methods and techniques have been used to analyse spatial dynamics in case of war events (Wang et al., 2019); and the above reflections on the poor network resilience of the whole grid of Kharkiv should be taken into account when considering the effects of war destruction on the working of the settlement.
Furthermore, the role of configuration and visual image in the interpretation of the urban landscape in post-war reconstruction was acknowledged and discussed (Czarnecki, Chodorowski, 2021), showing a decrease in the number of spatial elements of the urban grid as a frequent result of post-war reconstructions, actually impoverishing the imageability of the city and the complexity of its whole configurational state: all the more reason to give very careful consideration to visual and configurational issues while discussing strategies and choices for reconstructing Kharkiv when the war comes to an end.
In fact, it has to be said that, as early as in the first months of the war, Ukrainian architects in close cooperation with the team of Norman Foster started discussing the Kharkiv masterplan in a context of post-war reconstruction, so as to seize the chance for a fundamental revision of the entire urban structure of the city.

4. The image of Kharkiv through the eyes of students

The findings resulting from the configuration analysis ought to be complemented by the exploration of the perceived vision of urban space. Lynch's (1960) concepts of imageability and readability, the idea of the relevance of how people see and interpret the city, create their own image of it, their own mental maps, through the elements and signs of the urban landscape on the behaviour within it, as well as Robert Venturi's reflections (Venturi et al., 1972) on the importance of signs and symbols in sensing the urban landscape suggest to consider the effects of the change in the perception of the physical elements of the city (signs, posts, lighting, parks, stores etc.). And the eyes of students provide a prominent point of view on Kharkiv.
Pre-war Kharkiv was in fact considered the "student capital" of Ukraine: 69 higher educational establishments of various forms of ownership and accreditation levels, including 17 universities and 9 academies, trained

specialists in Kharkiv. The specializations of universities are very different: from technical to agricultural, from military to creative, from medical to economic. Three Nobel laureates lived and worked in Kharkiv. More than 160,000 students, including about 12,000 foreign students, have studied (and are studying now, but remotely) at the universities of Kharkiv (Kharkiv City Council, 2021).

In 2020, a survey was conducted among students of the Historical and Philological Faculties and the Faculty of Mathematics and Information of V.N. Karazin Kharkiv National University within the framework of the inter-university project for the exploration and rethinking of the symbolic space of several key cities in eastern and southern Ukraine including Kharkiv "CityFace: Practices of the Self-Representation of Multinational Cities in the Industrial and Post-Industrial Era". Respondents' answers made it possible to identify the architectural dominants, attractive places and locations of the urban space, which, according to students' opinion, are significant for the city. The survey materials show the peculiarities of interaction / mutual influence of residents and urban space. The results interpretation was based on the lifestyle concept of the French sociologist P. Bourdieu (Bourdieu, 1998) and the lifestyles theory of the German historian M. Dinges (Dinges, 2000).

Without any doubt, the students' perception of the city is influenced by their daily route through the urban space: their housing - university buildings (educational buildings, laboratories, the Central Scientific Library, a sports complex, etc.) - places of recreation in the city (parks, food services areas, cultural and educational institutions or cultural and entertainment centres) - place of work / another option - their own housing. In fact, this route determines that for the vast majority of the interviewed students (more than 83%) Kharkiv is the "centre", first of all. Among the mentioned objects that characterize the city, such buildings as Derzhprom (House of State Industry), V. N. Karazin Kharkiv National University and Kharkiv National Academic Opera and Ballet Theatre named after M. V. Lysenko, the "Mirror Stream" fountain, Maxim Gorky Central Park of Culture and Leisure, and Freedom Square are of high priority. An interesting fact is that young people do not pay much attention to the historic and cultural objects, which were chosen in the contest «Seven Wonders of Kharkiv» in July 2008 (Kharkiv guide, 2008), primarily religious buildings - the Pokrovsky and Annunciation Cathedrals, the Cathedral of the Assumption of the Blessed Virgin Mary. Students are more unanimous in choosing a monument - the "face" of Kharkiv. In particular, more than 120 respondents give preference to the monument to the Ukrainian Kobzar Taras Shevchenko in the City Garden.

Fig.8 Derzhprom (House of State Industry), the first Soviet skyscraper, built in 1925-1928, the main architectural landmark of Kharkiv (Source: Photo by Vasily Golosny)

It should be noted that a number of other buildings and architectural monuments of Kharkiv, mostly (but not only) located in its central part, making up the "postcard" representations of the city, as traditionally placed in photo albums and guidebooks, remain unnoticed or not understood: among them, for instance, the building of the Mechnikov Institute of Microbiology and Immunology of the early twentieth century, which is one of the most striking buildings in the neoclassical style of the most eminent Kharkiv architect Oleksii Beketov, or the building of Kharkiv State Academic Puppet Theatre named after V. A. Afanasiev in the Art Nouveau style, also designed by O. Beketov, as well as the Centre for Science and Technology and the Kharkiv State Automobile Transport College. All those three buildings are located in one row in the historical part of Kharkiv, on the central and the oldest square of the city - the Constitution square. The two last-named buildings were badly damaged during the war of 1941-1945, and now they are again with broken windows.

The students did not mention the architectural monuments of other famous Kharkiv architects of the beginning of the last century - Volodymyr Pokrovskyi and Viktor Velychko (a residential building in the Art Nouveau style with elements of English Gothic), Oleksandr Ginzburg (a residential building on Pushkinska Street and a commercial apartment building on Sumska Street, both in the Art Nouveau style, or one of the first modernist buildings in the city on the same street). It is surprising that, in the survey, students have ignored the Commercial and Manufactory building in the constructive modernist style of Oleksandr Rzhepishevskyi and Oleksandr Ginzburg, to say nothing of the constructivist era monuments of the 1930s such as the Central Post Office (architect Arkadii Mordvinov), and the Palace of Culture for the Railway Workers (architect Oleksandr Dmitriev) (in August 2022, this building was almost completely destroyed by a missile that directly hit it). Generally speaking, it is understandable, because students of architectural faculties didn't participate in the survey.

It can be considered as the important observation that in the minds of its inhabitants, Kharkiv was not a "border" city. In any case, the survey results showed that this fact was not perceived as its main characteristic (Krasko, 2020).

During the war, the same team of professors and students from V. N. Karazin Kharkiv National University, Kharkiv State Academy of Culture, Kharkiv National Medical University and other Ukrainian higher educational institutions has launched a project "City and War: Destruction, Preservation and Rethinking of the Urban Cultural Heritage of Large Cities in Eastern and Southern Ukraine within the Russia's Military Aggression". The project "City and War" focuses on the issues of preservation, investigation, and mediatization of various urban cultural heritage (tangible heritage - architectural monuments, urban area development, industrial heritage, monuments, memorials, landmarks, as well as museum, archival, and library objects; intangible heritage - urban celebrations, festivals, customs, urban language, street painting, cuisine, etc.), transformations of collective cultural memory and interpretation of cultural heritage by urban communities as well.

Tangible sites and intangible cultural values belonging to the cultural heritage of large cities in eastern and southern Ukraine are in the limelight of the project. As a complex, they create a unique historical and cultural urban landscape, which is embodied and at the same time influences the formation of cultural values and the collective identity of the urban communities (CityFace, 2022).

Among the specified topics of research, which is based mainly on the survey of respondents among student youth, are the following: "Mechanisms for creating a mental image of the city", "Self-representation of Kharkiv in coins, stamps and envelopes", "Reflection of the history of Kharkiv in guide books, religious images of Kharkiv", "Consumer goods in the symbolic space of the city", "Visual image of the city in the industrial and post-industrial era", "The Influence of Street Art on a City's Image".

5. A new image of the Kharkiv metro as a reflection of its new functions

Many objects have changed their usual functions out of necessity. The most illustrative change of the nominal function, formation and solution of new urgent tasks, brought by time, and, as a result, the change in the

perception of the visual and mental image of the urban space, can be traced on the example of the Kharkiv metro. This is understandable, since the underground is the safest place for citizens to stay. The Kharkiv metro is the fourth largest metro in the former USSR states. It is the second by the number of stations (30) and the length of the lines (39.3 km) in Ukraine after Kyiv.

From the first hours of the war, all metro stations have been transformed into shelters. Hundreds of people, fleeing the shelling, settled down inside the stations, on platforms, in lobbies and in train carriages. On February 24 at 15:00, trains of the Kharkiv metro were stopped to accommodate as many people as possible. Initially, the city dwellers went down into the subway to wait out the bombing, over time, the bulk of the people remained. As it turned out later, they remained for a long time. These are those who are fleeing the shelling, those who are forced to leave their homes and those whose homes have been destroyed. People organized their life: put up tents, arranged sleeping places. Metro workers equipped fountains with drinking water on the platforms and installed electric kettles.

Most live on mattresses on the small patches of platform space they have staked as theirs, beside their most treasured belongings and pets. Many on the platform are transfixed by their phones, their only contact with the outside world, other than a few minutes above ground each day for fresh air and some quiet, until it's punctured by the heart-stopping roars of shelling. The lucky few live in tiny tents for privacy or inside the subway cars, where blankets hang as walls from railings, which double as drying racks for clothes (Rubinsztein-Dunlop, 2022).

The director of Caritas-Spes reports on her visit to one of Kharkiv metro stations: "An underground network of train carriages and tunnels where people sleep, cook, study and where babies continue to be born despite the bombs. The metro station is a city within a city for a lot of people. The entire metro system has become a shelter housing approximately 60 to 70 people per station. The person in charge is responsible, among other things, for keeping a register of arrivals and departures so as to avoid overcrowding or vacancies. Once inside, we find a kitchen to our right. A form is displayed indicating the shifts and the number of people entitled to eat breakfast, lunch and dinner. A first-aid station on the left offers medical advice and medication. The trains – which once brought residents back and forth between the city – are no longer running. Each carriage has three entrances and a room has been created in each compartment for each family or group" (Biagioni, 2022).

TV reporters, photographers, bloggers began to fill the media space with video materials, where they recorded how people live, sleep, cook and eat, give birth, get sick and recover, play with children, walk dogs, how teachers try to engage schoolchildren and pre-schoolers in their studies and keep them busy as far as possible under the current conditions. The visual image of the underground life of Ukraine's second-largest city was supplemented by pictures of a hairdressing and nail salon organized in the centre of the railway platform. Some reports give publicity to the work of volunteers performing a wide range of medical services: from cold symptoms treatment and dressings, bandages for the wounded and injured inhabitants during shelling of residential buildings to managing pregnancy and the coronavirus busting. Since the beginning of the Russian invasion, more than 100,000 Kharkiv residents live or have lived in the metro. Many of them have been living underground for several months, they experience panic attacks when undertaking attempts to go outside. Traumatized, some still refuse to leave these tunnels, which have been transformed into cavernous cities.

To ensure the vital activity of underground residents, the metro staff from the first days of the war remained at their posts to maintain technical units of the station in good order. This includes electricity, technical water, toilet facilities and so on. In addition, subway workers guided refugees through tunnels between stations to evacuate city residents to safer places. The Department of Civil Protection of Kharkiv Regional Military Administration, together with the Main Directorate of the State Emergency Service in the Kharkiv region, took actions to inform and educate the population regarding the necessary measures and rules of conduct under shelling. They were told how to behave correctly during shellfire, how to distinguish "outgoing", "incoming" strikes, and what to do in such situations, and how to provide first aid.

Fig.9 Fleeing shelling people live in the metro. Kharkiv, Heroiv Pratsi Station (meaning: Heroes of Labor), March 2022 (Source: https://www.reuters.com/world/kharkiv-metro-is-city-where-hundreds-shelter-bombardment-2022-03-11/)

The subway is the safest disaster shelter during bombing and even nuclear strikes. The Kharkiv metro, like many subways in the USSR, was built as a dual-use facility - both as a transport facility and as a shelter for civil protection of the population. Therefore, its entire infrastructure is intended for civil defence in case of armed hostilities. Consequently, the metro infrastructure is maintained in good condition in peacetime. Exercises are held on a scheduled basis for employees of the metro and related services. Therefore, the subway was ready to perform this function. However, before the war, the concept of organizing the stay of population in the shelter was somewhat different. It was considered that modern military operations are conducted differently than during the Second World War or other large-scale military operations of the past. They are more targeted, mass bombing with striking the civilian population is almost nowhere used. So all shelters were designed for temporary staying there for 1-2 hours with a capacity of 1-1.5 square meters per person.

In Soviet times, there was the concept of a bomb shelter. However, in accordance with the Legislation of Ukraine "Code of Civil Protection of Ukraine", such a concept didn't exist. As amended and supplemented in 2022, there are civil protection facilities, i.e. engineering facilities designed to protect people against exposure to hazard resulting in emergency, military operation or terrorist attack (shelters, antiradiation shelters, prefabricated civil protection structures), dual-use structures and simple design structures which can also be used to protect people against some hazards arising from an emergency in peacetime and munition impact during the special period. A dual-use structure is defined as a land or underground structure that can be used for its primary function and people protection (Verkhovna Rada of Ukraine, 2022).

On February 23, 2022, the day before the beginning of the invasion, Kharkiv Mayor Ihor Terekhov assured that, according to the regulatory standards, 154,000 people would be able to take shelter in the Kharkiv metro if necessary. All systems and conditions were prepared there: a ventilation system, an air supply system, food, medical care, water, both technical and drinking. All regulations and all requirements were absolutely met (Terekhov, 2022).

However, the doctrine of the civil protection did not assume the massive destruction of residential areas and, consequently, the constant stay of a large number of people in the metro space for a long time. Moreover, all conventions, regulations and customs of modern war did not let expect the bombing of civilian buildings, residential areas, cultural sites, places of people concentration such as shopping centres, train stations, markets. Furthermore, on June 20, after four months of the war, the depot building was destroyed as a result of a ballistic missile strike on the infrastructure of the Kharkiv metro. The roof was damaged, walls were partially destroyed, the explosion smashed in windows and several train carriages were also damaged.

According to Maslow's pyramid, the physiological needs are the most important, as they include those that are vital for survival. If physiological needs (e.g. air, water, food, shelter, clothing) are not satisfied the human body cannot function optimally. At the second level of Maslow's hierarchy, the needs for security and safety become primary. The long stay made it necessary to meet more complex needs of higher levels in the hierarchy. Educational classes were provided for schoolchildren daily at the metro stations "Students'ka" (meaning: Students' station), "Akademika Pavlova" (meaning: Academician Pavlov station) and "Zakhysnykiv Ukrainy" (meaning: Defenders of Ukraine station). A team of caring teachers was organized who volunteered to conduct classes in the metro.

To brighten up the joyless days of the war for the underground temporary residents, various activities were often organized there. Within the framework of the "Funk The Police" project, children from the Kharkiv metro were taught breakdance. The initiators of the idea, who for more than 20 years, together with the police, have been dealing with the problems of children in difficult life circumstances, tried to return children to normal life through dancing.

There were also other cultural and entertainment programs for underground residents. Artists of Kharkiv Academic Theater of Musical Comedy performed at different metro stations with concerts. Puppets and poetry also went underground to entertain Ukrainians sheltering in the Kharkiv metro. They exchanged emotions and it lifted their spirits. The children had the possibility to play with the puppets (Stenson, 2022).

Fig.10 Station "Istorychnyi Muzei" (meaning: Historical Museum) of the Kharkiv metro. Children's drawings are printed on top of advertising posters (Source: Photo by Mykhaylo Averbakh, August 2022)

An exhibition of art works created by children and teenagers with the support of a teacher from the Kharkiv art studio took place at the "Istorychnyi Muzei" metro station. Over the period of two weeks, young artists were reflecting on the topic of modern superheroes. They were drawing, cutting out paper figures, painting. As a result, four monumental sculptures of a Warrior, a Medical professional, a Volunteer and a Mother with Children appeared. Classes for children were initiated by the Aza Nizi Maza art studio with the "Together. Meeting Points" project, which was created by the non-governmental organization "Professional Development of Kharkiv" with support from UNICEF Ukraine. According to the founder of the art studio Mykola Kolomiitsev, the project about modern superheroes is an act of gratitude to all those who hold on and defend Ukraine.

Drawing is the most common activity for children in the underground city. Kharkiv Mayor Ihor Terekhov said that when he was at the first wedding in the subway, he noticed many children's drawings. "Children live there, and they draw their family, their car, their house, mom and dad with holding hands. After the war, I will display these huge children's drawings in place of advertising in the metro," said Terekhov (Terekhov, 2022).

The advertising in the Kharkiv metro mentioned by the Mayor was investigated by the authors of this article some time ago. The research was carried out in the context of the problem of contamination of the city's visual environment by the dominance of outdoor advertising (Averbakh, Demydiuk, 2017). Advertising in the city, being an integral attribute of the modern economy, and therefore practically not subject to regulation, distorts the architectural intent, violates the visual harmony created by authors-architects, artists, designers, based on verified compositional solutions, colour and light combinations, plasticity, architectural forms, careful selection of finishing materials and decor. Intrusive advertising, which claims to become almost the main factor in creating the visual environment of the modern city, has also penetrated underground. Substantially all free surfaces and spaces of the Kharkiv metro were sold for advertising. Everything is used, where a passenger is located: entrance lobbies, passages, stations, underground rolling stock outside and inside.

Successful underground spaces should be multifunctional, with well-planned and safe spaces for the public, but there is again a little bit more to it than that. Art and culture should also be included within underground spaces (Besner, 2017).

We can only hope that the post-war restoration of Kharkiv, whenever it may be, will give impetus to reconceptualize or develop a new concept for the making of the city's spatial environment, including the subway.

6. Conclusions

Each city has a spatial configuration, that keeps the keys for understanding its intimate raison d'être and its working as a socio-spatial mechanism for social encounter and interaction. And a city contains places, where people live and interact; the places that the war is massively destroying in Ukrainian cities. But "places are not local things. They are moments in large-scale things, the large-scale things we call cities. We cannot make places without understanding cities" (Hillier, 1996, p. 112).

Each city has its own face, its own image. This image is a mosaic, a combination of those sensations and visualizations that are formed by its inhabitants, guests of the city, and even those who have never been in it, but know something about it. For people temporarily residing in the city, these are mainly experiences that are associated with the places of stay (work, study, recreation, excursions, travels). For city-dwellers, these visualizations are more stable, because the accumulated impressions from childhood, myths and stories are added to them.

In the era of globalization, digitalization, informatization, virtualization and other "zations", any stories are brought into world on the web-pages, telemedia screens and social network channels. This is the place where the face, the image of the city is formed. The most attractive plots, facts, stories are published, and if we talk about the visual imagery, then these are camera angles, perspectives, plans, panoramas, fragments, details, and so on.

Since the beginning of the war, the city and its places were devastated. All mass media and social networks began to post pictures of destroyed buildings, broken military equipment, military heroes and captured invaders, people crushed by the war, bloodied, homeless and sitting in shelters. The pictures were reprinted, multiplied and dispersed by information channels around the world, imprinting to millions of people an overwhelming visual image of a wounded and bleeding city. The destroyed buildings of the Kharkiv region state administration, the V.N. Karazin Kharkiv National University and the "Palace of Labor", North Saltivka,

the largest residential district in the city, which has been turned into ruins, have become for the whole world a symbol of the horrors of war, suffering, deprivations, but also resistance to violence.

The image of a fighting city is formed not only by the chronicles of hostilities, shots of destruction, stories about the life of citizens living in the subway. It is complemented by people of creativity - artists, graphic artists, poster artists. They create their own cultural battlefront, expressing their attitude to what is happening in a visual form.

Architects, designers, urbanists create concepts for the future city, offer options for reconstruction, renovation, revival. Professionals and not only express their vision of the prospects for the restoration of Kharkiv. It is clear that the problems are much deeper, not only regarding the rebuilding of the destroyed buildings, but involving a fundamental revision of the city's resilience and security strategies and concepts of its development as a whole. It remains to express hope, moreover, confidence that in the near future it will be possible to investigate a rebuilt, renovated Kharkiv and to complete a chapter with the research of its new, changed image, well aware that the forthcoming planning strategies and choices will be called to define the urban and social conditions for future generations.

References

Alforov, I. (1972). The present and the future of socialist Kharkiv, *Construction and Architecture*, 12, 28-33 [in Ukrainian].

Alvanides, S., Ludwig, C. (2023). Bombed Cities: Legacies of Post-War Planning on the Contemporary Urban and Social Fabric, *Urban Planning, 8* (1), 165-168.

Averbakh, M., Demydiuk, O. (2017). *Sign of Visual Communication in Architectural Environment*. LAP Lambert Academic Publishing.

Besner, J. (2017). Cities think underground–Underground space (also) for people. *Procedia engineering*, 209, 49-55. https://doi.org/10.1016/j.proeng.2017.11.129

Biagioni, C. (2022). Kharkiv: the bombed city that lives in underground metro stations. Official website of S.I.R. Agenzia d'Informazione. Retrieved from: https://www.agensir.it/europa/2022/05/06/kharkiv-the-bombed-city-that-lives-in-underground-metro-stations/

Bourdieu, P. (2018). Structures, habitus, practices. In *Rethinking the Subject* (pp. 31-45). Routledge.

CityFace (2022). City and War. Website of the project. Retrieved from: https://en.cityface.org.ua/projectheritage.html [in Ukrainian and English]

Cutini, V. (2001). Centrality and Land Use: Three Case Studies on the Configurational Hypothesis, *CYBERGEO – Revue Européenne de Géographie*, vol. 188. https://doi.org/10.4000/cybergeo.3936

Cutini, V. (2013). The city, when it trembles. Earthquake destructions, post-earthquake reconstructions and grid configuration. In: Y O., Park H.T., Seo K.W. (eds.) *9thSSS Proceedings, Space Syntax 9th International Symposium,* Seoul (South Korea), 30.10.2013–04.11.2013

Cutini, V. (2016) Motorways in Metropolitan Areas: The Northwestern Growth of Florence and the Urban Use of Motorway A1, *IJGI International Journal of Geo-Information, 5* (77), 1-18. https://doi.org/10.3390/ijgi5060077

Cutini, V. (2022). Cities at risk: spatial matrices of resilience and security, *Territorio*, vol. 97, 77-84.

Cutini, V., Farese, D., & Rabino, G. (2020). Configuration and resilience: some remarks from the cases of Florence and Milan. *Plurimondi,* (18), 35-51.

Czarnecki, B., & Chodorowski, M. P. (2021). Urban Environment during Post-War Reconstruction: Architectural Dominants and Nodal Points as Measures of Changes in an Urban Landscape. *Land, 10*(10), 1083. https://doi.org/10.3390/land10101083

Didenko, C., Bouryak, A., & Antonenko, N. (2016). Residential Housing in Kharkov (Ukraine) 1920–1935. ZARCH *Journal of interdisciplinary studies in architecture and Urbanism*, 5.

Dinges, M. (2000). Historical anthropology and social history: through the theory of "style of life" to the "cultural history of everyday life", In: *Odysseus. Man in history*, 96-124 [in Russian].

Gubkina, I., Bykov, A. (2019). *Soviet modernism, brutalism, post-modernism : buildings and structures in Ukraine* 1955–1991. Kyiv, Berlin: Osnovy DOM.

Hewryk, T. D. (1992). Planning of the Capital in Kharkiv. *Harvard Ukrainian Studies, 16*(3/4), 325-359.

Hillier, B. (2007). *Space is the machine: a configurational theory of architecture*. Space Syntax.

Hillier, B., & Hanson, J. (1984). *The social logic of space.* Cambridge university press.

Hillier, B., & Vaughan, L. (2007). The city as one thing. *Progress in planning, 67*(3), 205-230. https://doi.org/10.1016/j.progress.2007.03.001

Kharkiv City Council (2021). Kharkiv is a student capital. Official website of the Kharkiv City Council, mayor, executive committee. Retrieved from: https://www.city.kharkov.ua/ru/o-xarkove/xarkov-studencheskaya-stolicza.html [in Russian]

Kharkiv guide (2008). Seven wonders of Kharkiv. Official website of the Kharkiv City Council, mayor, executive committee Retrieved from: https://www.city.kharkov.ua/uk/dovdnik/putevoditel-po-xarkovu.html [in Ukrainian].

Kharkiv Today (2022). Displaced residents of Kharkiv. How many of them are scattered across Ukraine? Official website of Kharkiv information and analytical portal "Kharkiv Today". Retrieved from: https://2day.kh.ua/ua/kharkow/kharkivski-pereselentsi-skilky-yikh-rozkydano-po-ukrayini [in Ukrainian]

Knauer, B. (2023). From Reconstruction to Urban Preservation: Negotiating Built Heritage After the Second World War. *Urban Planning, 8*(1), 196-210. https://doi.org/10.17645/up.v8i1.6133

Kolovou, I., Gil, J., Karimi, K., Law, S., Versluis, L. (2017). Road Centre Line Simplification Principles for Angular Segment Analysis. In: Heitor T., Serra M., Pinelo Silva J., Bacharel M., Cannas da Silva L. (Eds.) *Proceedings of the 11th Space Syntax Symposium*, 11. 2017, Lisboa: Instituto Superior Técnico.

Krasko O. (2020). Features of perception of the city of Kharkiv by student youth (by survey materials), The Journal of V. N. Karazin Kharkiv National University. Series: History, 57, 106-119 [in Ukrainian].

Liubarskyi, R. (1960). Unloading the center of Kharkiv from motor vehicles, *Construction and Architecture*, 7, 6-8 [in Ukrainian].

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

Mayor's Office (2022). More than 4000 buildings are destroyed and damaged in Kharkiv. Official website of Media Group "Obektiv". Retrieved from: https://www.objectiv.tv/objectively/2022/08/17/v-harkove-razrusheny-i-povrezhdeny-bolshe-4000-domov-meriya/ [in Russian]

Rabino, G., & Cutini, V. (2012). Searching for Ariadne's thread. Some remarks on urban resilience and orientation. *TeMA-Journal of Land Use, Mobility and Environment, 5*(2), 7-22. https://doi.org/10.6092/1970-9870/889

Reliefweb (2022). UNOSAT Damage Assessment Overview Map - Ukraine: Kharkiv, Kharkiv Oblast, Imagery Analysis: 15 June 2022 Published: 25 November 2022 V1. Retrieved from: https://reliefweb.int/map/ukraine/unosat-damage-assessment-overview-map-ukraine-kharkiv-kharkiv-oblast-imagery-analysis-15-june-2022-published-25-november-2022-v1

Rubinsztein-Dunlop S. (2022). Inside Ukraine's underground city: No showers, no sunlight and no peace from Putin's rockets. Official website of ABC News, Sydney. Retrieved from: https://www.abc.net.au/news/2022-04-22/kharkiv-a-new-secret-ukrainian-city-has-emerged-underground/101000764

Shkodovskyi, Y., Lavrentiev, I., Leibfreid, O., Poliakova, Y. (2002). *Kharkiv. Yesterday, today, tomorrow*. Kharkiv: Folio [in Ukrainian].

Shpara, P. (1967). Kharkiv in the present and in the future. [The city development and improvement masterplan]. *Construction and Architecture*, 6, 8-11 [in Ukrainian].

Stenson, J. (2022). Puppets, poetry go underground to entertain Ukrainians sheltering in Kharkiv metro. Official website of the online newspaper "The Times of Israel" Retrieved from: https://www.timesofisrael.com/puppets-poetry-go-underground-to-entertain-ukrainians-sheltering-in-kharkiv-metro/

Szczepańska, B. (2023). Post-War Architecture and Urban Planning as Means of Reinventing Opole's Past and Identity. *Urban Planning, 8*(1), 266-278. https://doi.org/10.17645/up.v8i1.6079

Terekhov, I. (2022). Advertisements in the metro will be replaced by children's drawings about the war. Official website of Kharkiv information and analytical portal "Kharkiv Today" Retrieved from: https://2day.kh.ua/ua/kharkow/pislya-viyny-u-kharkivskomu-metro-rozvisyat-dytyachi-malyunky [in Ukrainian]

Terekhov, I. (2022). Kharkiv metro will be able to shelter 154,000 people. Official website of Kharkiv information and analytical portal "Kharkiv Today" Retrieved from: https://2day.kh.ua/ru/kharkow/kharkovskiy-metropoliten-smozhet-prinyat-154-000-chelovek [in Russian].

Tiulpa, L. (1964). Planning of the Saltiv residential area. *Construction and Architecture*, 3, 6-8 [in Ukrainian].

Turner, A. (2000). *Angular analysis a method for the quantification of space*, paper 23, CASA working paper series.

Venturi, R., Scott Brown, D., Izenour, S., (1972). *Learning From Las Vegas*. MIT Press.

Verkhovna Rada of Ukraine (2022). Code of Civil Protection of Ukraine. Official web-portal of the Parliament of Ukraine. Legislation of Ukraine. Retrieved from: https://zakon.rada.gov.ua/laws/show/en/5403-17?lang=en#Text

Wang, H., Newman, G., & Wang, Z. (2019). Urban Planning as an Extension of War Planning: The Case of Shenyang, China, 1898-1966. *Journal Of Contemporary Urban Affairs, 3*(1), 1-12. https://doi.org/10.25034/ijcua.2018.4677

West, R. L. (2023). Dockers in Poplar: The Legacy of the London County Council's Replanning of Poplar, East London. *Urban Planning,* 8(1). https://doi.org/10.17645/up.v8i1.6075

Image Sources

Figg.1-4: Authors;

Fig.5: STRINGER/Reuters/Forum. https://www.pism.pl/publications/sweden-on-the-russian-aggression-against-ukraine;

Fig.6: https://deepstatemap.live/en#9.75/49.9346/36.1983;

Fig.7: https://reliefweb.int/map/ukraine/unosat-damage-assessment-overview-map-ukraine-kharkiv-kharkiv-oblast-imagery-analysis-15-june-2022-published-25-november-2022-v1;

Fig.8: Photo by Vasily Golosny;

Fig.9: https://www.reuters.com/world/kharkiv-metro-is-city-where-hundreds-shelter-bombardment-2022-03-11/;

Fig.10: Photo by Mykhaylo Averbakh, August 2022.

Author's profile

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 in the analysis of urban settlements and regional networks, assessing their development and evolutionary process of their morphology and functional aspects.

Mykhaylo Averbakh

PhD in Architecture, Former Associate Professor in Kharkiv National University of Civil Engineering and Architecture, Ukraine; Associate Professor in O.M. Beketov National University of Urban Economy in Kharkiv, Ukraine; Visiting Fellow at the Department DESTeC, University of Pisa, Italy; Expert of Romualdo del Bianco Foundation, Florence, Italy; Member of National Union of Ukrainian Architects. His research interests are generally oriented towards visual communication in the architectural environment and city visual image.

Oksana Demydiuk

PhD in Psychology; Former Associate Professor in Kharkiv National University of Civil Engineering and Architecture, Ukraine; Research work and complex evaluation as an expert within Tempus projects; Visiting Fellow at the Department DESTeC, University of Pisa, Italy; Expert of Romualdo del Bianco Foundation, Florence, Italy. Her research activity concerns functioning the interface of urban space with regard to the psychology of visual perception.

TeMA
Journal of
Land Use, Mobility and Environment

TeMA 1 (2023) 27-45
print ISSN 1970-9889, e-ISSN 1970-9870
DOI: 10.6093/1970-9870/9392
Received 10th September 2022, Accepted 6th March 2023, Available online 30th April 2023

www.tema.unina.it

The city challenges and the new frontiers of urban planning

Digital twins as tools of urban resilience: research and practices

Gabriella Pultrone

Department Architecture and Territory - dArTe
Mediterranea University of Reggio Calabria,
Reggio Calabria, Italy
e-mail: gabriella.pultrone@unirc.it
ORCID: https://orcid.org/0000-0003-4683-5997

Abstract
The exponential growth of the world population must deal with the limitedness of the planet and its resources. The challenge is even more difficult as by 2050 two-thirds of the world's population will live in cities, urban ecosystems are becoming larger and more complex, and many other global challenges (climate, energy, health, ecological) require innovative answers in a very short time, with an integrated approach and in a medium-long and wide-ranging vision.
Within this complex framework: a multiple transition (digital, ecological, energy) is undelayable; the way of planning, designing, and managing cities is going through a phase of deep change; a new culture is emerging and spreading to improve informed and data-driven decision making.
Therefore, the article addresses the potential of new technologies, yet to be adequately explored in the fields of planning and design at different territorial scales, for better governance, sustainable development and quality habitats. It consists of three main sections, consistent with the methodology and the main steps of the ongoing research to which it refers. The first section focused on global challenges and on the potential of new technologies to make cities and territories more resilient and sustainable, in line with SDG 11 of UN 2030 Agenda. The second section addresses the theoretical aspects and implementation regarding the concept of urban resilience and the role of new digital technologies with reference to significant case studies in the EU panorama. The third and final section contains some concluding remarks on the limits and prospects of research for urban planning, territorial governance and management.

Keywords
Digital twin; Technological digital innovations for urban planning; Urban resilience to climate change.

How to cite item in APA format
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. http://dx.doi.org/10.6093/1970-9870/9392

1. Introduction. Cultural background, critical framework of the scientific debate, methodological approach

Cities represent an unmissable opportunity for leveraging innovation and creative planning to combat global challenges and make meaningful improvements in the lives of billions of people, in an increasingly populated and interconnected world, as widely recognized, stated, and reaffirmed internationally (The Rockefeller Foundation, 2019; UN-Habitat, 2020 and 2022).

Given that the exponential growth of the world population has to deal with the limitedness of the planet and its resources, the challenge becomes even more difficult since by 2050 two thirds of the world population will live in cities and urban ecosystems will tend to become bigger and more complex, also due to unexpected and unpredictable (only at first glance) events like the COVID-19 pandemic and the conflict in Ukraine (EEA, 2020; UN-Habitat, 2022; United Nations Department of Economic and Social Affairs, Population Division, 2022). Therefore, the climatic, social, economic and health phenomena that have increasingly affected our cities in recent years require the identification and implementation of mitigations and adaptation actions aimed at improving the resilience of urban systems, both internally and in relation to the wider territorial systems (IPCC, 2022). Better and more effective governance, sustainable development and quality habitats, connected and efficient infrastructures are needed.

The ability to address this unprecedented *polychrysis* requires innovative approaches, more effective tools, and resilience strategies that can improve contemporary cities' capacities to address the multiple and often interconnected challenges to face[1] (Leone et al., 2020; UN-Habitat, 2020 and 2022), in line with SDG 11 of UN 2030 Agenda, "Make cities and human settlements inclusive, safe, resilient and sustainable" and with the other 16 Goals[2]. City sustainability is a multifaceted task entailing non-linear processes and system complexity on different spatial scales and with a long-term view (Pelorosso et al., 2018). In a nutshell, as important political centers, and major engines of innovation, cities stand at the forefront of the challenges, and opportunities of the 21st century, and the global pressures affecting both individuals and whole systems.

Within this framework, the climate, energy, health and ecological challenges make the multiple transitions (ecological, digital, energy) indispensable and the new technologies must be considered as enabling factors and tools capable of increasing resilience, intelligence and sustainability of cities and territories.

Increasingly over the last decade, cities worldwide have built digital infrastructure and embedded digital technologies into urban services and *smart cities* have become the dominant paradigm for innovative urban planning and governance strategies (Barresi & Pultrone, 2013; Campbell, 2012; Caragliu & Del Bo, 2019; Mills et al., 2021) (Fig.1).

Digital technologies such as Digital Twin (DT), artificial intelligence (AI), the Internet of Things (IoT), cloud computing, 5G connectivity, Big Data Analytics, Blockchain, Building Information Modeling (BIM), City Information Modeling (CIM) are all providing municipal authorities a powerful set of tools to make cities smarter, safer, cleaner and more inclusive[3] (Al Furjani et al., 2020; Birks et al., 2020; Charitonidou, 2022; Deng et al., 2021; Jones et al., 2020; Economist Impact, 2022; Elsheikh et al., 2021; Jiang et al., 2022; Lee et al., 2022; Leplat et al., 2022; Major, 2022; Yin & Cai, 2022; Zhao, 2022).

---

1 With respect to any crisis advent, A. Leone, P. Balena and R. Pelorosso R. (2020) highlight it is necessary to pay attention to the resilience of the system, so the goal must be the robustness and even the anti-fragility of the socio-ecosystem, not the pursuit of the specific black swan in its different possible forms: from financial perfect storms to pandemics, to the unpredictable effects of climate change.

2 See: https://sdgs.un.org/goals/goal11; Striving for People, Plant and Peace. 2022 JOINT MEDIA PROJECT REPORT (2021). Berlin: The Non-Profit International Press Syndicate.

3 Inter alia, Deng, Zhang & Shen (2021) highlight the following different roles of technologies in DTCs: surveying and mapping technology, for collecting the static data of the buildings in cities; BIM technology, for the asset and infrastructure management of cities; IoT and 5G, for collecting dynamic data and feedback effectively; Blockchain technology, for the trust mechanism of transactions, logistics, and human behaviour; collaborative computing with 5G, for efficient real-time responses; simulation technology, for policy support, planning, and early warning mechanisms.

It is therefore more than ever essential to understand the technological transformations taking place in order to govern and manage them in the best way. About this, *The Digital Disruptions for Sustainability Agenda* (*The D^2S Agenda*), developed by Future Earth's Sustainability in the Digital Age (2020), explores the opportunities and challenges of leveraging the digital age to tackle the climate crisis.

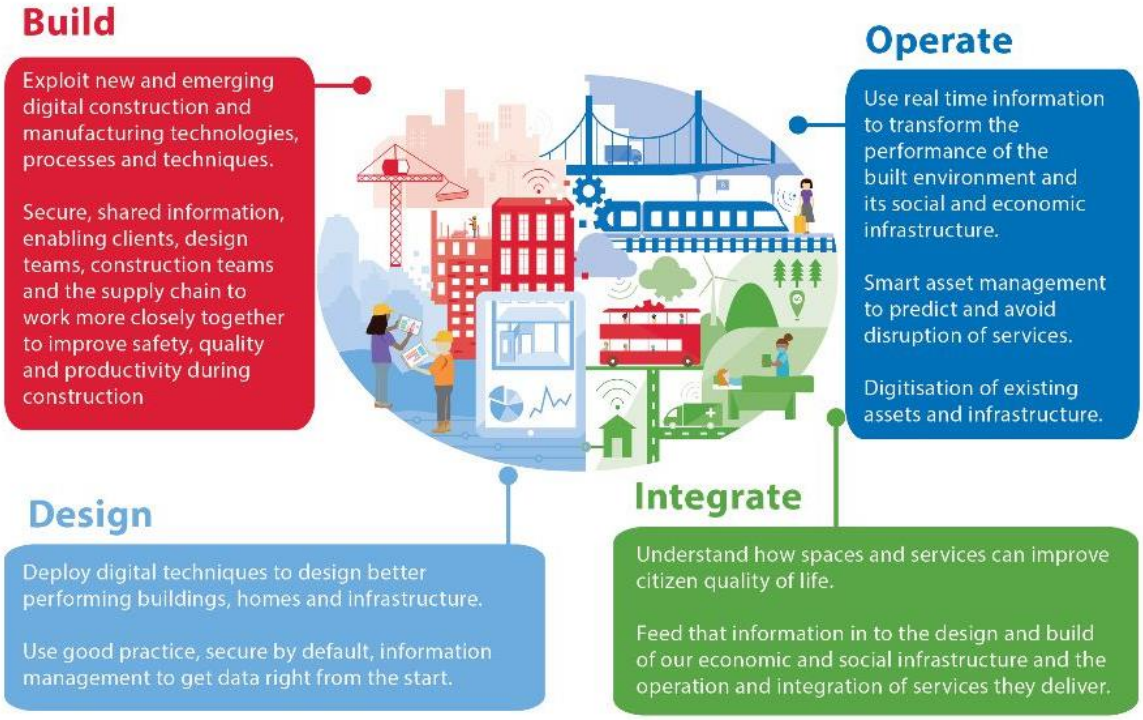


Fig.1 The potentials of digital Technologies for built environment as schematized by the Centre for Digital Built Britain

From analysis of the document, four key messages emerged, as below highlighted by A. Luers et al. (2020): 1) There are tremendous opportunities for leveraging the digital age to drive the transformative systems changes needed to address the climate crisis, but there are also major risks; 2) Tackling climate change and building a just and equitable digital world are one intertwined agenda, because humans are interconnected through and dependent on both the natural and digital worlds and our current trajectory poses global systemic risks that emerge from both worlds; 3) Seizing the opportunities of the digital age to drive transformative systems changes will require transdisciplinary research and innovation and collaborative actions; 4) Success will depend on overcoming the digital divide and developing inclusive strategies that consider differences among social and cultural contexts.

Specifically, in the field of planning and design at different territorial scales, DT and CIM have enormous potential yet to be explored, ranging from modeling, planning, forecasting through digital models made dynamic and interactive by real-time data. Through DT, in particular, the physical and digital worlds merge for interactive experiences, almost real-time information exchanges and better decisions

Taking into account the fact that the way of planning, designing and managing cities and territories is going through a phase of profound change, made even wider because it is linked to the way of understanding knowledge, a renewed cultural approach that enhances informed decision-making processes based on knowledge is indispensable in addition to the aforementioned procedures and tools.

These, in fact, tend to assume an increasingly central role also in urban and territorial planning and design processes as means and tools that, thanks to the convergence between 3D and 4D visualization, modelling of reality, mixed reality and engineering geotechnics allow you to create a complete and immersive view of infrastructural assets, on the surface and in the subsoil.

At the same time, as cities become more digital, a key question concerns the sustainability of the relationship between smart technologies and the need to overcome social problems, such as injustices and inequalities, in the age of the Big Data Revolution (Cavalli, 2023; Giovannini, 2016)[4]. In this regard, if on the one hand the new technologies can become a vital force of social evolution, many scholars highlight the possible sources of injustice seeping through a series of sociotechnical *assemblages* of the smart cities, and wonders whether working towards more just, sustainable, livable and just cities requires that we look beyond the limits of the "intelligence" of the whole (Mackinnon et al., 2022; Mergel et al., 2019; Papa et al., 2015; Peixoto & Steinberg, 2019; Rosol & Blue, 2022). In the light of above, the article has to be interpreted as a first stage of an innovative and recent wider research[5] addressed to explore and highlight the potentials provided by new technologies to have data and flows in real time (Ratti, 2013), and to give sustainable, immediate and effective responses to specific local problems in the coherent and integrated framework of a longer-term strategic planning that takes due account of the possible/different evolutions/developments of the ongoing urban dynamics. The following aspects are considered most relevant: 1) retrieval of information that improves the urban infrastructure; 2) improving collaboration and creating added value for cities and their inhabitants; 3) improvement of mobility and safety in public spaces; 4) involvement of citizens and investors, to whom to communicate, promote and share urban projects in an interactive way to obtain consensus; 5) creation of a resilient infrastructure, capable of predicting, responding and reacting to extreme events; 6) adoption of open data initiatives that allow others to design, develop and deliver services based on reliable information about cities and infrastructures. Furthermore, the DTs can also represent the strategic element to enhance the value of territorial assets (natural and anthropogenic) through the new projects and transitions underway favored by the National Recovery and Resilience Plans (NRRP) at EU level (thanks to *Next Generation EU* funding[6]), increasing the effectiveness of their governance, allowing processes of simulation and control of the complexity of socio-economic, environmental and landscape phenomena, positively feeding collective intelligence.
Anyhow, although the concepts of *resilience* and *smartness* applied to the cities, according to current scientific literature, seem to play a leading role in enhancing cities' capacities to cope with climate change (Papa et al., 2015; De Gregorio Hurtado et al., 2015; Galderisi & Ferrara 2012), as a matter of fact, urban innovation goes beyond the technological, encompassing essential social and institutional aspects, and requires a context specific, place-based and people-centred localized approach.

2. The new digital technologies (R)Evolution[7] for strenghtening urban resilience

2.1 The necessary *Resilience Thinking*

According to *The Global Risk Report 2022* (WEF, 2022), economic, geopolitical, public health and societal fractures, increased after Pandemics, risk leading to divergent and delayed approaches to the numerous critical challenges facing people and planet: accelerating the green transition in response to climate change, coordinating against heightened digital vulnerabilities, managing mobility and migration and safeguarding

4 As for Big Data, in August 2014 UN Secretary-General Ban Ki-moon asked an Independent Expert Advisory Group to make concrete recommendations on bringing about a data revolution in sustainable development. http://www.undatarevolution.org. L. Cavalli (2023) points out that, although none of the Sustainable Development Goals of the UN 2030 Agenda is directly dedicated to digital and technology, the world of politics and above all that of research are now unanimous in recognizing their role as a lever, an enabling factor for a faster achievement of sustainable development as, for example, also within the Italian National Recovery and Resilience Plan.

5 The article proposes a reflection on ongoing research by the Author concerning "Global Challenges, Technological Digital Innovations and the New Frontiers of Urban Planning Research", here declined more specifically on "urban resilience" in the face of the climate challenge.

6 See https://europa.eu/next-generation-eu/index_en

7 The term is taken from Khaled Diab (2022). The next (r)evolution: AI v human intelligence. Should we worry about chatbots becoming 'sentient'?. 18 Jun 2022, https://www.aljazeera.com/opinions/2022/6/18/artificial-intelligence-v-human-intelligence

space, defined as the next global commons. For governments, balancing costs, regulating for resilience, and adjusting data-sharing arrangements to ensure sharper crisis management are key to galvanizing stronger interaction between public and private sectors. Communities can help local governments to join up with national efforts, improve communication and support grassroots resilience efforts (WEF, 2022).

As highlighted in the first paragraph, in a world more densely populated and more interconnected than ever before, global challenges – such as extreme weather, refugee crises, disease pandemics, cyberattacks, war conflicts, problems of food and energy supply – become much more complex and new models of governance are required to mitigate risk and respond to challenges. *Business-as-usual* models will not generate the fundamental strength and flexibility, essential to thrive in the face of the aforementioned shocks and stresses. As a matter of fact, the harm caused by acute shocks is exacerbated by chronic stresses and pressures, as recurrent flooding, high unemployment, social inequalities, and overtaxed or inefficient public transportation systems, that affect especially the poor and the most vulnerable social groups. It is difficult for cities to tackle just one challenge at a time, considering the interdependent combinations of acute shocks and chronic stresses (The Rockefeller Foundation, 2019).

As for the EU context, around 75% of Europe's population live in urban areas and estimates predict that European urban population will rise to 80% in 2050. Furthermore, the European urban landscape is heterogenous and characterized by a diversity of mostly small and medium cities (EEA, 2021). The main challenge for the EU is to satisfy citizens' demand for cities while making them resilient to climate change, circular from the point of view of resource management, improving the quality of life that these environments offer and developing a green economy that allow an innovative economic development with limited environmental impact. This translates into the achievement of urban sustainability, conceived as efficient and intelligently planned cities in all their aspects: economy, personal services, mobility, water management, waste management, building management and regeneration, resilient to climate change. Cities can become the main driving forces for a green and just recovery. Infrastructure[8] investments, which can stimulate urban economic activity, above all, after the easing of pandemic measures, can be an opportunity to align the recovery with climate, environmental and social equity programs, but will need to be accompanied by better integration of policy sectors and by actions to maximize benefits, overcoming the still prevailing sectoral and silo approach (EEA, 2021). Adapting European cities and towns to inevitable climate change is crucial for the overall resilience of European society because of the population concentration — including vulnerable groups — assets and economic activities in urban areas (EEA, 2020).

In this context, the concept of *resilience* – born from the exigencies of the three converging trends of climate change, urbanization, and globalization – is defined as "the capacity of social, economic and environmental systems to cope with a hazardous event or trend or disturbance, responding or reorganizing in ways that maintain their essential function, identity and structure while also maintaining the capacity for adaptation, learning and transformation" (IPCC, 2022) and *urban resilience* as "the capacity of individuals, communities, institutions, businesses, and systems within a city to survive, adapt, and grow no matter what chronic stresses and acute shocks they experience".

Building urban resilience is a multisectoral, multidimensional, multi-stakeholder process that requires a clear change of trajectory from previous paths, a key principle to re-frame urban policies, paving the way to cross-

[8] As for the concept of "infrastructure", reference is made to IPCC Sixth Assessment Report (2022: 940) as specified below. Infrastructure includes the social systems, ecological systems and grey/ physical systems that underpin safe, satisfying and productive life in the city and beyond (Grimm et al., 2016). Social infrastructure includes housing, health, education, livelihoods and social safety nets, cultural heritage/institutions, disaster risk management and security and urban planning. Ecological infrastructure includes nature-based services: temperature regulation, flood protection and urban agriculture. Grey, or physical infrastructure, includes energy, transport, water and sanitation, communications (digital), built form and solid waste management. Framing infrastructure in this way enables an assessment of adaptation that is not constrained to the administrative boundaries of urban settlements, but also includes the flows of material, people and money between urban, peri-urban and more rural places, and can include adaptation actions deployed by government, individuals and the private sector.

sectoral urban strategies capable of better coping with contemporary challenges (Pultrone, 2018a and 2018b; Galderisi et al., 2020; UN-Habitat, 2022). Compound, cascading and transboundary impacts for humans and ecosystems result from the complex interaction of multiple climate hazards, exposures and vulnerabilities (IPCC, 2022: 82-83). So, the identification of urban fragilities could represent a fundamental first step in order to develop and to propose methodological and operative innovations for the planning and the management of the urban and territorial transformations as highlighted in recent European adaptation plans that provide for environmental actions aimed at ensuring sustainable use of the soil and also helping to contain the effects of climate change (Zucaro & Morosini, 2018).

Equally crucial, the next step of identifying approaches, methods, tools, and significant case studies on this highly innovative research topic, especially in the field of urban planning, and deserving of further developments and future insights.

2.2 The smart cities transformA(c)tion: continuous technological innovation as key opportunity for *Resilience Building*

According to the latest *The World City Report* (henceforth WCR, 2022), over the past two years, two important areas of socio-technical development have continued to accelerate and have taken an even more important phase in planning the urban future with attention to increasing urban resilience: the first area is the growing urgency for unprecedented, aggressive decarbonization; the second one relates to unparalleled advancements in the digital world (UN-Habitat, 2022).

Digitalization encompasses various smart technological innovations that enable ubiquitous computing, big data collection from widespread deployment of sensors and devices, large-scale data analytics, machine learning and autonomous decision-making. With reference to urban systems, these connected and digital technologies find expression in the *smart city*, which is a major paradigm of urban policy and have fundamental implications for the way in which cities are governed and planned, as complex systems involving a symbiotic linkage among people, institutions, technology, organizations, building environment, and physical infrastructure (Angelodu, 2017; Barresi & Pultrone, 2013; Caprari et al., 2022; Caragliu & Del Bo, 2019; Pultrone, 2014; Söderström, 2016; Zheng et al., 2020)[9].

In any case, the guiding question should be how to achieve inclusive urban development in the interest of citizens' wellbeing and environmental protection.

The same WCR (UN-Habitat, 2022) explores the role of cities as places of innovation, highlighting and deepening the following aspects: 1) the necessary interplay between technological, social and organizational innovation, and the four challenges for the smart city innovation; 2) the emergent frontier technologies centring upon the convergence of green and smart technology, and their adaptation to adapted to local contexts; 3) how combination of digitalization and automation forces are transforming the world and how will likely affect cities; 4) how cities can face both the digital divide and environmental divide arising from technological innovations, and related risk of creating new or exacerbating existing urban inequalities; 5) the opportunities of connected and digital technologies to enhance participatory governance through more open e-government, civic engagement and community technology making; 6) the benefits of responsible innovation as a tool for assessing both opportunities and risks of technology; 7) finally, seven policy lessons for inclusive sociotechnical innovations for urban futures. As known, the *smart city* has become a globally major policy

[9] For further information on the smart cities challenges see also: the articles published in the six issues of TeMA - Journal of Land Use, Mobility and Environment, vol. 6 (2013) and 7 (2014). http://www.serena.unina.it/index.php/tema/issue/archive; the specific section Smart cities Cities using technological solutions to improve the management and efficiency of the urban environment, on the website of European Commission, https://ec.europa.eu/info/es-regionu-ir-miestu-pletra/temos/miestai-ir-miestu-pletra/miestuiniciatyvos/smart-cities_en

paradigm for technology-driven urban innovation and development from the late 2000s onwards alongside other key urban conceptual paradigms, such as the *compact city*, *resilient city*, the most widespread *sustainable city* or even, more recently, the *circular city*, as documented by the extensive scientific production and experiments in many cities around the world.

However, many smart city initiatives have faced significant criticism, due to the risk of an overly technological approach to innovation without regard to different urban and social contexts. Specifically, the following four main challenges have been identified: 1) respect city-specific contexts; 2) adopt a people-centred perspective, to avoid the risk of an overly technocratic approach; 3) provincialize smart cities, developing more grounded approaches also in the global peripheries, in contrast to typically large-scale, capital-intensive interventions in the Global North; 4) ensure environmental sustainability, since the environmental costs of smart city projects are often overlooked, while there is growing evidence that technological Innovations can be carbon-intensive and harmful to the environment, a more explicit alignment of the smart city with the goals of city sustainability (UN-Habitat, 2022).

The application of frontier technologies, particularly related to green and smart technology sectors, has the potential to reconfigure urban development in radical and disruptive ways, not only in large global cities, but also in lower-tier cities and even in settlements informal.

This is because frontier technologies can be designed to be relatively low-cost and suitable for local adaptation. In this direction Digital Twins (DTs) can be considered an innovative tool to develop new patterns of urban governance, planning and design for sustainability and resilience, in order to deal with *polychrysis* and implement the right multiple transition, to which reference was made in the first paragraph[10].

2.3 Digital twins and new patterns of urban governance between theoretical approach, research activities and local implementation

City governments and other urban stakeholders have an active role to play in deciding how innovation and technology are adapted in ways that suite to specific urban contexts, foster sustainable development and enhance resilience.

According to the *Digital City Index* 2022 (Economist Impact, 2022), above all the involvement of citizens in the design of smart cities determines the projects' success. The last decade has marked great strides in digital infrastructure, providing municipalities with a range of features that are extremely important for developing safer, cleaner, smarter and more inclusive cities.

Some cities are making innovative use of data such as social media posts to track the progression and impact of floods and earthquakes, while micro sensors are pinpointing urban *heat islands* where temperatures are higher due to the presence of heat-trapping materials like glass and concrete.

Among the examples of frontier technologies in urban contexts[11], here it is argued that Digital Twins (DTs) are of particular interest for Urban Planning, in terms of the methodological approach and possible

[10] The concept of a virtual, digital equivalent to a physical product or the Digital Twin was introduced at first in 2003 at the University of Michigan Executive Course on Product Lifecycle Management (PLM), as specified in the Digital Twin White Paper by Michael W. Grieves titled Digital Twin: Manufacturing Excellence through Virtual Factory Replication (2014). Furthermore, to be precise, one of the first examples of a working DT was realized in 1996 during the construction of the Heathrow Express facilities at Heathrow Airport's Terminal 1. Consultant Mott MacDonald and BIM pioneer Jonathan Ingram connected the motion sensors in the cofferdam and wells to the digital model object to visualize the motions in the model. A digital grouting object was made to monitor the effects of pumping mortar into the ground to stabilize ground movements (Bolton et alii, 2018).

[11] Other examples of frontier technologies in urban contexts, in addition to Digital Twins (DT), as reported in WCR 2022 (UN-Habitat, 2022: 281):
- Artificial intelligence, or machine learning, increasingly deployed by municipal governments in the form of virtual agents like chatbots for issuing parking permits and in road traffic management;
- Blockchain, or distributed ledger technology, for secure, decentralized exchange of data among network partners. Used by transport operators to deliver shared mobility services, or by city governments to issue residents with digital identifiers for accessing local services;

implementations, since they are virtual representations of urban objects at various scales (building, neighborhood, district, etc.) used as planning tools, support diagnostic and prognostic analysis and model-making, dependent on completeness and accuracy of underlying data known as digital thread (Lv et al., 2022). Basically, DTs, as means to link digital models and simulations with real-world data, create new possibilities for improved creativity, competitive advantage and human-centred design. Moreover, DTs can help deliver on the grand challenges facing society, including achieving the United Nations' 17 Sustainable Development Goals and addressing rapid urbanization, population growth, and escalating infrastructure costs.

Definitely, they are becoming a critical tool for urban development in cities around the world, offering the following four new capabilities: 1) Planning; 2) Research; Virtual experimentation; 4) Virtual testing[12].

The undoubted importance of the wide innovative reach of the DTs is also highlighted in the *Action Plan for a Sustainable Planet in the Digital Age* (CODES, 2022), which places the following innovation at the top of the list: "Build Planetary Digital Twin: Prioritize innovations to measure, monitor and model the health of the planet's biosphere and interactions with economic and social systems". A key contributor to increasing resilience lies in the fact that DTs combined with AI can conduct automated risk and threat monitoring to key protected areas (natural or cultural areas as part of protection frameworks), global ecosystem services or endangered species[13].

The Report *Digital Twin. Towards a Meaningful Framework* (ARUP, 2019) examines the current state of DTs in the built environment and their potential value within five key markets – cities, energy, property, transport and water – providing an interesting review of the opportunities, challenges and exemplary case studies.

The aforementioned document notices that urban planners have long used data on places and people in their work, and that a traditional source of data for development proposals is census data, which is rather static, with respect to the periodicity of the update. Better data can, however, allow you to make better planning, design and management decisions, even considering the great potential in the volumes and speed with which the data itself is becoming available.

This is therefore an innovative topic in the field of Urban Planning worthy of further developments and insights since little has yet been done to explore the potential of using this data and new technology for planning and design processes. This is despite the 21st century has witnessed unprecedented technological advances and an explosion of available data on the built environment and the people who inhabit it, and city authorities are beginning to realize the potential to improve city management, to making it smarter. Intelligent use of data could help design places that effortlessly respond to public needs or reduce and reuse excess energy, better designed places and better design processes. Advances in Artificial Intelligence (AI) have enabled better understanding and analysis of physical assets, producing a wide and rich dataset of previously inaccessible information, and advanced DTs can be found more widely in the real estate and transportation markets. AI can also help to tackle broader policy goals, including sustainability and inclusion, as in the case of AI and

- 3D printing, allows for offsite fabrication of building components, thus potentially lowering construction costs of new buildings;
- Electric vehicle (EV) technology, a key technological challenge is the roll-out of electric charging networks. To date, 15 countries and 31 cities are committed to phasing out the sale of combustion-engine vehicles;
- Internet of Things (IoT), broad range of applications by embedding a multitude of sensors, smart meters and computer processors in urban infrastructure and objects, and connecting these to digital management systems via cloud computing (remote storage and analysis system over the internet);
- Renewable energy technologies, deployed for clean energy production, using various renewable energy sources (solar, wind, hydro, biomass, geothermal);
- Robotics, multiple urban applications, including drones for last-mile delivery and connected autonomous vehicles (CAVs). Dependent on 5G/6G technology to deliver high-speed broadband, ultra-reliable connectivity (for low latency) and ability to connect to a multitude of devices simultaneously.

12 https://www.asme.org/topics-resources/content/infographic-urban-digital-twins-reflect-smart-cities

13 For further information on the main research questions, innovative needs and critical issues concerning "Build Planetary Digital Twin" please refer to the cited Action Plan.

machine learning used to map the accessibility of sidewalks and pavements for people with disabilities including gauging width, gradient and surface composition[14].

Staying at the city scale, the *Smart City Digital Twin* (SCDT) paradigm has been introduced to increase the transparency of human-infrastructure technology interactions through the exchange of spatiotemporal information.

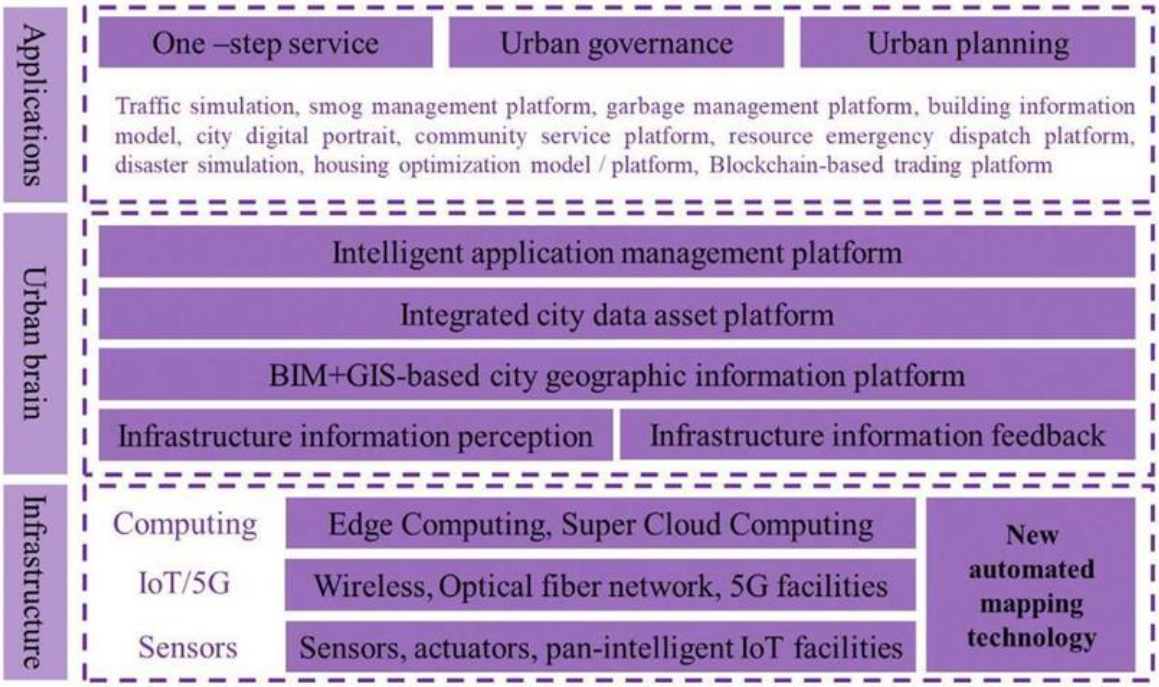


Fig.2 The composition of digital twin cities structure according to Deng et al.,2021

DTs may at first appear to be an exact replica, however, they are not necessarily realistic representations, but are rather relevant abstractions of the physical asset.

Ultimately, fit-for-purpose DTs need to be developed, and the level of fidelity will vary depending on the primary use cases. Of crucial importance is the connection between the physical and the digital system, which requires data exchange, as well as the inclusion of human beings in the role of designers or users. DTs must make better and better predictions about our physical infrastructure and, in their most advanced instances, they will continually increase in intelligence in an ongoing dynamic process.

Some issues are essential in the scientific debate on DTs, such as the steps required for planning, designing and implementing DTs in cities; how these can empower cities, even those of medium and small size, and increase urban resilience; the challenges and potential for their implementation.

DTs, virtual 3D replicas of a given system, place, or thing, allow cities and property owners to test changes before they implement them in the real world (Salomon, 2020).

Many North American or Asian cities, such as the well-known case studies in Boston, New York, Los Angeles, Orlando or Singapore (Fig.3), are increasingly using this technology to study the effects of development, traffic, climate change, and a host of other challenges that cities must face, so to increase also the resilience to these critical issues[15].

[14] See *Smart Cities for All. AI for Inclusive Urban Sidewalks* Project. https://www.smartcities4all.org/ai-for-inclusive-sidewalks/

[15] See also: https://www.esri.com/about/newsroom/blog/3d-gis-boston-digital-twin/; https://sig-digitaltwin-smartgeohub.hub.arcgis.com/; https://www.webuildvalue.com/it/megat rend/digital-twins-citta-usa.html; https://www.nrf.gov.sg/programmes/virtual-singapore; https://www.3ds.com/insights/customer-stories/virtual-singapore; https://www.smartnation.gov.sg/.

Fig.3 Representation of the digital space in Singapore

Local Digital Twins in the EU panorama

Focusing only on the European context, according to European Commission, Local Digital Twins (LDTs) will enable the next phase of smart and sustainable cities and communities. During the European Week of Regions and Cities 2021, the session *Local Digital Twins - Forging the cities of tomorrow* [16] explored the main challenges and potential are for the implementation of LDTs, defined as the virtual representation of a city's physical assets, processes and systems, using data, data analytics and machine learning to help simulation models that can be updated and modified (in real time) as their physical equivalents. They vary in terms of maturity and capacity, but this can actually allow even smaller cities to test their potential. When planning to create a LDT, cities need to consider a number of important aspects, the main challenges the city wishes to address, the scale and scope of the digital twin, its governance and expected functionalities. When designing the DT, it is important to consider the data base (availability, quality and interoperability) and the technical base (IoT, cloud computing, big data, AI, 5G). The Commission has indicated future funding for *an EU Local Digital Twin toolbox*, consisting of open standard solutions, reference architecture and reusable tools, through the DIGITAL program[17].

DUET Project: to break silos in urban management

In the case of European innovation project DUET[18], powerful analytics embedded within the digital twins integrate data silos and model the expected impacts of potential decisions across city systems, such as the

16 The session – organised in collaboration with DG CONNECT Technologies for smart communities, the LEAD and DUET H2020 projects working on Local Digital Twins, the Union of Municipalities of Turkey as well as ENoLL – took place on the 13th October, https://digital-strategy.ec.europa.eu/en/library/local-digital-twins-forging-cities-tomorrow

17 The Digital Europe Programme – the new EU funding programme focused on bringing digital technology to businesses, citizens and public administrations – provides strategic funding to answer these challenges, supporting projects in five key capacity areas: in supercomputing, artificial intelligence, cybersecurity, advanced digital skills, and ensuring a wide use of digital technologies across the economy and society, including through Digital Innovation Hubs. The Programme complements the funding available through other EU programmes, such as the Horizon Europe programme for research and innovation and the Connecting Europe Facility for digital infrastructure, the Recovery and Resilience Facility and the Structural funds. It is a part of the current long-term EU budget, the Multiannual Financial Framework 2021-2027. https://digital-strategy.ec.europa.eu/en/activities/digital-programme

18 Developed and tested in cities and Regions at different points in their digital transformation journeys – Flanders Region, Belgium, the City of Athens, Greece and City of Pilsen, Czech Republic – DUET has the aim to create the concept of Policy-Ready-Data-as-a-Service and ensure all cities across Europe will be able to create their own their

knock-on effects of road closures, new housing estates, and location of transport hubs, on roads, public transport, air quality and health. The evidence-based simulations support both city managers and policy makers in working together around common scenarios to make better, cross-domain, operational decisions and longer-term policy choices whilst enhancing transparency, citizen involvement and resource optimization. A pilot project by the City of Pilsen, Czech Republic, is using its 3D digital twin for urban planning to model and assess the predicted impact of new buildings on the local area. Improving citizen engagement in public decision making is the focus of the final pilot in the city of Athens, Greece[19] (Ruston McAleer et al., 2021).

URBANAGE Project to address extreme heat

Concerning the *resilience to extreme heat*, as part of the EU URBANAGE project[20], URBANAGE Digital Twin is an extensible platform that allows you to model the city and its processes through a virtual replica. The implementation of the DT involves the development of components to facilitate data modeling and mapping, geospatial analysis and data retrieval through web services (API and advanced visualization services). The modeling of the elements of the city is carried out through the City Information Model (CIM) which represents the four layers that allow to connect the different elements/levels that define the city and its processes: citizen, urban planning, both physical and technical infrastructure. The project is focused on improving, through smart city data, the life quality of senior citizens, the most vulnerable to the harmful effects of extreme heat during the summertime. In fact, one of the URBANAGE challenges, related to the aim of detecting comfortable, shadow rich places inside the city. In this case, the main challenge is to customise this information and make it relevant and easily understandable for the senior citizens community. Regarding the operating modes being tested in the city of Ghent (Belgium), based on soil data and the spread of trees and buildings, the impact of the shadow can be perfectly simulated at different time intervals during the day and for each day of the year using the specially designed map viewer. In this way, senior citizens of the city of Ghent can see where to find refreshing and shaded areas within the city on extremely hot summer days.

LISBON and the challenge of flood resilience

As for the challenge of climate change that is accelerating extreme weather events around the world, especially in coastal and lowland areas, the Lisbon case study is particularly significant[21]. As a matter of fact, in Portugal's capital, rapid urbanization has combined with climate-related problems such as rising sea levels and frequent and extreme rainfall, leading to increased flood risks and soil impermeability in the region. To improve the *city's flood resilience* with data-driven planning, development and operation, the city government decided to create a DT for urban flood simulation. Flood resilience models using DT help optimize the performance of existing drainage infrastructure resources and take preventative measures for superior flood resilience planning. The development of a flood resilience model involves the integration of urban-scale reality modeling, 3D mapping and flood modeling, which, when combined on a GIS platform, can be used for visualization, simulation and analyses. DT solutions help the city comprehensively model alternative scenarios to develop a comprehensive and foolproof master plan for multiple payback periods. Flood resilience models therefore allow you to better respond to extreme weather conditions. In Lisbon, the what-if scenario generates from the flood resilience models on the DT models is estimated to prevent 20 floods in the next 100 and save over EUR 100 million in damaged infrastructure and loss of livelihoods. The authorities also used the flood resilience model to define the best trajectory and size of the two tunnels to be built using the different simulations. The various simulations allowed the authorities to assess flood risks for the condition of existing drainage infrastructures

own Digital Twins that address ethical considerations around data use whilst also complying with Europe's stringent privacy and security regulations. https://cordis.europa.eu/project/id/870697/it

19 https://citytwin.eu/

20 https://www.urbanage.eu/

21 In general, the city of Lisbon is particularly attentive and active with regard to resilience strategies, see https://www.lisboaenova.org/images/stories/PontodeEncontro/2018/CML_PENCONTRO17ABRIL18.pdf

and also to assess and mitigation and resilience strategies for the new infrastructures. In addition, the city is now able to efficiently perform predictive analyzes of city supply, wastewater, stormwater and other water systems to predict flood risks and take necessary proactive actions and preventive measures before arrival of any wave of flood[22] (Fig.4).

Fig.4 The Digital Twin of Lisbon. Flood simulation in downtown: two different scenarios

ZURICH: the DT as an opportunity for desirable future urban scenarios

Also, Zurich, like many other European cities, will cope with a series of challenges in the coming years, as the increase in population and jobs will lead to densification and competing land uses. City administration faces increasingly complex tasks, while tools and methods are often based on traditional and static approaches while engaging a limited number of citizens and stakeholders in relevant decisions. The digital transformation of more and more parts of the planning process becomes indispensable and this is achieved through the creation of the DT of the city. Through the visualization and analysis of digital prototypes and the demonstration of interactions with the built environment, scenarios can be developed digitally and discussed in decision-making bodies. Urban climate questions can be simulated with the help of the digital twin and the results can be linked to existing 3D spatial data. This spatial and digital model of Zurich integrates the existing spatial data and metadata infrastructure (compliant with the European INSPIRE Directive and the GeoCat 2019 catalog) with 3D spatial data. Moreover, for the development of the city Master Plan (Municipal Structure Plan for Settlements, Landscape, Public Buildings and Facilities, 2018) the digital twin was used and different growth scenarios were developed and represented in 3D models, containing different levels of data: the state of the art of the building development, the maximum building capacity according to the rules of the Plan, the densification scenarios, information and impacts on the urban microclimate (heat islands), up to the 3D models of the proposals of competition notices for architects (Fig.5).

Through the visualization and analysis of digital prototypes and the demonstration of interactions with the built environment, the DT opens up new opportunities for discussion and dialogue on the future urban scenarios of the city between decision-makers and stakeholders, while the open model and collaborative

[22] https://www.geospatialworld.net/prime/lisbons-city-scale-digital-twins-for-flood-resilience-2/; https://www.gim-international.com/content/article/city-scale-digital-twins-for-flood-resilience

system allows the development of targeted applications and the development of diversified models according to the questions entered[23].

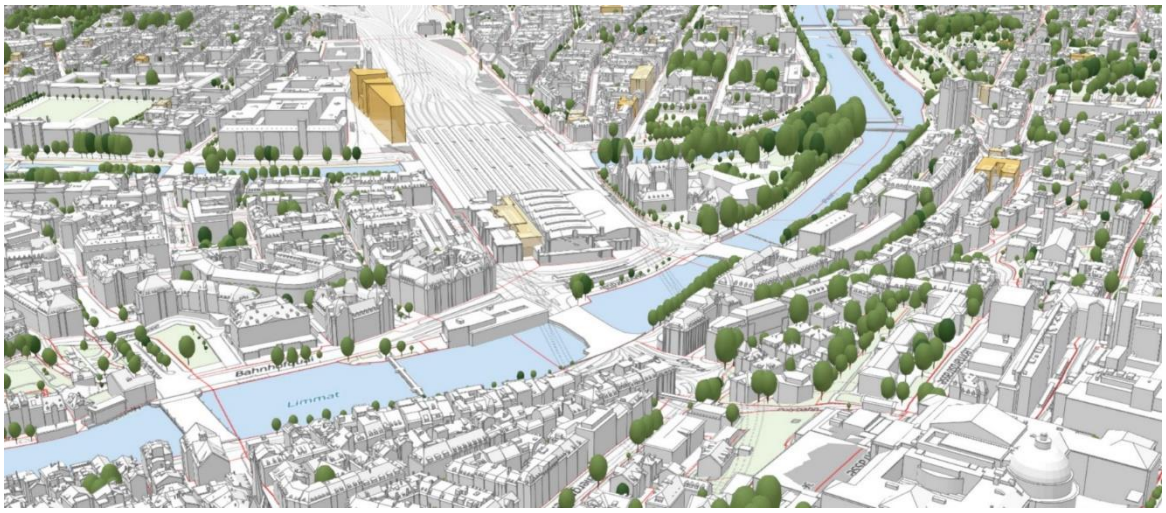


Fig.5 Representation of a 3D model of Zurich

Italian cities towards innovative resilient urban development

In Italy, cities do not yet appear adequately ready in the management of climatic emergencies, structured and efficient in the management of service networks (energy, transport, etc.), and need to design and introduce integrated operating and management systems, including protection, enhancement and enjoyment of the historical-cultural and natural heritage. In any case, here too, the first significant projects were launched: in addition to the city of Bologna which intends testing the first urban digital twin through the collaboration between the University and the city administration, the Department of Engineering, ICT and Technologies for Energy and Transport (DIITET) of the CNR is carrying out the strategic project *Urban Intelligence* (UI), based on an innovative paradigm consisting of an ecosystem of digital technologies aimed at supporting urban governance in achieving the sustainability goals defined by international documents such as the UN Agenda 2030, proposing to identify processes, tools and technologies for resilient urban development [24]. As part of this project, particularly relevant is a complex multidisciplinary work at the center of an experimentation of excellence, that is the DT of Matera, which also involves the House of Emerging Technologies of Matera. The main challenge is to transfer the DT to the urban environment where citizens are clearly the main actors. The goal is to put people at the center so that are both users and providers of information and content (Perna, 2022).

Preliminary concluding comments

This brief review of case studies is obviously not exhaustive but significant, and the next step of the ongoing research will take into consideration the systematization of the other collected, selected and in-depth case studies. Through synthetic tables and matrices, which will be specially elaborated starting from the data

[23] https://www.forumpa.it/citta-territori/il-digital-twin-per-la-pianificazione-urbana-il-caso-di-zurigo/; https://www.stadt-zuerich.ch/portal/de/index/politik_u_recht/stadtrat/weiterepolitikfelder/smartcity/english/ projects/zwilling.html

[24] The project is in line with the current approaches of MIT's "Senseable city" (https://senseable.mit.edu) https://senseableamsterdam.mit.edu/ and New York University's Urban Intelligent Lab (http://www.urbanintelligencelab.org) to think of an intelligence of the city that knows, models, builds scenarios and learns to then orient innovative policies. See also:
http://www.diitet.cnr.it/urban-intelligence/;
http://audis.cervelliinazione.net/dai-soci/il-progetto-strategico-urban-intelligence-del-cnr-diitet-8511/

available for each case study, the twofold objective is pursued, on the one hand, to relate the various challenges identified with the policies, strategies, actions and innovative projects thanks to the new digital technologies, of each city, on the other one, to make a comparison between the case studies to highlight the most relevant aspects of success and any critical issues, as well as emerging trends, and propose a useful virtuous process of mutual learning.

Anyway, at the conclusion of the current paragraph, it clearly emerges that DTs are an innovative tool to increase urban resilience, through a series of different functions, including in a broader sense: knowing the evidence of the territory and prevent emerging damage, with the solution of the modalities of these events, know the evidence of the territory and prevent damage deriving from emerging social, economic and environmental challenges; visualize streets that could become too crowded or busy, that could have significant problems in the event of a cyber-attack, such as a better response to buildings in danger of attack, establish the modalities of these events, direct maintenance interventions to the primary infrastructures and necessary networks for a strong containment of maintenance costs, last but not least, the integration in the Urban Planning practice, in the planning and management phase of plans and projects at different territorial scales.

3. Conclusion. Final remarks and future research directions

In the path undertaken so far, the article has focused and developed the role of New Digital Technologies, with particular reference to Digital Twins (DTs), in increasing urban resilience with respect to the global challenges arising from the exponential growth of the world population, the limitedness of the planet and its resources, and from other interrelated challenges (climate, energy, health, ecological). In this context, building urban resilience is a multisectoral, multidimensional, multi-stakeholder process that requires a clear change of trajectory from previous paths, and integrated urban planning is an essential component and prerequisite for resilient urban futures. In increasingly interconnected urban systems, the ability to predict the effects of perturbative events in real time, crucial for limiting human and economic losses, seems to become a concrete possibility. Big data for cities connects fundamentally different time scales of urban dynamics: the short-term scale of fast or real-time dynamics and the much slower long-term dynamics of urban structure and policies. The potential of urban digital twins for data-based decision making in urban planning therefore lies in our ability to jointly address these two different time scales and to develop conceptual and methodological tools that are able to do so. Another fundamental aspect in the use of big data for urban analysis concerns the social aspects involved in the formation strategies of urban policies,

Over the last decade, a growing number of cities have sought to take advantage of improving frontier technologies and the *smart city* is the most emblematic contemporary expression of the fusion of urbanism and digital technologies. As well as the improving quality and affordability profile of digital technologies, cities now also have a sizeable bank of experience to draw on when determining the best course of action to take and can improve their level of smartness/urban intelligence. As a matter of fact, cities are complex systems, not silos. Planning for more resilient cities and territories entails tackling challenges and creating solutions in an integrated, inclusive, risk-aware, and forward- looking manner. Solutions developed through resilience thinking can allow cities to enjoy multiple benefits, reducing and even helping to prevent the impact of shocks and stresses on the city's people, economy, and physical environment, and improving residents' quality of life. (The Rockefeller Foundation, 2019). This perspective requires the assumption of co-responsibility by politicians and administrators, research and education institutions, the various economic and financial sectors, all citizens. As also stated in the latest World City Report (UN-Habitat, 2022), municipal governments should: 1) align innovation policy and practice with major societal challenges, including climate change, pollution, poverty and inequalities; 2) support the urban agglomeration, and in particular the co-localization of complementary resources and organizations, through territorial and socio-economic planning and regulation; 3) create or support workshops and that involve stakeholders and communities in creating visions and creating scenarios;

4) conduct evaluations of innovation programs to assess impact and ensure feedback for continuous improvement, learning and capacity building. Above all, cultural change is needed in municipalities to show the relevance of digital skills and re-direct their investments and finances towards tailored capacity building programmes. Capacity building programmes can provide effective capacities and resources for improving urban planning, decision making, impact assessment, and change management.

Urban Digital Twins are really useful and effective when used to obtain new information and thus make better decisions, with a view to greater resilience and sustainability. This requires a culture that values informed and data-driven decision making, as well as business procedures that exploit infrastructural DTs. Agreeing with T. Elliot (2020), the advantages for cities thanks to the DTs can be summarized in seven points as follows: 1) Retrieval of information that improves urban infrastructure; 2) Improving collaboration across a broad ecosystem of stakeholders and creating added value for cities and their inhabitants; 3) Improvement of mobility and safety in public spaces, even during the organization of great events; 4) Improvement of urban planning and visualization of projects; 5) Improvement of urban planning and visualization of projects; 6) Involvement of citizenship and creation of a feedback sequence; 7) Adoption of open data initiatives that allow others to design, develop and deliver services based on reliable information about cities and infrastructures.

Though Digital twins are already used today for many purposes, there is still a lot to be experimented with. They can address a variety of spatial scales – territorial, environmental, landscape; building, urban or neighborhoods, regional, national – and a variety of time scales, as they can represent any point in the life cycle of resources, processes and systems, can be static or dynamic and face different time scales (reactive maintenance times, planned maintenance times, capital investment times). The discussions highlighted the need for both digital, i.e., data and ecosystem governance, data analysis, modeling, AI, DT, interoperability, and transversal skills, i.e., cultural change or new ways of working. On *Digital Twins and Digital Cities* held at GWF, 2022 in Amsterdam[25], industry leaders discussed how the latest developments in digitization will empower individuals, governments and citizens alike: a virtuous relationship between urban communities and urban planning and design. The new centrality of cognitive processes, Big Data and ICT, ex ante evaluation of decisions to compare alternative planning hypotheses, predict and anticipate the consequences of human actions changes the relationship with science and power, between technology, politics and the economy, if we consider digital technology as a means at the service of the quality of life and the environment in which we live, towards new knowledge-based urban futures (Campbell, 2012; Carta, 2017; Ratti, 2013).

The spread of DTs is taking on the character of an inevitable phenomenon, supported by the progress of the digital technologies used. Therefore, taking advantage of the experiences gained at the international level by pioneering cities, an increasing number of local public administrations, also in Italy, will look with increasing interest to the DT of their territory, as a valid tool to expand the possibility of creating innovative services to support of decision-making processes and to pursue the resolution of the problems of one's community in harmony with the objectives of sustainable development. Data is the *lifeblood* of decision making, but it is clear that data and the most innovative technologies alone are not enough, the ability to read them and predict future trends in the light of the changes expected from policies is also needed (Giovannini, 2016). Agreeing with Peixoto and Steinberg (2019) great attention must be paid to the fact that emerging new technologies are only as good as the institutions and processes in which they are embedded. What is needed are true institutional upgrades since the full benefits of emerging technologies are unlikely to be reaped under institutions that do not modernize their rules and cultural norms.

Ultimately, we must all probably understand and accept that significant changes are inevitable during periods of transition, such as the current one of the multiple transition (energy, ecological, digital) in the face of *polychrysis*. Flexible skills and capabilities are therefore required for the continuous evolution of digital

[25] https://geospatialworldforum.org/2022/aec.asp

technologies, which however only the human mind could execute and control, in order to increase the resilience of cities and territories to successfully face decisive global challenges, such as climate change.

References

Abdallat, A. for Forbes Technology Council (2022). *Forbes: Formidable Human-AI Relations Can Accelerate Sustainability Efforts*. Posted 13 May, 2022 Los Angeles, CA. Retrieved from: https://www.beyond.ai/news/forbes-formidable-human-ai-relations-can-accelerate-sustainability-efforts/

Al Furjani, A., Younsi, Z., Abdulalli, A., Elsaeh, M., Almahdi, A., Jouil, K., & Lashihar, S. B. (2020). Enabling the City Information Modeling CIM for Urban Planning with OpenStreetMap OSM. In *The Fourth International Conference for Geospatial Technologies–Libya GeoTec 4*.

Angelidou, M. (2017). The role of smart city characteristics in the plans of fifteen cities. *J. Urban Technol.*, 24(4), 3-28. https://doi.org/10.1080/10630732.2017.1348880

ARUP (2019). *Digital twin. Towards a Meaningful Framework*. London: ARUP. Retrieved from: https://www.arup.com/perspectives/publications/research/section/digital-twin-towards-a-meaningful-framework

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

Birks, D., Heppenstall, A. & Malleson, N. (2020). Towards the development of societal twins. *Frontiers in Artificial Intelligence and Applications. 24th European Conference on Artificial Intelligence* (ECAI 2020), 29 Aug - 08 Sep 2020, Santiago de Compostela, Spain. 2883-2884. https://doi.org/10.3233/FAIA200435

Bojanić Obad Šćitaroci, B., Pierantoni, I., Sargolini, M., & Sopina, A. (2021). Fostering holistic natural-risk resilience in spatial planning. *TeMA - Journal of Land Use, Mobility and Environment*, s.i. 1.2021, 155-179. https://doi.org/10.6093/1970-9870/7427

Bolton, A., Butler, L., Dabson, I., Enzer, M., Evans, M., Fenemore, T., ... & Makri, C. (2018). *The Gemini Principles: Guiding values for the national digital twin and information management framework.* Cambridge: Centre for Digital Built Britain and Digital Framework Task Group. https://doi.org/10.17863/CAM.32260

Campbell, T. (2012). *Beyond Smart Cities: How Cities Network, Learn and Innovate*. New York (NY): Earthscan. https://doi.org/10.4324/9780203137680

Caprari, G., Castelli, G., Montuori, M., Camardelli, M., Malvezzi, R. (2022). Digital Twin for Urban Planning in the Green Deal Era: A State of the Art and Future Perspectives. *Sustainability*, 14, 6263. https://doi.org/10.3390/ su14106263

Caragliu, A., & Del Bo, C. F. (2019). Smart innovative cities: the impact of Smart City policies on urban innovation. *Technol. Forecast. Soc. Change*, 142, 373-383, https://doi.org/10.1016/j.techfore.2018.07.022

Carta M. (2017), *Augmented City. A Paradigm Shift*, Trento-Barcelona: List.

Cavalli, L. (2023). Le Città Digitali e la sfida della sostenibilità. *Equilibri Magazine. Rivista per sviluppo sostenibile*, 31 gennaio 2023. Retrieved from: https://equilibrimagazine.it/tecnologia/2023/01/31/le-citta-digitali-e-la-sfida-della-sostenibilita/

Charitonidou, M. (2022). Urban scale digital twins in data-driven society: Challenging digital universalism in urban planning decision-making. *International Journal of Architectural Computing*, 20 (2),238-253. Article first published online: January 10, https://doi.org/10.1177/14780771211070005

Coalition for Digital Environmental Sustainability - CODES (2022). *Action Plan for a Sustainable Planet in the Digital Age*. https://doi.org/10.5281/zenodo.6573509.

De Gregorio Hurtado, S., Olazabal, M., Salvia, M., Pietrapertosa, F., Olazabal, E., Geneletti, D., D'Alonzo, V., Di Leo, S., & Reckien. D. (2015). Understanding How and Why Cities Engage with Climate Policy: An Analysis of Local Climate Action in Spain and Italy. *TeMA - Journal of Land Use, Mobility and Environment*, s.i. ECCA 2015, 23-46. https://doi.org/10.6092/1970-9870/3649

Deng, T., Zhang, K., Shen, Z. (2021). A systematic review of a digital twin city: A new pattern of urban governance toward smart cities. *Journal of Management Science and Engineering*, Volume 6 (2), 125-134. https://doi.org/10.1016/j.jmse.2021.03.003

Economist Impact (2022). *Digital Cities Index. Making digital work for cities: A global benchmarking of urban technology*. The Economist Group. Retrieved from: https://impact.economist.com/projects/digital-cities/2022-executive-summary/

EEA (2020). *EEA Report No 12/2020. Urban adaptation in Europe: how cities and towns respond to climate change.* Luxembourg: Publications Office of the European Union. https://doi.org/10.2800/324620

EEA-European Environmental Agency (2021). *Urban Sustainability in Europe-Opportunities for Challenging Times*. Briefing no. 03/2021, https://doi.org/10.2800/870229

Elliot, T. (2020). Digital Twin, o Gemello Digitale: 7 modi in cui le città possono trarne vantaggio dal loro uso. *Ingenio, Informazione Tecnica e Progettuale*, 17/09/2020. Retrieved from: https://www.ingenio-web.it/28260-digital-twin-o-gemello-digitale-7-modi-in-cui-le-citta-possono-trarne-vantaggio-dal-loro-uso

Elsheikh A. et al. (2021). Integration of GIS and BIM in Urban Planning -A Review, IOP Conf. Ser.: Mater. Sci. Eng. 1090 012128, https://doi.org/10.1088/1757-899X/1090/1/012128

Fistola, R., & La Rocca, R. A. (2014). New Technologies for Sustainable Energy in the Smart City: the WET Theory. *TeMA - Journal of Land Use, Mobility and Environment*, 7(1), 29-42. https://doi.org/10.6092/1970-9870/2267

Galderisi, A., & Ferrara, F. (2012). Enhancing urban resilience in face of climate change: a methodological approach. *TeMA - Journal of Land Use, Mobility and Environment*, 5(2), 69-88. https://doi.org/10.6092/1970-9870/936

Galderisi, A., Limongi, G. & Salata, KD (2020). Strengths and weaknesses of the 100 Resilient Cities Initiative in Southern Europe: Rome and Athens' experiences. *City Territ Archit* 7, 16. https://doi.org/10.1186/s40410-020-00123-w

Giovannini, E. (2016). La rivoluzione dei big data a sostegno dell'Agenda 2030. *Equilibri, Rivista per lo sviluppo sostenibile* 1/2016, pp. 64-69. https://doi.org//10.1406/83553

Grieves M. W. (2014). *Digital Twin: Manufacturing Excellence through Virtual Factory Replication. Digital Twin White Paper.*

Grimm, N.B., Cook, E.M., Hale R.L. & Iwaniec, D.M. (2016). A broader framing of ecosystem services in cities: benefits and challenges of built, natural or hybrid system function. In Seto, K.C., W. Solecki and C.A. Griffith (eds.). *Routledge Handbook of Urbanization and Global Environmental Change*, 202-212, New York: Routledge.

Hollands, R. G. (2015). Critical Interventions into the Corporate Smart City. *Cambridge Journal of Regions, Economy and Society* 8 (1): 61–77. https://doi.org/10.1093/cjres/rsu011

Hudson-Smith, A., Batty, M. (2022). *Ubiquitous geographic information in the emergent Metaverse. Transactions in GIS*. https://doi.org/10.1111/tgis.12932.

IPCC (2022). *IPCC Sixth Assessment Report. Climate Change 2022: Impacts, Adaptation and Vulnerability*. Retrieved from: https://www.ipcc.ch/report/ar6/wg2/

Jiang, F., Ma, L., Broyd, T., Chen, W., Luo, H. (2022). Digital twin enabled sustainable urban road planning. *Sustainable Cities and Society*, 78, art. no. 103645. https://doi.org/10.1016/j.scs.2021.103645

Jones, D., Snider, C., Nassehi A., Yon J., Hicks B. (2020). Characterising the Digital Twin: A systematic literature review. *CIRP Journal of Manufacturing Science and Technology*, Vol. 29, Part A, 36-52, https://doi.org/10.1016/j.cirpj.2020.02.002

Kim, B., Lim, C.-G., Lee, S.-H., Jung, Y.-J. (2022). A Framework of Large-Scale Virtual City Simulation with Land-Use Model. *International Conference on Advanced Communication Technology*, ICACT, 2022-February, 58-61. https://doi.org/10.23919/ICACT53585.2022.9728864

Lee, A., Lee, K.-W., Kim, K.-H., Shin, S.-W. (2022). A Geospatial Platform to Manage Large-Scale Individual Mobility for an Urban Digital Twin Platform. *Remote Sensing*, 14 (3), art. no. 723. https://doi.org/10.3390/rs14030723

Leone, A., Balena, P. & Pelorosso R. (2020). Take advantage of the black swan to improve the urban environment. *TeMA - Journal of Land Use, Mobility and Environment*, 247-259. https://doi.org/10.6092/1970-9870/6851

Leplat, L., da Silva Torres, R., Aspen, D., Amundsen, A. (2022). GENOR: A Generic Platform for Indicator Assessment in City Planning. *Proceedings - European Council for Modelling and Simulation*, ECMS, 2022-May, pp. 245-253.

Luers, A., Garard, J., Clair, A.L.S., Gaffney, O., Hassenboehler, T., Langlois, L., Mougeot, M. & Luccioni, S. (2020). Leveraging Digital Disruptions for a Climate-Safe and Equitable World: The Dˆ2S Agenda. *IEEE Technology and Society Magazine*, 39(2), pp.18-31. https://doi.org/10.1109/MTS.2020.2991495

Lv, Z., Chen, D., and Lv, H. (2022). Smart City Construction and Management by Digital Twins and BIM Big Data in COVID-19 Scenario. *ACM Trans. Multimedia Comput. Commun*. Appl. 18, 2s, Article 117 (June 2022), 21 pages. https://doi.org/10.1145/3529395

Major, P., da Silva Torres, R., Amundsen, A., Stadsnes, P., Mikalsen, E.T. (2022). On the Use of Graphical Digital Twins for Urban Planning of Mobility Projects: a Case Study from a new District in Ålesund, Norway. *Proceedings - European Council for Modelling and Simulation*, ECMS, 2022-May, pp. 236-242.

Mackinnon, D., Burns, R. & Fast V. (2022). *Digital (In)justice in the Smart City*. Technoscience and Society Series. Toronto: University of Toronto Press.

Mergel, I., Edelmann, N., & Haug, N. (2019). Defining digital transformation: results from expert interviews. *Government Information Quarterly*, 36(4), https://doi.org/10.1016/j.giq.2019.06.002

Mills, D.E., Izadgoshasb I, Pudney S.G. (2021). Smart City Collaboration: A Review and an Agenda for Establishing Sustainable Collaboration. *Sustainability*, 13(16):9189. https://doi.org/10.3390/su13169189

Papa, R., Galderisi, A., Vigo Majello M.C., Saretta E. (2015). Smart and resilient cities. A systemic approach for developing cross-sectoral strategies in the face of climate change. *Tema. Journal of Land Use, Mobility and Environment*, *8* (1), 19-49. https://doi.org/10.6092/1970-9870/2883

Papa, R., Gargiulo, C., Cristiano, M., Di Francesco, I., & Tulisi, A. (2015). Less Smart More City. *TeMA - Journal of Land Use, Mobility and Environment, 8* (2), 159-182. https://doi.org/10.6092/1970-9870/3012

Pelorosso, R., Gobattoni, F., Ripa, M.N., Leone, A. (2018). Second law of thermodynamics and urban green infrastructure. A knowledge synthesis to address spatial planning strategies. *Tema. Journal of Land Use, Mobility and Environment, Issue Volume 11*(1), 27-50. http://dx.doi.org/10.6092/1970-9870/5326

Perna, M. (2022). *Matera sogna il suo avvenire tra gemello digitale e blockchain*. On line 04.07.2022. Retrieved from: https://www.wired.it/article/matera-digital-week-blockchain-gemello-digitale/

Peixoto, T. & Steinberg, T. (2019). Citizen Engagement: Emerging Digital Technologies Create New Risks and Value. Washington, DC.: World Bank. https://openknowledge.worldbank.org/handle/10986/32495 License: CC BY 3.0 IGO.

Pultrone. G. (2014). Participation and Governance for More Human Smart Cities. *TeMA - Journal of Land Use, Mobility and Environment*, 7(2), 159-172. https://doi.org/10.6092/1970-9870/2558

Pultrone, G. (2018a), Urban fragilities and resilience strategies. In L. Pignatti P. Rovigatti F. Angelucci M Villani (Eds.). *IFAU 2018. 2nd International Forum on Architecture and Urbanism. Territori Fragili/Fragile Territories. Paesaggi_Città_Architetture/Landscapes_Cities/Architecture*, 440-447, Roma: Gangemi Editore International Publisher.

Pultrone, G. (2018b). What Planning for Facing Global Challenges. In A. Leone & C. Gargiulo (Eds.), *Environmental and territorial modelling for planning and design*, 577-587, Napoli: fedOA Press. https://doi.org/10.6093/978-88-6887-048-5

Pultrone, G. (2020). La sfida del cambiamento climatico come opportunità per rafforzare la resilienza delle città in cammino verso la sostenibilità. Strategie, strumenti, sperimentazioni. In M. Talia (Ed.). *La città contemporanea*, 332-229, Roma-Milano: Planum Publisher. http://www.planum.net/planum-magazine/planum-publisher-publication/citta-contemporanea-atti-urbanpromo-2019

Ratti C. (2013). *Smart City, Smart Citizen*, M.G. Mattei (Ed.), Milano: Egea.

Rosol, M. & Blue, G. (2022) From the smart city to urban justice in a digital age*, City*, 26:4, 684-705. https://doi.org/10.1080/13604813.2022.2079881

Ruston McAleer, S., McAleer, M. and Kogut P. (2021). *Forging the Future of Responsive Cities Through Local Digital Twins*. Last update 30 Sept. 2021. Retrieved from: https://ercim-news.ercim.eu/en127/special/forging-the-future-of-responsive-cities-through-local-digital-twins

Salomon, A. (2021). *Are digital twins the future of urban planning? Digital 3D models can help city leaders plan for the future, but their value will depend on the data*. Published Nov. 1, 2021. Retrieved from: https://www.smartcitiesdive.com/news/are-digital-twins-the-future-of-urban-planning/609232/

Schrotter, G., Hürzeler, C. (2020). The Digital Twin of the City of Zurich for Urban Planning. *PFG 88*, 99–112. https://doi.org/10.1007/s41064-020-00092-2

Söderström, O. (2016). From a Technology Intensive to a Knowledge Intensive Smart Urbanism. In *Beware of Smart People!*, edited by J. Stollmann, K. Wolf, A. Bruck, S. Frank, A. Million, P. Misselwitz, J. Schlaack, and C. Schroder, 63–69. Berlin: Universitatsverlag TU Berlin.

Sustainability in the Digital Age-SDA (2020). *Digital Disruptions for Sustainability Agenda (D^2S Agenda): Research, Innovation, Action. Future Earth*. https://sustainabilitydigitalage.org/d2s-agenda/

Starr, P. (1994). Seductions of Sim: Policy as a Simulation Game. *The American Prospect* no. 17 (Spring 1994): 19-29. Retrieved from: https://www.princeton.edu/~starr/17star.html

Striving for People, Plant and Peace. 2022 JOINT MEDIA PROJECT REPORT (2021). Berlin: The Non-Profit International Press Syndicate. Retrieved from: https://www.sdgsforall.net/documents/Striving_for_People_Planet_and_Peace_2022.pdf

The Rockefeller Foundation (2019). *100 Resilient Cities. Learning from the 100RC Network*. Last access 2022, August 30. Retrieved from: https://resilientcitiesnetwork.org/downloadable_resources/UR/Resilient-Cities-Resilient-Lives-Learning-from-the-100RC-Network.pdf

Topping, D., Bannan, T.J., Coe, H., Evans, J., Jay, C., Murabito, E., Robinson, N. (2021). Digital Twins of Urban Air Quality: Opportunities and Challenges. *Frontiers in Sustainable Cities*, 3, art. no. 786563. https://doi.org/10.3389/frsc.2021.786563

UN-Habitat (2020). *World City Report 2020. The Value of Sustainable Urbanization*. United Nations Human Settlements Programme: Nairobi, https://unhabitat.org/sites/default/files/2020/10/wcr_2020_report.pdf

UN-Habitat (2022). *World City Report 2022. Envisaging the Future of Cities*. United Nations Human Settlements Programme: Nairobi, https://unhabitat.org/sites/default/files/2022/06/wcr_2022.pdf

United Nations Department of Economic and Social Affairs, Population Division (2022). *World Population Prospects 2022: Summary of Results*. UN DESA/POP/2022/TR/NO. 3.

van der Lans, R.F. (2019). *The Fusion of Distributed Data Lakes. Developing Modern Data Lakes. A Technical Whitepaper*. R20/Consultancy, https://www.tibco.com/sites/tibco/files/resources/Whitepaper%20TIBCO%20BigData%20V1.pdf

van Wynsberghe, A. (2021). Sustainable AI: AI for sustainability and the sustainability of AI. *AI Ethics 1*, 213-218. https://doi.org/10.1007/s43681-021-00043-6

Vander Meer, E. (2022). Green Infrastructure Mapping for Adaptation, Biodiversity, and Health and Wellbeing: A Tool Development Case Study in Edinburgh. *Palgrave Studies in Sustainable Business in Association with Future Earth*, 39-62. https://doi.org/10.1007/978-3-030-86803-1_3

WEF-World Economic Forum (2022). The Global Risk Report 2022. Edition 17th. Insight Report. Retrieved from: https://www3.weforum.org/docs/WEF_The_Global_Risks_Report_2022.pdf?_gl=1*a93krw*_up*MQ..&gclid=CjwKCAjw9suYBhBIEiwA7iMhNJ_qkqK1frxmpL_r8ukkKjARJpKeG3iCocp39SjY6Nzs2jwNOG3mUBoCeVsQAvD_BwE

Yin, N., Cai, M. (2022). Urban Road Landscape Design and Digital Twin Simulation Modeling Analysis. *Discrete Dynamics in Nature and Society*, 2022, art. no. 8020549, https://doi.org/10.1155/2022/8020549

Zhao, D., Li, X., Wang, X., Shen, X., Gao, W. (2022). Applying Digital Twins to Research the Relationship Between Urban Expansion and Vegetation Coverage: A Case Study of Natural Preserve. *Frontiers in Plant Science*, 13, art. no. 840471. https://doi.org/10.3389/fpls.2022.840471

Zheng, C., Yuan, J., Zhu, L., Zhang, Y., & Shao, Q. (2020). From digital to sustainable: a scientometric review of smart city literature between 1990 and 2019. *Journal of Cleaner Production*, 258. https://doi.org/10.1016/j.jclepro.2020.120689

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

Image Sources

Fig.1: Centre for Digital Built Britain website, https://www.cdbb.cam.ac.uk/AboutDBB/whatisdbB;

Fig.2: Deng et al., 2021, p.132;

Fig.3: https://codedesign.org/digital-space-singapore-everything-you-need-know-2022;

Fig.4: https://www.geospatialworld.net/prime/lisbons-city-scale-digital-twins-for-flood-resilience-2/;

Fig.5: https://www.stadt-zuerich.ch/ted/de/index/geoz/geodaten_u_plaene/3d_stadtmodell.html.

Author's profile

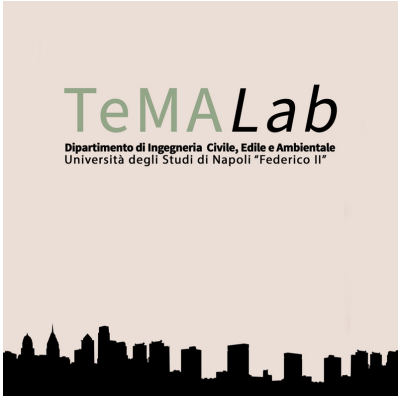
Gabriella Pultrone

Architect, PhD in Planning and Design of the Mediterranea City, Associate Professor in Urban Planning, SSD ICAR/21 - Mediterranea University of Reggio Calabria, National Scientific Qualification as Associate Professor for Scientific Sector 08/F1 - Urban and Territorial Planning and Design. Member of the: Department Architecture and Territory-dArTe; Teaching staff of the Research Doctorate Programme in Architecture; University Quality Committee (PQA). Research topics: Cultural Heritage and Tourism for Sustainable Development; Planning and Design of the Mediterranean City with particular reference to the Adriatic Region and the port city of Trieste; Human Smart Cities; EU Cohesion policy; Social Innovation; Urban and regional planning for the implementation of the Sustainable Development Goals (SDGs) and New Urban Agenda; Mitigation and adaptation to climate change; Urban Resilience; Urban Regeneration; Revitalization of historic minor centres and strategies for peripheral and inner areas. The results of her scientific research are the subject of over one hundred publications including scientific articles, essays on collective volumes and monographs and presented at national and international conferences.

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 (2023) 47-65
print ISSN 1970-9889, e-ISSN 1970-9870
DOI: 10.6093/1970-9870/9736
Received 11th January 2023, Accepted 20th February 2023, Available online 30th April 2023

www.tema.unina.it

Nature-based solution for climate change adaptation and mitigation in urban areas with high natural risk

Proposals of possible measures for a municipality in the Vesuvius area

Giuseppe Mazzeo [a], Salvatore Polverino [b*]

[a] National Research Council - Institute for Studies on the Mediterranean (CNR – ISMed), Naples, Italy
e-mail: giuseppe.mazzeo@ismed.cnr.it
ORCID: https://orcid.org/0000-0001-6204-9940

[b] Department of Architecture and Design
University of Genoa, Genoa, Italy
e-mail: salvatore.polverino@unige.it
ORCID: https://orcid.org/0000-0001-9058-3606
* Corresponding author

Abstract

Nowadays, due to the problematic containment of pollutant emissions worldwide, the process of global warming is inevitable. Moreover, in urban environments, due to the strong anthropisation of the spatial context, these phenomena are often accentuated (e.g. urban heat islands). At the same time, the detrimental effects of the aforementioned process are often combined with other pre-existing risks linked to urbanisation in areas of high natural risk (e.g. hydrogeological and volcanic risk).

In this context, the first examples of the application of measures for adaptation and mitigation of climate change in urban areas are recorded in formulating the latest generation of urban plans. In this respect, natural-based solutions (NBS) are becoming favoured. These measures have a twofold beneficial effect on the urban reality, i.e., adaptation to the effects of climate change and increased renaturalisation of the urban area, with consequent mitigation of other natural hazards.

The present contribution aims to offer an analysis of the main NBSs applicable in an urban context and on different scales (from urban to building) and an applicative example related to their integration into territorial governance tools. In particular, the municipality of Cercola, a territorial context with a high natural risk in the Vesuvian area, has been analysed as a case study.

Keywords

Nature based solution; Adaptation; Urban planning; Sustainable construction techniques; Architectural engineering.

How to cite item in APA format

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

1. Introduction

City and sustainability have become antithetical terms since the industrial revolution. Urban areas have increasingly evolved into an externally dependent ecosystem, i.e., the largest consumer of natural resources and the largest producer of pollution and waste (Mazzeo, 2016; Newman, 2006).

In recent years, global warming has become inevitable, despite numerous international efforts to limit it. The effects and consequences of this process on society and ecosystems can threaten the livability of urban systems, even threatening their survival, e.g. sea level rise in the case of coastal cities (Strauss et al., 2021).

Many phenomena characterise the Mediterranean area, which has become a hot spot of climate change (Lionello et al., 2014). The warming exceeds the global average increase of 20% (Lionello & Scarascia, 2018) and a reduction of precipitation in hot periods (Ulbrich et al., 2006) and sudden and destructive rainfall events (Cramer et al., 2018).

The radicalisation of environmental situations (e.g. climate change, reduction of habitat extent and species quality, modification of ecosystems, etc.) affects urbanised space. The effects are so significant that a rapid change in the planning approaches of cities and territories is required. This process pushes towards a radical rethinking of urban structures (Jenks & Jones, 2008; Mazzeo, 2021).

In this context, planning is thinking in depth about how it has acted in the recent past. The reasoning is also underway on the solutions that can positively affect territories and their ability to change the current paths. Examples of such trends are the fight against land consumption, the renaturalisation of territories, the application of design solutions based on the use of natural practices, the production and use of energy from renewable sources, attention to the natural capital present in territories, and adaptation to the effects of climate change (Balletto et al., 2022; Guida, 2022; Mazzeo, 2013; Pelorosso et al., 2018).

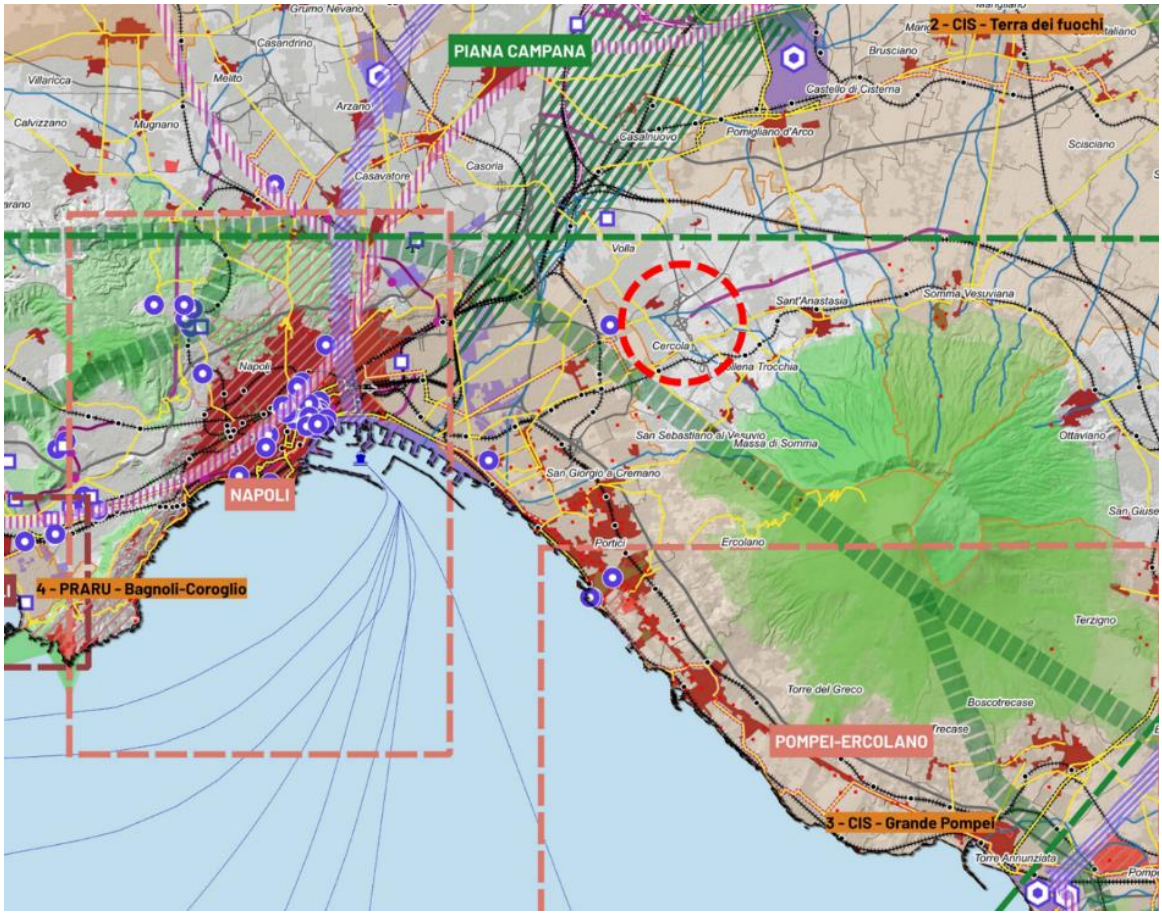


Fig.1 Municipality of Cercola within Metropolitan city of Naples. Extract from Metropolitan Territorial Plan, 2. Preparatory Strategic Scheme (2023)

A significant milestone is transitioning from the theoretical elaboration of principles to their implementation in planning practices.

At the same time, studies on possible applications of NBS for mitigation and adaptation often focus on highly urbanised contexts. As a result, they neglect the small to medium-sized urban realities that form the backbone of the Italian municipal system (ISTAT, 2022).

This paper aims to identify a series of supporting actions for an area at high natural risk in the context of climate change effects, i.e. the Municipality of Cercola located in the Metropolitan City of Naples (Fig. 1). In this respect, a series of actions are proposed to increase the capacity of the urban area to respond to the effects of climate change.

The following sections present the main nature-based solutions compatible with application in the Cercola municipal territory. The relation between applying mitigation and adaptation measures and the strategies outlined in the urban plans is then discussed, highlighting their location in the municipal territory.

2. Methodology

This research aims to present a proposal for applying land naturalisation and climate change mitigation and adaptation measures as an element to be integrated into urban planning (Fig.2).

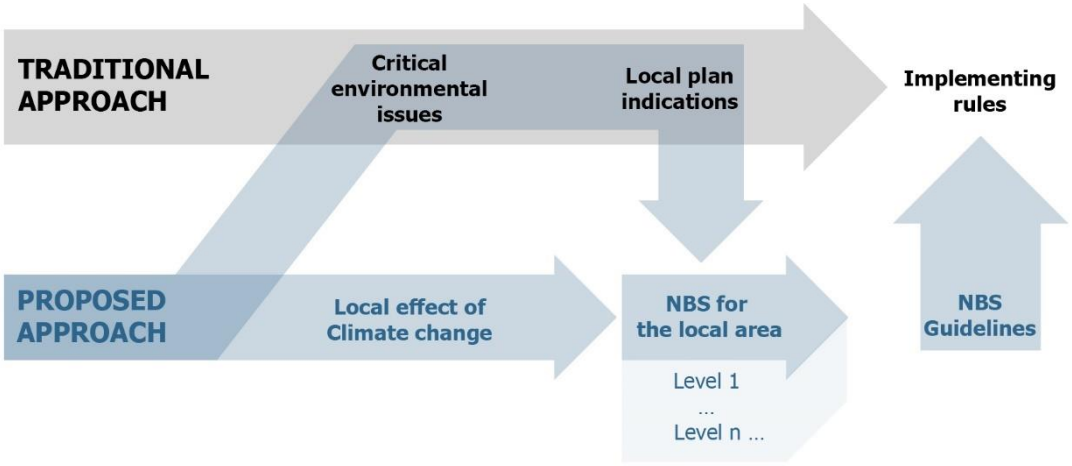


Fig.2 Proposed method for the integration of multiscalar NBSs into Urban plans

In order to achieve this objective, three main stages of research were identified.

In the first phase, the main characteristics of the Cercola territory were identified, and the principal risks and criticalities were analysed. The current territorial plans concerning the municipality and databases on climate and building stock were analysed for a better knowledge of the territory.

Next, the leading Nature-based solutions (NBS) compatible with the territory were analysed. At this stage, there was no intention to carry out a taxonomy of the main measures.

The main NBS measures applicable in the territorial context that can respond to specific criticalities of the territory were selected. The criteria that led to their selection were the following: the size of the intervention, i.e., the interventions range from the building scale to the urban scale; the comparability of the contexts where these measures were applied with the territory studied, i.e., measures were selected whose effectiveness has already been demonstrated in contexts that can be dimensionally compared with the Cercola territory; the feasibility of the intervention, i.e., solutions were selected whose realisation is compatible with the spending capacity of a municipal authority.

Finally, the last phase was formulating guidelines for the location of the identified measures on the analysed territory. The operation was carried out based on the vocational characteristics of the individual areas of the territory in order to define the most compatible and effective solutions.

2.1 Case study

The municipality of Cercola belongs to the Metropolitan City of Naples and is located on its eastern border. It has a population of 17,124 inhabitants (data as of 1 January 2022) with a limited territory (i.e., 4.23 km^2), resulting in a population density of 4,049 inhabitants/km^2. The settlement characteristics are influenced by its proximity to the city of Naples and its position in the metropolitan system. Many specificities characterise the urban area of the municipality of Cercola. The first characteristic consists of a complex system of communication infrastructures formed by medium-speed networks (SS162, SS268) serving the entire metropolitan area and by one of the Circumvesuviana railway lines that crosses the municipal territory from west to east. The intersections of the road networks, in particular, create an infrastructure system that occupies about 10% of the municipal territory.

A second specificity is in the north-western part of the municipal territory, bordering the city of Naples. In this part, there is a system of productive settlements, some of which are currently disused. This feature implies that the area presents significant degradation conditions that negatively affect the remaining urbanised part of the municipal territory. At the same time, there is a potential reserve of urbanised areas strategically located close to an area of Naples where significant transformation projects are underway and planned (Lanzi, 2016).

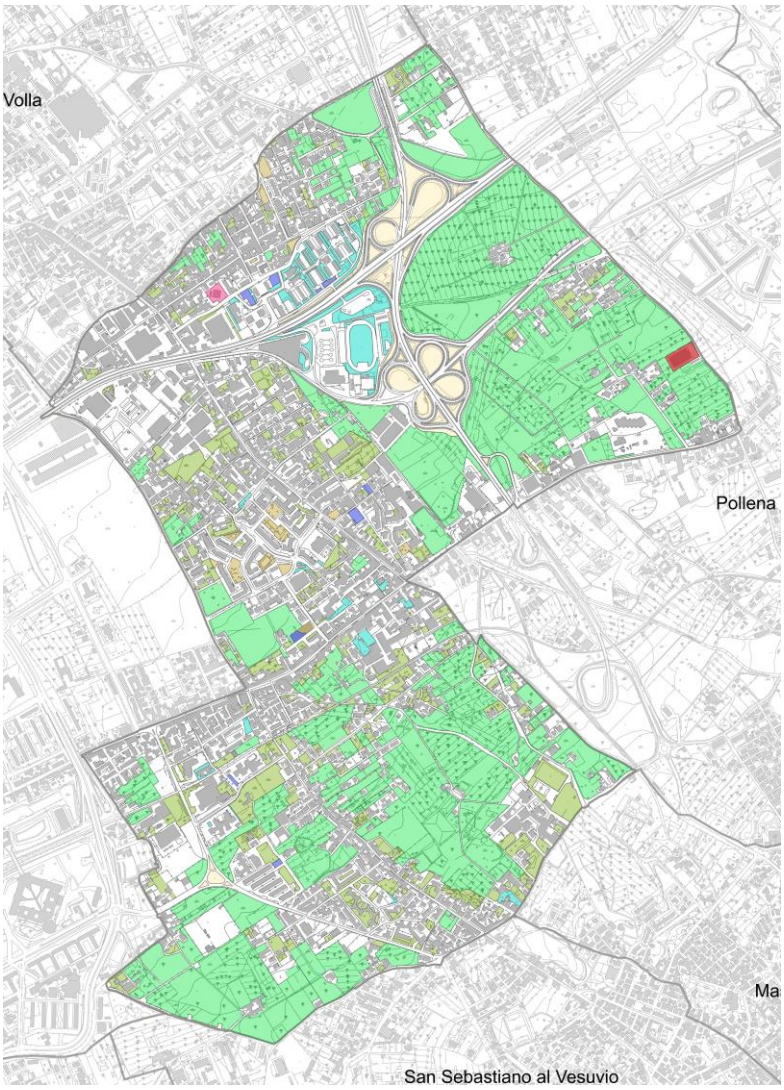


Fig.3 Municipality of Cercola. Ecological equipments present on the municipal territory

A third feature concerns the southern part of the municipality of Cercola, which is placed within the territory of the 'Piano Paesistico del Vesuvio' (Vesuvius landscape plan). Plan restriction should have protected the natural and agricultural characteristics of this part of the territory, which has all the features of the Campania Plain. However, despite the objectives, the protection of the territory has been partial. Diffuse settlement processes have occurred in the area, causing a significant fragmentation of the natural and agricultural fabric and, consequently, an overall loss of environmental quality.

The specificities mentioned above have negatively affected the urbanisation levels of the municipal territory. In this regard, according to ISPRA's 2021 data (ISPRA, 2022), reported by the web mapping of the Regional Environmental Protection Agency of Piedmont, soil consumption in the municipality of Cercola stands at the elevated value of 55.3%, well above the national (7.1%) and regional (10.5%) averages, which are already significantly high (Papa & Mazzeo, 2014).

Considering the critical issues outlined above, drafting the Municipal Urban Plan sought to respond systemically to the main problems in the area. The objectives identified are as follows:

- improvement of urban accessibility;
- increase of urban-territorial service facilities and simultaneous extension-modernisation of productive and tertiary activities;
- implementation of commercial activity;
- regeneration of the historical centre and environmental enhancement of the green system and agricultural parks;
- revitalisation of disused production sites;
- redevelopment, recovery and valorisation of the settlement structure.

A reading of the objectives shows that, although they cover diverse issues, they strongly focus on aspects related to environmental quality (Fig.3). Therefore, their transposition into the plan can have a particular impact on increasing the quality of the settlement fabric and must be coordinated with the indications and forecasts concerning the protection and quality of the natural system and agricultural landscape.

The municipal urban plan has focused on a project to increase the quality of the existing urban fabric, considering that the municipal territory cannot receive additional population; in this regard, it is within the perimeter of the High Volcanic Risk Zone due to its proximity to the volcano Vesuvius. Therefore, the interventions envisioned by the plan are to be implemented using interventions on existing buildings and infrastructures. In addition, another strategy concerns incremental action on specific environmental indicators affecting the adaptive capacity of the municipal territory. Therefore, one of the thematic studies within the Municipal Urban Plan focuses on the types of Nature Based Solutions to be applied in the requalification, regeneration and urban maintenance actions of Cercola's territory. This study, written by the Authors, is presented in detail in the following paragraphs.

3. Climatic/environmental framework of the case study

The analysis of the environmental and climatic peculiarities and criticalities of the Cercola area allowed the outlining of NBSs compatible with the territorial context.

The Cercola territory is closely characterised by the presence of natural and anthropic risks that highlight the territory's high vulnerability (Metropolitan City of Naples, 2013). The main natural criticalities that threaten the Cercola territory are related to volcanic, seismic, geomorphological and hydrogeological risks.

The main natural risk is the proximity of the municipal territory to the volcano Vesuvius. The short distance from the volcanic massif puts the municipality at risk of lava and pyroclastic flows (Red Zone of the Civil

Protection Emergency plan[1]); as a result, the territory is subject to specific sector plans aimed at decongesting the urban fabric (e.g. Strategic Operational Plan - Campania Region, 2006) [2]. Existing volcanic risk plans imply that new constructions for residential purposes are forbidden and that only productive, commercial, and public utility uses are allowed.

Regarding hydrogeological and geomorphological risk (Autorità di Bacino Distrettuale dell'Appennino Meridionale, 2015), documentation from the basin authorities shows that the municipal territory is not subject to landslide risk but to hydraulic risk. The surface hydrographic network of the municipal territory is characterised by the presence of two 'lagni' (i.e., canals), Pollena and Trocchia.

The hydro-geomorphological risk in the Cercola area is mainly linked to environmental and ecological degradation. Points classified as very high and moderate risk are located near the filled watercourses. In this case, the plans prescribe measures that do not increase the hazard characteristics (Autorità di Bacino Distrettuale dell'Appennino Meridionale, 2015). In recent years, intervention in the surface water network has been combined with massive soil sealing due to urban expansion. This phenomenon affects groundwater recharge and leads to increased water volumes for sewage disposal systems (Scalenghe & Ajmone-Marsan, 2009). The critical nature of the issue is evidenced by intervention indications in other territorial plans (Campania Region, 2002) that prohibit further sealing of open areas, prescribing filter paving.

Critical issues related to anthropogenic activities are ecological-environmental degradation, weakness of the infrastructure network, morphological-settlement degradation, urban discomfort and loss of agricultural-natural land.

The ecological-environmental degradation concerns the land use of the municipal territory. In particular, there is an evident prevalence of urbanised land (256 ha), while only a small part still has agricultural connotations (148 ha). Moreover, the agricultural land is fragmented throughout the territory and, together with the 19 ha that present natural characteristics represent the only portions of land that have survived the massive urbanisation that began in 1960 (Municipality of Cercola, 2019).

Rapid and uncontrolled urbanisation has triggered critical issues concerning road infrastructure and the built fabric. The road network constitutes the primary source of morphological settlement degradation and the principal source of noise disturbance and pollution from vehicle traffic. However, in recent years, the impact of traffic has yet to be the subject of intervention, as witnessed by the absence of specific measures to mitigate the phenomenon, i.e., buffer strips (Metropolitan City of Naples, 2013). In addition, the urban road system is also affected by the lack of parking areas, which currently fall short of the minimum allocation required by law (Municipality of Cercola, 2019).

The building fabric has been characterised, as in neighbouring municipalities, by intense building growth that has distorted the original agricultural vocation of the area (Metropolitan City of Naples, 2013). According to the age of construction and building characteristics, the urbanised territory can be divided into four types of settlements: the historic "core" city, the linearly dispersed historic city, the newly formed city, and the agricultural city (Municipality of Cercola, 2019). The unevenness of the building fabric is evidence of how the municipality presents, at the same time, peculiarities of a centre in a highly urbanised metropolitan area and of an environment that is still rural (Metropolitan City of Naples, 2013).

Morphological and settlement degradation and urban discomfort are linked to criticalities such as limited access to public facilities, e.g. public green spaces. The criticalities inherent in the built fabric are evidence of the unbalanced nature of the built fabric, the result of a lack of a unitary settlement rule, which has led to the maximum exploitation of building lots. In addition, the speculative logic has led to the construction of

[1] Updated by Regional Law no. 21, "Norme Urbanistiche per i comuni rientranti nelle zone a rischio vulcanico dell'Area Vesuviana".

[2] Guideline of the President of the Council of Ministers of 14 February 2014 entitled "Disposizioni per l'aggiornamento della pianificazione di emergenza per il rischio volcanico del Vesuvio" (GU n.v108/2014).

buildings of low architectural quality, which are characterised by reinforced concrete and load-bearing masonry structures (ISTAT, 2011).

At the same time, in recent years, there has been a considerable increase in brownfield sites (Municipality of Cercola, 2019), which are portions of territory that can be used as a driving force for economic development. A fraction of the Cercola municipal territory is still used for agricultural purposes. The rural territory can be subdivided into two main areas: the first is hilly, close to the built-up area in the southern part of the territory, and the second is linked to Monte Somma, an element of the Vesuvius volcanic complex. Due to its peculiarities, agricultural activity is based on orchards, a type that enriches the biodiversity of the area and is less impacting than intensive farming (e.g. wheat, maize, etc.). (Metropolitan City of Naples, 2013). Currently, the loss and fragmentation of the agricultural fabric emerge, which is not linked to a change of use at the planning level but to a progressive abandonment and reduction of agricultural land use.

The current state contrasts with the potential of the sector, which is characterised by territorial excellence that can represent a resource for the economic development of the area (Municipality of Cercola, 2019).

Closely linked to agricultural land are the areas for naturalistic purposes, which cover a total of 19 ha. These are primarily bushes and scattered trees that contribute to the networks of natural connections. The natural areas form a buffer zone between the urban centre (i.e., building fabric and infrastructure networks) and the agricultural areas (Metropolitan City of Naples, 2013). In addition, the Cercola area also lies along the Tyrrhenian corridors for migratory avifauna. These areas are progressively threatened by anthropic actions (fires, groundwater pollution, etc.) that threaten their existence.

The protection and enhancement of natural areas is a priority highlighted by territorial planning (Campania Region, 2008), which can take place through the reconstitution of an ecological network using operations to restore environmental continuity. The protection operation is of primary importance since the municipal territory is on the edge of the Vesuvius National Park and is particularly important in protecting biodiversity and the ecosystem.

Another critical aspect of the territory linked to human activities that threatens the local ecosystem is environmental pollution, which affects the state of air and water. Air pollution in the Cercola area is mainly linked to vehicle traffic and PM10 emissions, the maximum value of which has been exceeded several times in recent years (e.g. 36 times in 2022) (ARPAC, 2022). Air quality is consistent with that characterising the Naples metropolitan area, identified as a 'rehabilitation zone', i.e., a territory where the threshold values of pollutants are exceeded several times during the year (Campania Region, 2005).

Water pollution affects the hydrographic network of the adjacent Campania plain. In particular, like other centres in the Vesuvian area, the pollutants are nitrates from agricultural activities and runoff from urban roads (Campania Region, 2019).

Lastly, in addition to the critical issues highlighted above, there are also meteorological phenomena linked to the effects of climate change. The Cercola territory, like the Neapolitan metropolitan area, will be increasingly affected by rising summer temperatures and heat island phenomena, more prolonged droughts and extreme rainfall phenomena (Metropolitan City of Naples, 2022). The main measures for the municipal area to cope with present and future criticalities are presented in the next section.

4. Identification and classification of the suitable NBSs

The second phase of this work was identifying possible nature-based solutions for climate change adaptation and mitigation for the municipality of Cercola.

As known, among the strategies to cope with the effects of climate change, those aimed at adaptation and mitigation are among the most widely adopted. These two concepts are often confused, but they present different approaches to the same problem; in fact, mitigation involves acting on the causes of climate change in order to avoid worse effects, e.g. interventions to improve energy efficiency in order to reduce the

consumption of the building stock for heating and cooling. On the contrary, adaptation focuses more on effects by defining strategies to limit the potentially destructive consequences of climate change effects, e.g. the use of measures to face cloudbursts due to Mediterranean climate tropicalisation (IPCC, 2022). Recently, measures for adaptation and mitigation defined as nature-based (NB) have been reported in the literature (Johnson et al., 2022). Their name is due to their low environmental impact and contribution to the renaturalisation of the urban territory. Generally, these measures can be classified into mitigation measures (e.g. urban farms that optimise resources by cutting pollutant emissions related to goods transport) and adaptation solutions (e.g. urban green areas that limit UHI). However, often the division into two families is not very clear-cut as some elements can be considered "mixed" and whose beneficial effects of their adoption can be exploited for both adaptation and mitigation. Among these, a significant example is the use of the green envelope of buildings, as it improves the energy performance of buildings and, at the same time, mitigates extreme phenomena such as UHI. As mentioned in section 2, this work does not intend to produce a generic taxonomy of all NBSs, which has already been extensively addressed in the literature (Fan et al., 2017; Zoppi, 2020). Instead, starting from an analysis of the state of the art of the subject and exploring the potential and limitations of the solutions, the main NBSs compatible with the case study were identified and classified according to their effect (e.g. mitigation and/or adaptation). In particular, the scale of intervention, similar PUC objectives and case studies reported in the literature in contexts similar to the municipality of Cercola were considered primary criteria for the choice.

The identified solutions were divided into three main categories according to the scope scale: 'building scale', 'urban public space and efficient water management' and 'natural and rural areas'. The chosen criteria are derived from analysing the PUC's transformation objectives and responding to specific actions.

The NBS solutions for adaptation and mitigation to climate change at the building scale (Tab. 1) selected act mainly on the building envelope, favouring its naturalization, with a re-greening process as highlighted in the territorial plans (Metropolitan City of Naples, 2022).

This category includes green roofs, a widely established solution in the Mediterranean climate that has evolved into solutions such as urban farms and wetland roofs in recent years (Zehnsdorf et al., 2019). Urban farms respond to the need to strengthen social communities in an urban environment and optimise the food production cycle, i.e., the time and impact of transport are reduced (de Oliveira et al., 2021). Wetland roofing, on the other hand, is a system that combines the benefits of a green roof with better rainwater management, i.e., it allows rainwater to be stored and does not overload urban drainage systems (Petreje et al., 2023).

Another intervention at the building scale is the construction of so-called green walls, which involve installing elements employing plant organisms to mitigate phenomena such as the urban heat island (UHI) (Susca et al., 2022) and improve air quality (Ysebaert et al., 2021).

Many green wall systems are currently applicable in the Cercola context: from climatic façades, i.e., the installation of rows with creepers (Chàfer et al., 2021), to more complex systems, e.g. living walls (Susorova, 2015); the latter involve the installation of felts in which tree essences are grown, fed by hydroponic irrigation systems, which allow considerable water savings (Kazemi et al., 2020).

At the building scale, in addition to the measures already shown, there are home gardens, easy-to-implement solutions that have less impact on urban comfort but affect indoor ones (Zhang et al., 2021). Lastly, a further solution working at the building scale is the installation of vertical farms, which can contribute to the reuse of disused production areas (Boganini & Casazza, 2017); this measure has a low environmental impact, i.e., it cuts transport emissions and optimises the necessary water resources (Naskali et al., 2022).

The solutions at the building scale meet the PUC's transformation objectives, e.g. regeneration of the historical centre and redevelopment, recovery and valorisation of the settlement structure. Furthermore,

they are compatible with the specific objectives of the territorial plans, such as improving the quality of the public-private building stock and improving the energy efficiency of buildings (Karimi et al., 2022).
For the population, the presence of green elements also contributes to meeting the plan's objectives concerning the quality of life within the city. They act on the outdoor comfort in case of extreme events and on the psychophysical well-being of citizens (van den Berg et al., 2017). In the agricultural sector, through careful control of their function, vertical farming meets the inherent objective of improving the quality control of production systems (Kozai et al., 2019). Roofing measures, especially wet zone green roofs, meet the objectives of spatial plans regarding the hydrosphere, acting on the desire to reduce water consumption (Lubna et al., 2022).
Nature-based solutions for urban space were selected because they can address present (e.g. lack of public green space) and future (e.g. UHI and drought) problems in the Cercola area.
The measures identified on the urban scale (Tab.2) can act on the naturalisation of the urban environment, mainly increasing the presence of greenery, favouring proper water resource management, or acting on both aspects (Bayulken et al., 2021). Furthermore, the solutions identified can concentrate on specific areas (e.g. gardens) or have a more linear course corresponding to the road axes present (e.g. trees and roadside flowerbeds).
In the first case, we have interventions such as gardens and urban gardens that contribute to the improvement of public services, at the same time naturalising the territory. This criticality is present and highlighted in urban plans (Municipality of Cercola, 2019). Furthermore, there can be composite solutions where several solutions are combined in order to improve their effect on the built-up area. Bioswales, for example, whose primary purpose is the filtration and accumulation of rainwater using proper stratigraphy (Ekka et al., 2021), can be employed in urban or community gardens, also improving soil fertility (Brodsky et al., 2019). Furthermore, the symbiotic use of two identified solutions can lead to developing further nature-based hybrid solutions, e.g. raingardens (Morash et al., 2019).

Field of application	Solution	Typology	Objectives of the urban plan	Reference
Building scale	Green roof	Adaptation Mitigation	Ensuring the quality of living within the city. Improving the quality of the building stock. Increasing energy efficiency. Reducing water consumption.	de Oliveira et al., 2021; Zehnsdorf et al., 2019
	Green wall/ living wall	Adaptation Mitigation	Ensuring the quality of living within the city. Improving the quality of the building stock. Increasing energy efficiency.	Susca et al., 2022; Susorova, 2015
	Domestic gardens	Adaptation	Improving the quality of the building stock. Ensuring the quality of living within the city.	Zhang et al., 2021
	Vertical farming	Mitigation	Improving the quality of the public and private building stock. Regenerate degraded urban areas. Subjecting agricultural production to quality control systems. Increasing energy efficiency.	Boganini & Casazza, 2017; Naskali et al., 2022

Tab.1 Nature-based solutions at building scale for Cercola Municipal territory

Considering the peculiarities of the territory and the saturation of the urban soil, further NBS considered and analysed for their possible use on the territory concerns roads. In this context, naturalisation can take place on different levels. In this respect, this can involve the green system (e.g. tree rows), thus improving the urban microclimate by mitigating the effects of the UHI in the warmer months (Elliott et al., 2020). Another

effect of climate change that can be mitigated with NBS on the street axis is cloudburst management. Indeed, stormwater can be managed by filtering flowerbeds and road surfaces that avoid flash floods and contribute to their storage to cope with dry periods (DeBusk et al., 2010). A further solution that intervenes in urban mobility is the naturalisation of public and private parking areas by combining microclimate improvement with the maintenance of soil permeability (Tong et al., 2022).
The selected NBSs act on individual aspects identified by the PUC. In particular, they contribute to achieving transformation objectives, e.g. the environmental improvement of the green system and indirectly affecting the urban mobility system. The measures identified also impact multiple specific objectives identified by the urban plans. Regarding the population, elements such as the construction of community and urban gardens contribute to the allocation of public green space (Wolch et al., 2014).

Field of application	Solution	Typology	Objectives of the urban plan	Reference
Public space and rainwater management	Bioswale	Adaptation	Ensuring the quality of living within the city. Reducing the hydraulic risk factors.	Ekka et al., 2021
	Roadside trees	Adaptation Mitigation	Regenerate degraded urban areas.	Maher et al., 2013
	Green parking lot	Adaptation	Regenerate degraded urban areas.	Tong et al., 2022
	Community gardens	Mitigation	Ensuring the quality of living within the city. Ensure adequate areas for public facilities and green and collective spaces.	Wolch et al., 2014
	Urban gardens and flowerbeds	Adaptation	Ensuring the quality of living within the city. Ensure adequate areas for public facilities and green and collective spaces.	DeBusk et al., 2010
	Filtering floor	Adaptation	Reducing the hydraulic risk factors. Maintaining aquifer recharge capacity.	Ahmad et al., 2017

Tab.2 Nature-based solutions for public space and rainwater management for Cercola Municipal territory

Including green elements such as gardens and roadside trees can also improve the quality of the urban fabric, acting on the redevelopment of degraded urban areas (Ghose & Pettygrove, 2014). On the other hand, NBSs for avenues meet the objective of increasing the quality of the road network since the use of filtering pavement can contribute to reducing accidents (Tsubota et al., 2018). At the same time, the use of tree planting along roads can contribute to an improvement in air quality by reducing pollutants and traffic noise (Maher et al., 2013).
In addition, bioswales, green parking lots, and filtering floors contribute to the objective of maintaining and improving water resources. As mentioned above, these help limit hydraulic risk elements (Ahmad et al., 2017) and contribute to a reduction in water consumption by favouring the storage of rainwater and its use for irrigation of green and agricultural areas.

Field of application	Solution	Typology	Objectives of the urban plan	Reference
Natural and rural area	Community composting	Mitigation	Turning waste into a resource	Cai et al., 2019
	Phytoremediation	Mitigation	Regenerate degraded urban areas. Reclaiming polluted sites	O'Connor et al., 2019
	Tree/hedges fence	Adaptation	Preserving biodiversity and maintaining ecological connections Enhancing and protecting natural habitats	MacDonald & Johnson, 1995

Tab.3 Nature-based solutions for natural and rural area for Cercola Municipal territory

Finally, thanks to their filtering action, the bioswales also contribute to eliminating pollutants by purifying the first rainwater runoff from urban pavements (Purvis et al., 2018). At the same time, even within the geosphere identified by the PUC, the chosen measures maintain and improve the quality and permeability of soils, preserving the recharge capacity of the aquifer (Oral et al., 2020).

The selected solutions for natural and agricultural areas are measures aimed at re-naturalising the Cercola area and are characterised by limited land consumption. While common effects (e.g. mitigation of the urban microclimate) are identified for the measures on a building and urban scale, the measures for the rural and natural context differ in the object and beneficial effects of their intervention. Indeed, these intervene in a purely rural environment (e.g. trees as fences) or in a peri-urban context (e.g. phytoremediation and composting plant); moreover, they concern anthropised areas (e.g. brownfield rehabilitation and waste cycle), while the benefits of installing trees for fences concern more the animal and plant sphere (MacDonald & Johnson, 1995).

Also, for the natural and agricultural context, selecting suitable NBSs was guided by correspondence with the general and specific objectives defined by the PUC. Moreover, the selected interventions are non-invasive and respect the restrictive indications of the territorial plans for natural and agricultural areas. In particular, the installation of composting facilities is consistent in turning waste into a resource (Mamun et al., 2020). Furthermore, such measures contribute to the circularity of the city's economy as it is possible to obtain both fertilisers for agriculture (Cai et al., 2019), fulfilling another objective of the urban plan.

The use of phytoremediation, on the other hand, acts on disused environments by contributing to the objectives of the redevelopment of degraded landscapes and reclamation of polluted sites, as well as contributing to the renaturalisation of post-industrial spaces (O'Connor et al., 2019). Lastly, planting trees as natural fences for agricultural land works more on the aspects identified by the PUC for the biosphere by enhancing natural habitats and ecological connections (Hinsley & Bellamy, 2000).

5. Selected NBS proposals for the Cercola municipal area

NBS adaptation and mitigation measures, as seen in previous chapters, allow for an increase in the resilience of the anthropised environment concerning the extreme effects of climate change (e.g. UHI, the tropicalisation of the climate in the Mediterranean area, etc.) (Bianchi, 2007).

The application of NBSs in the Cercola municipal territory can affect the evolutionary trajectories identified by the environmental report of the Strategic Environmental Assessment (SEA) of the PUC (Municipality of Cercola, 2019). In this regard, the proposed interventions can impact agricultural land, biosphere and hydrogeological risk zones, contributing to the sustainable development of the Cercola territory.

The peculiarities of the area itself can also be considered NBS measures for adaptation and mitigation. In particular, the presence of the Vesuvius National Park near the urban centre can be categorised as a peri-urban park (i.e., carbon sink) (Marchetti et al., 2012). Moreover, thanks to the wooded area and the provision of a series of measures (e.g. optimising ventilation from the green area towards the built-up area) (Hou et al., 2018), this element can improve the urban microclimate by mitigating excessive urban summer overheating.

The present paragraphs outline the major NB adaptation and mitigation measures to be adopted on "Transformability Areas" identified by the new PUC (Fig. 4), i.e., macro-areas with unitary morphological and functional characteristics and specific transformation objectives.

5.1 Zone 1

In the proposal for the Territorial Coordination Plan (PTC) of the Province of Naples, this portion of the territory is classified as an area of particular agronomic importance. The PTC classification binds the PUC to safeguard current agricultural uses, prohibiting further uses. In particular, the plan requires recovering the

typical elements of the historical agrarian landscape and preserving the environmental value with eco-compatible production systems. In addition, analysing what is indicated in the local basin authority plan (Autorità di Bacino Distrettuale dell'Appennino Meridionale, 2015), in the territory falling within TA1, there are elements and areas of high and medium criticality from the hydrogeological point of view and a buffer zone according to R.D. 3267/23.

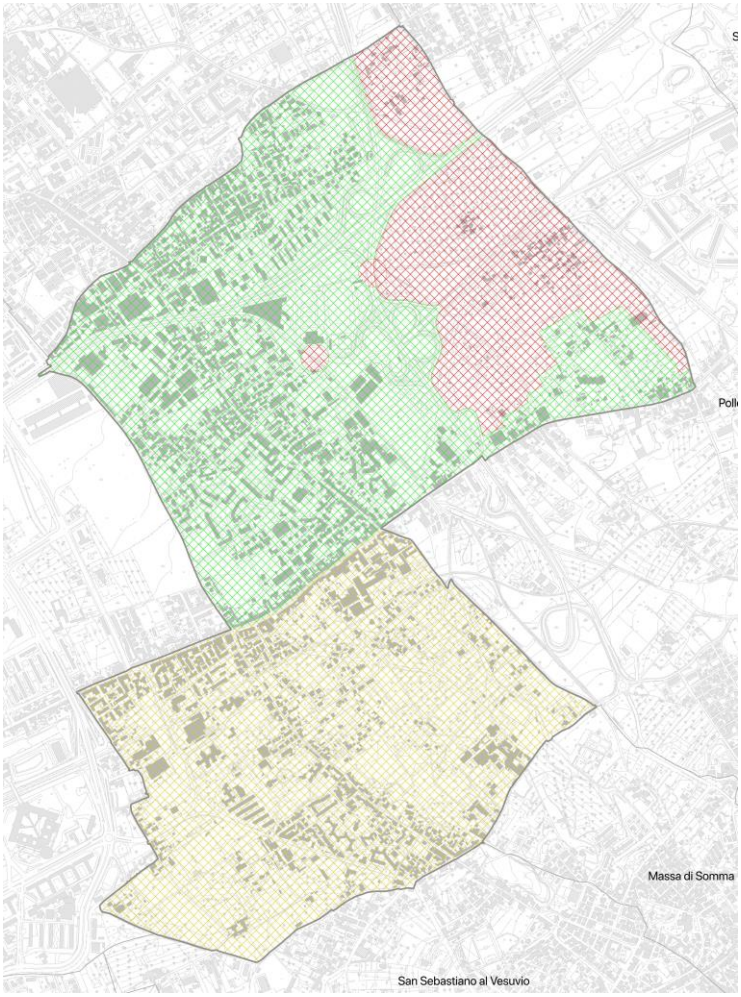


Fig. 4 Municipality of Cercola. Transformability areas related to the comprehensive quality of the territory

The mitigation and adaptation interventions applicable to the territory of TA1 mainly concern the agricultural areas and the hydrogeological structure of the territory. Due to the specific characteristics of the area, the only admissible interventions are mainly aimed at the maintenance and conservation of the existing structures in order to enhance and requalify the agricultural landscape.

For agricultural areas, the types of measures that can be adopted are mainly aimed at protecting biodiversity in the rural environment. For example, a first measure may consist of using lot delimitation systems employing natural elements (e.g. trees, shrubs, etc.) that can provide a refuge for local fauna[3]. In addition, measures may concern the end-of-life of agricultural products. These include sites for the installation of community composters in order to use production waste to obtain compost[4].

Another element that emerges is that there are currently no public green areas in TA1 despite the presence of an urban residential fabric. A possible solution is to envisage the reuse of abandoned uncultivated areas

[3] Together with the installation of punctual shelter elements, e.g. beehives and bird houses. The measures contribute to maintaining the naturalness of the Cercola area as an ecological corridor.

[4] To be used as fertiliser in the fields.

for the establishment of community farms, i.e. green spaces serving residents following the territorial vocation of the area.
Other measures that can be implemented in the area concern adaptation to extreme weather phenomena related to hydraulic risk, i.e. cloudbursts. In particular, thanks to the agricultural character of the area, it is possible to make bioswales to collect and filter rainwater. The collected precipitation can be used to irrigate crops and avoid overloading the drainage system. Further intervention may consist of installing filtering soils in areas of maximum hydrogeological criticality to ensure a rapid and efficient flow of rainwater. Furthermore, if water purification is required for irrigation purposes, ponds can also be provided to help eliminate toxic and polluting substances from grey water and first flush rainwater.

5.2 Zone 2

The portion of the municipal territory (North-South Axis) regulated by the Landscape Plan (Piano Paesistico) falls within Transformability Area 2 (TA2) and is characterised by naturalistic value and agricultural-productive character. The interventions allowed for the area with a strictly environmental character are the conservation and maintenance of the existing infrastructure. In particular, the only possible spatial operations concern the extension of the pedestrian and vehicular road network. For the built-up area in TA2, the following actions are identified: restoration and conservative renovation, building refurbishment with volume increases for hygienic and functional adaptation and the construction of new public facilities.
As seen for TA1, in TA2, there are elements of environmental criticality due to anthropic pressure that threaten the biodiversity and naturalness of the area. In this regard, further constraints on the area are due to the indications of the Piano Paesistico dei Comuni Vesuviani, which divides the TA2 into two main areas. The plan defines the following zones: Integral Protection with Environmental Landscape Restoration (PIR) and Urban-Building Recovery and Environmental Landscape Restoration (RUA).
Considering the specific restrictions of the area, feasible climate change mitigation and adaptation measures are limited to non-invasive actions. Regarding works on a building scale, only solutions that do not alter the volume of existing buildings may be applied. Possible actions include the development of home gardens, to be implemented considering the landscape protection criteria present, e.g. respect for panoramic viewpoints. Furthermore, installing green roofs can be a possible intervention on existing buildings, but only by extensive systems or 'wetland' covering. The types of green roofs indicated are limited to encouraging the growth of grass and small shrubs on the surface to improve the urban microclimate and optimised water management without altering the field of vision from panoramic viewpoints. Finally, the installation of urban farms dedicated to cultivating traditional crops can take place, but without the construction of service structures such as greenhouses.
Mitigation and adaptation measures concerning public space are allowed and can be operated in multiple aspects. Planting urban trees in the road network buffer strips can be a valuable resource for buffering the busiest arterial roads. Redevelopment of the road network can be an opportunity to use systems that allow greater soil permeability and better stormwater management in the event of extreme events. The requalification of the road network must take place with self-locking elements to maintain the indications of the territorial plans regarding the use of traditional and stone materials. Finally, a valuable operation for upgrading the roadway can be the installation of flowerbeds, which can be built with layers to absorb rainwater for future use for irrigation and other non-domestic purposes.
The analyses carried out for the urban plans show that Transformability Area 2 lacks public green spaces. The creation of green areas for residential use can be done by improving the urban microclimate. In this regard, urban gardens (e.g. arid gardens, sensory gardens) and community gardens can be realised in TA2 to cultivate tree essences typical of the agricultural tradition of the area. However, interventions in urban green areas are always to be realised by providing nature-based systems that allow rainwater storage.

Besides, in the portions of the TA2 territory that fall within the PIR zones, interventions on public spaces that alter the pre-existing course of the terrain (e.g. bioswales, channels, etc.) are not allowed.
Considering the restrictions of the plans, only natural fences (shrubs, linear trees, etc.) can be built in agricultural areas. Another feasible NBS is the construction of a system for the valorisation of agricultural production waste and part of the wet fraction of urban waste through sites for the collection of material for biomass production. In addition, sites can be provided for installing community composters to obtain fertiliser.
Finally, shelters for insect (beehives, insect farms, etc.) and migratory birds can be installed in the rural context to protect the biodiversity of the site and the existing eco-corridor.

5.2 Zone 3

The PUC identifies Transformability Area 3 (TA3) as the portion of the municipal territory to the northwest, which is characterised by medium transformability. In particular, the interventions allowed are the maintenance and conservation of the existing, urban restructuring and the extension of volumes with new constructions for non-residential purposes. Compared to the other two transformability areas, the greater freedom of action is due to fewer restrictions and a low vocational connotation, i.e., TA3 is made up of uncultivated areas and recently formed residential settlements.
The area includes the urban fabric close to the municipality of Volla and the main roads in the Cercola area[5]. The road network separates TA3 from TA1, which has an agricultural nature. In the vicinity of the road junction, there is a rainwater harvesting basin in TA3 where filled channels of the hydrographic network intersect (Autorità di Bacino Distrettuale dell'Appennino Meridionale, 2015).
In addition to hydraulically critical issues, the TA3 territory also presents significant issues from an environmental point of view. The area is almost entirely urbanised, with few natural areas for agricultural use threatened by existing anthropic pressure.
The PUC calls for preserving agricultural land in TA3 through maintenance, recovery and redevelopment, which may consist of the ruralisation of urbanised brownfields.
NBS for climate change mitigation and adaptation can contribute to protecting biodiversity threatened by disordered urbanisation in TA3.
Due to less restrictive indications from territorial plans in TA3, acting at the building scale is possible.
In the case of interventions more extensive than building renovation, vertical green systems (e.g. green and living walls) and green roof elements (e.g. extensive, intensive, urban farm) can be used as NBS. In addition to increasing the psychophysical well-being of inhabitants, the proposed interventions are helpful tools for decreasing outdoor discomfort in hot weather.
In the public space, planting urban trees and redeveloping parking areas using green landscaping with filter paving can be provided to ensure maximum permeability of the soil.
Bioswales (alternatively rain gardens) can be placed at the groundwater network, i.e., in areas subject to greater hydrological risk. NBSs can improve the local management of the rainwater cycle without burdening the existing sewage disposal system in case of extreme events.
For the upgrade of the road network, filter beds can be constructed to collect rainwater and its purification. The cleaning of contaminants is achieved through specific types of plants and the installation of natural filters made of gravel and crushed rocks of different granulometry.
A further measure to mitigate anthropic pressure on the environment is the adoption of vegetation noise barriers to act as a filter between the busiest axes (Via Argine) and the urban fabric of Cercola.

[5] The SS162 highway and the Via Argine axis.

In the TA3 area, the reconversion of disused and abandoned areas to green areas can be envisaged through the establishment of community gardens for agricultural purposes; in these green spaces, individual citizens can participate in the management and cultivation of the land as part of an urban farm. Furthermore, the wet fraction of urban waste produced by apartment blocks and agricultural activities can be processed in special neighbourhood composters. These sites valorise waste and give it new life by turning it into fertiliser. Moreover, for the most polluted soils, in the case of disused activities and reconversion of the intended use, phytoremediation systems can be implemented through the planting of plant organisms that can absorb the pollutants present in the soil, reclaiming it; finally, the plant organisms used can then be used for the production of biomass and thus for the production of electrical and thermal energy.

6. Conclusions

The present work deals with the application of measures for mitigation and adaptation to the effects of climate change in an urban context. In particular, it illustrates a multi-scalar approach (e.g. from building to urban scale) that enables mitigation of climate change effects and naturalisation of an area at high anthropogenic and natural risk.

The paper illustrates an operational example of the choice of NBS measures for the Cercola municipal territory as actions and guidelines to be integrated into the implementation rules of the urban plan.

In the first phase, the environmental context of the area subject to intervention was examined in depth. In particular, the main risks were analysed, and the intervention strategies of the territorial and municipal plans were outlined.

Then, starting from a critical analysis of the state of the art, the main NBSs that can be implemented in the Cercola area were outlined. The measures were categorised into three main fields of application: building scale, public space and water management, and rural and natural areas. The solutions identified were chosen based on their correspondence with the transformation objectives of urban planning.

Lastly, for the specific transformation zones outlined in the urban plan, the main NBSs that can be implemented to mitigate and adapt to the effects of climate change were identified. The choice was based on the peculiarities of the zones into which the Cercola territory was divided.

This paper aims to contribute to the ongoing debate on improving the urban territory and built heritage to cope with climate change effects. The work presented here is the first contribution of a structured path leading to the evaluation of the effectiveness of NBS in Italian small urban contexts. The future developments of this work will be the verification through simulations at the urban level of the solutions proposed at the building scale and their effects on the urban microclimate for further scaling down the intervention. In addition, once the first measures are applied in the Cercola area, the actual performance of the NBSs identified for the transformability areas will be monitored.

Authors' contribution

This paper is the result of the joint work of the authors. In particular: § 1 has been written by Giuseppe Mazzeo; § 3, 4, 5 and 6 have been written by Salvatore Polverino; § 2 has been jointly written by Giuseppe Mazzeo and Salvatore Polverino.

Acknowledgement

The paper is based upon a research activity supported by the National Research Council, Institute for Studies on the Mediterranean (CNR-ISMed) in Naples under Grant No. CIG-ZC333560E7 "Identification of urban adaptation measures to include in the municipal urban plan to increase the response capacity of the urban center of Cercola to climate change", February 2022. Authors thanks for the valuable collaboration the Eng. Lorenzo D'Alessandro, manager of technical office of Cercola municipality.

References

Ahmad, K.A., Abdullah, M.E., Hassan, N.A., Daura, H.A., & Ambak, K. (2017). A review of using porous asphalt pavement as an alternative to conventional pavement in stormwater treatment. *World Journal of Engineering*, *14*(5), 355–362. https://doi.org/10.1108/WJE-09-2016-0071.

ARPAC (2022). *Bollettini qualità dell'aria*. Retrieved from: https://arpacampania.clio.it/sito_temporaneo/atto.php?id=350, Accessed: 9/1/2023.

Autorità di Bacino Distrettuale dell'Appennino Meridionale. (2015). *Piano Stralcio per l'Assetto Idrogeologico - Rischio idraulico (PSAI-RI)*. Retrieved from: https://www.distrettoappenninomeridionale.it/index.php/elaborati-di-piano-menu/bacini-reg-nord-occidentali-bacino-reg-sarno-ex-adb-reg-campania-centrale-menu/piano-assetto-idrogeologico-rischio-idraulico-menu. Accessed: 16/02/2023.

Balletto, G., Sinatra, M., Mura, R., & Borruso, G. (2022). Climate variation in metropolitan cities. *TeMA - Journal of Land Use, Mobility and Environment*, *15*(3), 501-516. https://doi.org/10.6093/1970-9870/9265.

Bayulken, B., Huisingh, D., & Fisher, P.M.J. (2021). How are nature based solutions helping in the greening of cities in the context of crises such as climate change and pandemics? A comprehensive review. *Journal of Cleaner Production*, *288*, 125569. https://doi.org/10.1016/j.jclepro.2020.125569.

Bianchi, C.N. (2007). Biodiversity issues for the forthcoming tropical Mediterranean Sea. *Hydrobiologia*, *580*(1), 7-21. https://doi.org/10.1007/s10750-006-0469-5.

Boganini, L., & Casazza, C. (2017). Soilless Urban Temporary Agriculture as a Strategy for Brownfield Site Renewal BT. In A. Sayigh (Ed.), *Mediterranean Green Buildings & Renewable Energy.* 729-740. Springer International Publishing. https://doi.org/10.1007/978-3-319-30746-6.

Brodsky, O.L., Shek, K.L., Dinwiddie, D., Bruner, S.G., Gill, A.S., Hoch, J.M., Palmer, M.I., & McGuire, K.L. (2019). Microbial Communities in Bioswale Soils and Their Relationships to Soil Properties, Plant Species, and Plant Physiology. *Frontiers in Microbiology*, *10*, 1.10. https://doi.org/10.3389/fmicb.2019.02368.

Cai, X., Tan, J., Chen, H., Huang, M., & Huang, X. (2019). The Application of the Solid Waste Compost Products in Garden Plant Planting. *IOP Conference Series: Materials Science and Engineering*, *688*(3). https://doi.org/10.1088/1757-899X/688/3/033044.

Campania Region (2002). *Piano Territoriale Paesistico dei comuni vesuviani*. Retrieved from: http://cercola.asmenet.it/ Accessed: 22/01/2023.

Campania Region (2005). *Piano Regionale di Risanamento e Mantenimento della qualità dell'aria*. Retrieved from: https://www.regione. campania.it/assets/documents/Piano_regionale_di_risanamento.pdf. Accessed: 22/1/2023.

Campania Region (2006). *Piano Strategico Operativo dell'area vesuviana*. Retrieved from: https://www.cittametropolitana.na.it/ pianificazione_territoriale/piani_settore/piano_strategico_operativo. Accessed: 22/1/2023.

Campania Region (2008). *Piano Territoriale Regionale (PTR)*.
Retrieved from: http://www.regione.campania.it/regione/it/tematiche/piano-territoriale-regionale-ptr Accessed: 24/1/2023.

Campania Region (2019). *Piano di Tutela delle Acque (PTA)*. Retrieved from: http://www.regione.campania.it/regione /it/tematiche/acque/piano-di-tutela-delle-acque-2020-2026-j872?page=1. Accessed: 22/12/2023.

Chàfer, M., Pérez, G., Coma, J., & Cabeza, L.F. (2021). A comparative life cycle assessment between green walls and green facades in the Mediterranean continental climate. *Energy and Buildings*, *249*, 111236. https://doi.org/10.1016/j.enbuild.2021.111236.

Cramer, W., Guiot, J., Fader, M., Garrabou, J., Gattuso, J.P., Iglesias, A., Lange, M.A., Lionello, P., Llasat, M.C., Paz, S., Peñuelas, J., Snoussi, M., Toreti, A., Tsimplis, M.N., & Xoplaki, E. (2018). Climate change and interconnected risks to sustainable development in the Mediterranean. *Nature Climate Change*, *8* (11), 972-980. https://doi.org/10.1038/s41558-018-0299-2.

de Oliveira, R.L.M., Santos, I.V., Graciano, G.F., Cunha Libânio, A.A., Kelli de Oliveira, L., & Bracarense, L. dos S.F.P. (2021). A sustainable approach for urban farming based on city logistics concepts for local production and consumption of vegetables. *Research in Transportation Economics*, *87*, 101038. https://doi.org/10.1016/j.retrec.2021.101038.

DeBusk, K., Hunt, B., & Sydorovych, O. (2010). Watershed retrofit and management evaluation for urban stormwater management systems in North Carolina. *World Environmental and Water Resources Congress 2010: Challenges of Change - Proceedings of the World Environmental and Water Resources Congress 2010*, 3911-3920. https://doi.org/10.1061/41114(371)398.

Ekka, S.A., Rujner, H., Leonhardt, G., Blecken, G.T., Viklander, M., & Hunt, W.F. (2021). Next generation swale design for stormwater runoff treatment: A comprehensive approach. *Journal of Environmental Management*, *279*, 111756. https://doi.org/10.1016/j.jenvman.2020.111756.

Elliott, H., Eon, C., & Breadsell, J.K. (2020). Improving city vitality through urban heat reduction with green infrastructure and design solutions: A systematic literature review. *Buildings*, *10*(12), 1-30. https://doi.org/10.3390/buildings10120219.

Fan, P., Ouyang, Z., Basnou, C., Pino, J., Park, H., & Chen, J. (2017). Nature-based solutions for urban landscapes under post-industrialization and globalization: Barcelona versus Shanghai. *Environmental Research*, *156*, 272-283. https://doi.org/10.1016/j.envres.2017.03.043.

Ghose, R., & Pettygrove, M. (2014). Urban Community Gardens as Spaces of Citizenship. *Antipode*, *46*(4), 1092-1112. https://doi.org/10.1111/anti.12077.

Guida, C. (2022). Energy saving and efficiency in urban environments: integration strategies and best practices. *TeMA - Journal of Land Use, Mobility and Environment*, *15*(3), 517-531. https://doi.org/10.6093/1970-9870/9549.

Hinsley, S.A., & Bellamy, P.E. (2000). The influence of hedge structure, management and landscape context on the value of hedgerows to birds: A review. *Journal of Environmental Management*, *60*(1), 33-49. https://doi.org/10.1006/jema.2000.0360.

Hou, C., Hou, J., Kang, Q., Meng, X., Wei, D., Liu, Z., & Zhang, L. (2018). Research on urban park design combined with the urban ventilation system. *Energy Procedia*, *152*, 1133-1138. https://doi.org/10.1016/j.egypro.2018.09.139.

IPCC (2022). Annex II: Glossary [Möller, V., R. van iemen, J.B.R. Matthews, C. Méndez, S. Semenov, J.S. Fuglestvedt, A. Reisinger (Eds.)]. In *Climate Change 2022: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*. https://doi.org/10.1017/9781009325844.029.2897.

ISPRA (2022). *Il consumo di suolo in Italia*. Retrived from: https://geoportale.arpa.piemonte.it/. Accessed: 5/1/2023.

ISTAT (2011). *Censimento della popolazione e abitazioni*. Retrieved from: https://www.istat.it/it/censimenti-permanenti/censimenti-precedenti/popolazione-e-abitazioni/popolazione-2011. Accessed: 12/2/2023.

ISTAT (2022). *Principali statistiche geografiche sui comuni*. Retrieved from: https://www.istat.it/it/archivio/156224. Accessed: 12/2/2023.

Jenks, M., & Jones, C. (2008). *Dimensions of the sustainable city*. Dordrecht: Springer. https://doi.org/10.1007/978-1-4020-8647-2.

Johnson, B. A., Kumar, P., Okano, N., Dasgupta, R., & Shivakoti, B. R. (2022). Nature-based solutions for climate change adaptation: A systematic review of systematic reviews. *Nature-Based Solutions*, *2*, 100042. https://doi.org/10.1016/j.nbsj.2022.100042.

Karimi, K., Farrokhzad, M., Roshan, G., & Aghdasi, M. (2022). Evaluation of effects of a green wall as a sustainable approach on reducing energy use in temperate and humid areas. *Energy and Buildings*, *262*, 112014. https://doi.org/10.1016/j.enbuild.2022.112014.

Kazemi, F., Rabbani, M., & Jozay, M. (2020). Investigating the plant and air-quality performances of an internal green wall system under hydroponic conditions. *Journal of Environmental Management*, *275*, 111230. https://doi.org/10.1016/j.jenvman.2020.111230.

Kozai, T., Niu, G., & Takagaki, M. (2019). *Plant factory: an indoor vertical farming system for efficient quality food production*. Amsterdam: Elsevier Academic Press. https://doi.org/10.1016/C2014-0-01039-8.

Lanzi, M. (2016). Drosscape e reti di nuova urbanità nell'area orientale di Napoli. In G. Punziano (Ed.), *Società, economia e spazio a Napoli. Esplorazioni e riflessioni.* L'Aquila: GSSI Social Sciences.

Lionello, P., Abrantes, F., Gacic, M., Planton, S., Trigo, R., & Ulbrich, U. (2014). The climate of the Mediterranean region: research progress and climate change impacts. *Regional Environmental Change*, *14*(5), 1679-1684. https://doi.org/10.1007/s10113-014-0666-0.

Lionello, P., & Scarascia, L. (2018). The relation between climate change in the Mediterranean region and global warming. *Regional Environmental Change*, *18*(5), 1481-1493. https://doi.org/10.1007/s10113-018-1290-1.

Lubna, F.A., Lewus, D.C., Shelford, T.J., & Both, A.J. (2022). What You May Not Realize about Vertical Farming. *Horticulturae*, *8*(4), 1-9. https://doi.org/10.3390/horticulturae8040322.

MacDonald, D.W., & Johnson, P.J. (1995). The Relationship Between Bird Distribution and the Botanical and Structural Characteristics of Hedges. *Journal of Applied Ecology*, *32*(3), 492-505. https://doi.org/10.2307/2404647.

Maher, B.A., Ahmed, I.A.M., Davison, B., Karloukovski, V., & Clarke, R. (2013). Impact of roadside tree lines on indoor concentrations of traffic-derived particulate matter. *Environmental Science and Technology*, *47*(23), 13737-13744. https://doi.org/10.1021/es404363m.

Mamun, A. Al, Hayat, N., Malarvizhi, C.A.N., & Zainol, N.R.B. (2020). Economic and environmental sustainability through green composting: A study among low-income households. *Sustainability*, *12*(16), 6488. https://doi.org/10.3390/su12166488.

Marchetti, M., Sallustio, L., Ottaviano, M., Barbati, A., Corona, P., Tognetti, R., Zavattero, L., & Capotorti, G. (2012). Carbon sequestration by forests in the National Parks of Italy. *Plant Biosystems - An International Journal Dealing with All Aspects of Plant Biology*, *146*(4), 1001-1011. https://doi.org/10.1080/11263504.2012.738715.

Mazzeo, G. (2013). City and Energy Infrastructures between Economic Processes and Urban Planning. *TeMA - Journal of Land Use, Mobility and Environment*, *6*(3), 311-324. https://doi.org/10.6092/1970-9870/1929.

Mazzeo, G. (2016). *La città leggera: Smart City e urbanistica attuativa*. Napoli: FedOA Press. https://doi.org/10.6093/978-88-6887-008-9.

Mazzeo, G. (2021). *Sulla pianificazione territoriale in Italia. Cronache, testimonianze, prospettive*. Milano: FrancoAngeli.

Metropolitan City of Naples (2013). *Piano Territoriale di Coordinamento (PTC)*. Retrieved from: https://www.cittametropolitana.na.it/ pianificazione_territoriale/ptcp Accessed: 21/01/2023.

Metropolitan City of Naples (2022). *Piano Territoriale Metropolitano (PTM)*. Retrieved from: https://www.cittametropolitana.na.it/ documenti2. Accessed: 21/01/2023.

Morash, J., Wright, A., LeBleu, C., Meder, A., Kessler, R., Brantley, E., & Howe, J. (2019). Increasing sustainability of residential areas using rain gardens to improve pollutant capture, biodiversity and ecosystem resilience. *Sustainability*, *11*(12), 3269. https://doi.org/10.3390/SU11123269.

Municipality of Cercola (2019). *Piano Urbanistico Comunale*. Retrieved from: http://cercola.asmenet.it/. Accessed: 15/12/2023.

Naskali, A.T., Pinarer, O., & Tolga, A.C. (2022). Vertical Farming: Under Climate Change Effect BT. In C.M. Galanakis (Ed.), *Environment and Climate-smart Food Production*. 259-284. Berlin: Springer International Publishing. https://doi.org/10.1007/978-3-030-71571-7_8.

Newman, P. (2006). The environmental impact of cities. *Environment and Urbanization*, *18*(2), 275-295. https://doi.org/10.1177/0956247806069599.

O'Connor, D., Zheng, X., Hou, D., Shen, Z., Li, G., Miao, G., O'Connell, S., & Guo, M. (2019). Phytoremediation: Climate change resilience and sustainability assessment at a coastal brownfield redevelopment. *Environment International*, *130*, 104945. https://doi.org/10.1016/j.envint.2019.104945.

Oral, H.V., Carvalho, P., Gajewska, M., Ursino, N., Masi, F., van Hullebusch, E.D., Kazak, J.K., Exposito, A., Cipolletta, G., Andersen, T.R., Finger, D.C., Simperler, L., Regelsberger, M., Rous, V., Radinja, M., Buttiglieri, G., Krzeminski, P., Rizzo, A., Dehghanian, K., … Zimmermann, M. (2020). A review of nature-based solutions for urban water management in European circular cities: A critical assessment based on case studies and literature. *Blue-Green Systems*, *2*(1), 112-136. https://doi.org/10.2166/bgs.2020.932.

Papa, R., & Mazzeo, G. (2014). Characteristics of Sprawl in the Naples Metropolitan Area. Indications for Controlling and Monitoring Urban Transformations. In B. Murgante, S. Misra, A.M.A.C. Rocha, C. Torre, J.G. Rocha, M.I. Falcão, D. Taniar, B.O. Apduhan, & O. Gervasi (Eds.). *Computational Science and Its Applications – ICCSA 2014*. 520-531. Berlin: Springer International Publishing. https://doi.org/10.1007/978-3-319-09129-7_38.

Pelorosso, R., Gobattoni, F., Ripa, M.N., & Leone, A. (2018). Second law of thermodynamics and urban green infrastructure - A knowledge synthesis to address spatial planning strategies. *TeMA - Journal of Land Use, Mobility and Environment*, *11*(1), 27-50. https://doi.org/10.6092/1970-9870/5326.

Petreje, M., Sněhota, M., Chorazy, T., Novotný, M., Rybová, B., & Hečková, P. (2023). Performance study of an innovative concept of hybrid constructed wetland-extensive green roof with growing media amended with recycled materials. *Journal of Environmental Management*, *331,* 117151. https://doi.org/10.1016/j.jenvman.2022.117151.

Purvis, R.A., Winston, R.J., Hunt, W.F., Lipscomb, B., Narayanaswamy, K., McDaniel, A., Lauffer, M.S., & Libes, S. (2018). Evaluating the water quality benefits of a bioswale in Brunswick County, North Carolina (NC), USA. *Water*, *10*(2), 134. https://doi.org/10.3390/w10020134.

Scalenghe, R., & Ajmone-Marsan, F. (2009). The anthropogenic sealing of soils in urban areas. *Landscape and Urban Planning*, *90*(1-2), 1-10. https://doi.org/10.1016/j.landurbplan.2008.10.011.

Strauss, B.H., Kulp, S.A., Rasmussen, D.J., & Levermann, A. (2021). Unprecedented threats to cities from multi-century sea level rise. *Environmental Research Letters*, *16*(11), 114015. https://doi.org/10.1088/1748-9326/ac2e6b.

Susca, T., Zanghirella, F., Colasuonno, L., & Del Fatto, V. (2022). Effect of green wall installation on urban heat island and building energy use: A climate-informed systematic literature review. *Renewable and Sustainable Energy Reviews*, *159*, 112100. https://doi.org/10.1016/j.rser.2022.112100.

Susorova, I. (2015). *5 - Green facades and living walls: vertical vegetation as a construction material to reduce building cooling loads*. In F. Pacheco-Torgal, J.A. Labrincha, L.F. Cabeza, & C.-G.B.T.-E.-E.M. for M.B.C.N. Granqvist (Eds.), *Eco-efficient Materials for Mitigating Building Cooling Needs. Design, Properties and Applications*. 127-153. Cambridge: Woodhead Publishing. https://doi.org/https://doi.org/10.1016/B978-1-78242-380-5.00005-4

Tong, P., Yin, H., Wang, Z., & Trivers, I. (2022). Combining Stormwater Management and Park Services to Mitigate Climate Change and Improve Human Well-Being: A Case Study of Sponge City Parks in Shanghai. *Land*, *11*(9), 1589. https://doi.org/10.3390/land11091589.

Tsubota, T., Fernando, C., Yoshii, T., & Shirayanagi, H. (2018). Effect of Road Pavement Types and Ages on Traffic Accident Risks. *Transportation Research Procedia*, *34*, 211-218. https://doi.org/10.1016/j.trpro.2018.11.034.

Ulbrich, U., May, W., Li, L., Lionello, P., Pinto, J. G., & Somot, S. (2006). The Mediterranean climate change under global warming. In P. Lionello, P. Malanotte-Rizzoli, & R.B.T.-D. in E. and E.S. Boscolo (Eds.), *Mediterranean*. *4*, 399-415. Amsterdam: Elsevier. https://doi.org/https://doi.org/10.1016/S1571-9197(06)80011-X.

Van den Berg, A.E., Wesselius, J.E., Maas, J., & Tanja-Dijkstra, K. (2017). Green Walls for a Restorative Classroom Environment: A Controlled Evaluation Study. *Environment and Behavior*, *49*(7), 791-813. https://doi.org/10.1177/0013916516667976.

Wolch, J.R., Byrne, J., & Newell, J.P. (2014). Urban green space, public health, and environmental justice: The challenge of making cities "just green enough." *Landscape and Urban Planning*, *125*, 234-244. https://doi.org/10.1016/j.landurbplan.2014.01.017.

Ysebaert, T., Koch, K., Samson, R., & Denys, S. (2021). Green walls for mitigating urban particulate matter pollution. A review. *Urban Forestry and Urban Greening*, *59*, 127014. https://doi.org/10.1016/j.ufug.2021.127014.

Zehnsdorf, A., Willebrand, K.C.U., Trabitzsch, R., Knechtel, S., Blumberg, M., & Müller, R.A. (2019). Wetland roofs as an attractive option for decentralized water management and air conditioning enhancement in growing cities-A review. *Water*, *11*(9), 1845. https://doi.org/10.3390/w11091845.

Zhang, X., Zhang, Y., & Zhai, J. (2021). Home Garden With Eco-Healing Functions Benefiting Mental Health and Biodiversity During and After the COVID-19 Pandemic: A Scoping Review. *Frontiers in Public Health*, *9*, 1-13. https://doi.org/10.3389/fpubh.2021.740187.

Zoppi, C. (2020). Ecosystem services, green infrastructure and spatial planning. *Sustainability*, *12*(11), 10-13. https://doi.org/10.3390/su12114396.

Image Sources

Fig. 1: Metropolitan City of Naples. Metropolitan Territorial Plan, Preparatory Strategic Scheme (2023). Retrieved from: https://www.cittametropolitana.na.it/documents/10181/9998654/27_Tavola+PP2+Schema+strategico+preliminare.pdf/885def70-2560-4db6-b56c-299c2308dda4;

Fig. 2: Author's elaboration;

Figg. 3 and 4: Preparatory studies for the drafting of the municipal urban plan of Cercola.

Author's profile

Giuseppe Mazzeo

Researcher at the National Research Council, Institute for Studies on the Mediterranean (CNR-ISMed) in Naples. Professor of "Environmental Impact Assessment" at the Faculty of Science and Technology, University of Naples Parthenope. Professor of "Urban Planning Technique" at the School of Engineering of University of Naples Federico II. He carries out research activity in cooperation with the Department of Civil, Architectural and Environmental Engineering (DICEA, University of Naples Federico II) in regional planning, strategic environmental assessment, urban planning with a special focus on urban regeneration.

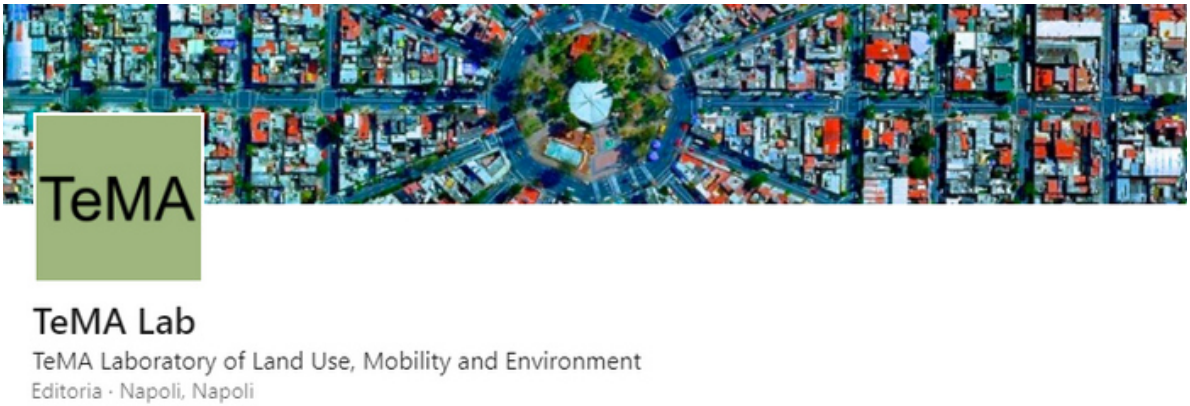
Salvatore Polverino

Building Engineer-Architect and PhD in Architecture and Design. He is currently a course leader on subjects of the scientific disciplinary sector of Architectural Engineering at the University of Genoa. Research fellow on the applications of advanced materials in the construction sector. He collaborates with research institutes and companies operating in the construction sector.

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 (2023) 67-82
print ISSN 1970-9889, e-ISSN 1970-9870
DOI: 10.6093/1970-9870/9390
Received 10th September 2022, Accepted 5th March 2023, Available online 30th April 2023

www.tema.unina.it

Social aspects in small ports tourism sustainability

Planning small ports and marinas through the lens of tourism and sustainability

Alessandro Bove [a]*, Elena Mazzola [b]

[a] Department of Civil, Architectural and Environmental Engineering (DICEA)
University of Padua, 35131 Padova, Italy
e-mail: alessandro.bove@unipd.it
ORCID: https://orcid.org/0000-0002-0189-4160
* Corresponding author

[b] Department of Civil, Architectural and Environmental Engineering (DICEA)
University of Padua, 35131 Padova, Italy
e-mail: elena.mazzola@unipd.it
ORCID: https://orcid.org/0000-0002-0189-4160

Abstract
The attraction of the place, the perception of services, the awareness, and the tourist satisfaction play an important role to motivate a tourist to visit and revisit a destination. Sustainability has also been receiving increasing attention and require also to promote inter-generational and intragenerational equity, to guarantee the cultural integrity and social cohesion of the communities, and to protect the environment and ecosystems. In this context, nautical tourism assesses some impacts to the economy, with the construction of port and the relative infrastructures and with all services to the boat, to the society and the local community that participate to the development and choices, and to the environment with significant potential risks. This paper focusses on small ports and marinas and investigates the real situation about services offered and the related possible tourism satisfaction for a socio-cultural sustainable development. In addition, FRAMESPORT project (FRAMEwork initiative fostering the sustainable development of Adriatic-Ionian Small PORTs) assists to these objectives collecting relevant experiences and feedbacks and developing a strategic guidance. For this reason, it has collected data from people connected to Italian and Croatian docks and are analyzed with statistic methods and georeferenced maps. The significance of the study is to understand similarities and differences of tourism in these two States and provide suggestions for a socio-cultural sustainable development.

Keywords
Social aspects; Small ports; marinas; Nautical activities and services; Sustainability.

How to cite item in APA format
Mazzola, E., Bove, A. (2023). Social aspects in small ports tourism sustainability. *Tema. Journal of Land Use, Mobility and Environment*, *16* (1), 67-82. http://dx.doi.org/10.6093/1970-9870/9390

1. Introduction

According to the World Tourism Organization, "tourism is a social, cultural and economic phenomenon which entails the movement of people to countries or places outside their usual environment for personal or business/professional purposes. These people are called visitors (which may be either tourists or excursionists; residents or non-residents) and tourism has to do with their activities, some of which involve tourism expenditure" (World Tourism Organization, n.d.).

Most studies have listed and explained which are the factors to motivate tourists to particular destinations. Indeed, tourist satisfaction refers to the pleasure that the tourists feel due to their travel experience (Chen & Tsai, 2007; Kozak & Remington, 2000; Quintal & Polczynski, 2010) and comprises of satisfaction related to services received by tourists, tourist destinations, and satisfaction with tourists (Lee et al., 2011; Santoso, 2019). Thus, tourist satisfaction represents the emotional feelings and pleasure derived from visiting various tourist places (Cole & Scott, 2004; Quintal & Polczynski, 2010). In addition, the literature documented a positive relationship between attraction, perception of service, and awareness and tourist satisfaction (Chiu et al., 2016; Naidoo et al., 2011; Okello & Yerian, 2009; Nguyen Viet et al., 2020; Zhang et al., 2018). Furthermore, opportunities available in tourist destinations play an important role in influencing tourist satisfaction and motivate tourist to revisit the destination and recommend them to others (Murphy et al. 2011; He & Luo, 2020; Joseph et al., 2021).

In general, tourism industry can be subdivided in several sectors as educational tourism, film tourism, health tourism, justice tourism, etc. (Weeden, 2013). Among various types of tourism, nautical tourism is in the middle between sea tourism, defined as tourism driven and motivated by marine resources, in which the sea and the marine environment represent the center of the tourist experience and its main motivation, and boating, defined as the set of leisure activities carried out with a pleasure boat (Benevolo, 2011). Nautical tourism is characterized by three aspects (Fortezza, 2008; Benevolo, 2010):

- the nautical tourist, that is who travels and stays on the sea and in the ports;
- the boat employment, for travel and accommodation (Candela & Figini, 2003);
- the tourist demand on the mainland with a several number of activities, once the boat has landed.

Some places are linked to this type of tourist experience:

- to sail (seas, lakes and other navigable inland waterways);
- to rest and stay, as ports and docks. Here, three main functions are carried out from a tourist point of view: i) origin or departure of tourists, with a possible permanent function (the boats remain "parked" there for most of the year, go out to sea for cruises or day trips, are often used for a stay in the port, like second homes. This last aspect is particularly critical in places that already have high tourist pressure for the impact on access infrastructures, consumption and uses related to the location); ii) stop or transit, as a stage for supplies or environmental, naturalistic, sporting interests, etc.; iii) destination;
- to visit and discover coastal and inland territory as natural, anthropic, cultural, historical, landscape resources etc. which the nautical tourist could be interested and can access from the sea through the landings (Benevolo, 2011).

In this context, sustainable tourism is when it "contributes to creating equality and economic and social welfare for the local community" (Aronsson, 1994). Indeed, tourism has socio-cultural, economic and environmental impacts on the population and the place; for the first effect, tourism can change traditional lifestyles, value systems, family relationships, individual behavior and community structure (Puczko & Ratz, 2000); for the economy, the region has greater benefits which are employment income and foreign generations but also socioenvironmental impacts (Vijayakumar, 2009; Zacharias et al., 2010); for the environment, tourism has different types of impacts, from soil/air/water pollution to ecosystem degradation, that derive from tourism

activities (Fachrudin & Lubis, 2016) and the different level of environmental literacy that tourist have (Chandy & Rajesh, n.d.).

In these terms, tourism development is truly sustainable if:

- "meet the need of the host population in terms of improved living standards both in the short and long term" (Carter, 1993) and guarantee the cultural integrity and social cohesion of the communities (Pearce et al., 1996; Burns & Holden, 1995; Wall, 1997; Murphy, 1995; McIntyre, 1993; Bramwell & Lane, 1993);
- control, evaluate, and improve host community quality of life (Christensen, 1994), promoting inter-generational and intragenerational equity (Kokkranlkal & Morrison, 2002);
- protect biological diversity and maintain ecosystems;
- use sustainable indicators to diagnose problems and understand their underlying causes, identifying sustainable solutions, defining goals and helping to determine future targets and goals (Bossel, 2002; Fraser et al., 2006; Shamim, 2012).

In addition, there is a relationship between competitiveness and sustainability, because the competitiveness is illusory if it is not sustainable, and sustainability can be a factor of competitiveness (Ruozi, 2005). Indeed, the literature (Ritchie & Crouch, 2003) affirms that a destination is competitive if it is capable to generate and preserve a tourist experience superior to the same offered in other territories and the destination success depends on the allocation resources and the ability to use and enhance them.

About nautical tourism sustainability, some impacts must be assessed: regarding economy, the construction of port and the relative infrastructures represent significant investments and also all services to the boat create a new economy; for social aspects, it is important that local community perceive ports as source of development, employment and income and participate to the choices; at the environmental level, existing ports have significant environmental impacts and significant potential risks, linked above all to the size of the infrastructures (Candela & Figini, 2003). There is an ample amount of literature about the consequences of tourism on environment and they analyze from the waste which are generated from house boats, hotels and resorts, oil from engines, plastic wastes and food wastes and propose an effective management of these predominant wastes (Chandy & Rajesh, n.d.), to the spatiotemporal trends in the tourist flow and changes in the ecology and environment (John, 2018).

This paper focusses on small ports and marinas and investigates the real situation about services offered and the related possible tourism satisfaction for a sustainable socio-cultural development. For this reason, it has collected data from people connected to Italian and Croatian docks and are analyzed with statistic methods and georeferenced maps.

2. Project background

Nautical tourism is a branch of maritime tourism—the "water-based" counterpart to "land-based" field of coastal tourism (Hall, 2001; Agarwal, 2002; Jennings, 2004). There's a strict link between nautical tourism and blue economy as clearly described in the EU's Blue Growth strategy. In detail, coastal and maritime tourism bears large potential to promote a smart, sustainable and inclusive Europe: coastal areas and islands tend to be major tourism hotspots. These areas have always been sought for their unique characteristics making them ideal places for leisure and tourism activities to take roll. In recent years, the increasing number of tourists have led to concerns around the sustainable development of coastal areas, especially those characterized by high-density building and expanding environmental footprints (European Commission, 2021).

In 2016, recreational nautical activities created around 234,000 jobs in the EU and generated an annual revenue of EUR 28 billion (European Commission, 2017) and have contributed significantly to the creation of the Adriatic area's identity, especially in countries as Italy and Croatia. In recent time, a study developed by the United Nations Conference on the impacts of COVID-19 on the blue economy projected a growth in preferences for outdoor experiences and contact with nature and water (UNCTAD — United Nations

Conference on Trade and Development, 2020), so the expansion of the boat-rental market worldwide is estimated to grow at 5% per year until 2025 (Report Linker, 2020). This trend can encourage the nautical tourism sector especially in consideration of the fact that, in some cases, it suffers from an important crunch in use (see Italian condition) linked to the economic and financial crisis.

From a touristic point of view, one of the main prerogatives is the presence of a recreational unit; so, this is a branch of marine tourism, with seasonal value, characterized by various distinctive aspects that will determine different types of boating tourism and therefore different profiles of users. Themes as the size of the boat used, then the type of propulsion, whether sailing or motor, thirdly the ownership of the right of use of the boat, still the socio-economic level of the users and the time which he dedicates to navigation, the type of experience pursued, the tourist offer "on the ground" of the place of arrival, the kinds of services sought and other aspects that differentiate boaters and influence the choice of final destination, are all aspects that can influence the boating activity and the success of a marina. Moreover, the traditional relationships between the Italian and Croatian systems in the Adriatic turns out to be unbalanced, as far as the Croatian marinas are attracting more users, especially in relation to fees and to the diffusion of small port in the territory. In fact, an overall issue of lack of competitiveness, exists for both Italian and Croatian small ports and marinas in the Adriatic. The presence of overcapacity implies that the most strategic goal for Italian marinas consists of implementing new business models, measures and actions aimed at recovering overall efficiency, that is, optimizing the existing assets as to be more competitive and attractive. Moreover, we need to understand the relationship between the characteristic of the marinas and the touristic demand as:

- the hiking practice, featured by a predominantly daily or limited duration (weekend), exercised to explore new shores and to pass a few hours in absolute relaxation with your boat, usually in places of natural beauty;
- the itinerant practice, that means living the boat to cruise and provide a period of stay. The purpose is the holiday at sea, to discover different places and coasts and their tourist attractions;
- the navigation practice, activity driven exclusively by the pleasure of sail. These are mainly sailors, both those who sail with very fast small sailboats (the drifts), which those who own boats to sailing capable of great crossings, even oceanic;
- the playful and sporty practice, characterized by short exits. The boat is used as a support for water sports (water skiing, freediving, underwater fishing), for diving or for sport fishing.

In this context, FRAMESPORT (FRAMEwork initiative fostering the sustainable development of Adriatic-Ionian Small PORTs) project aims to develop an initiative where framing the further developments of Adriatic small ports and marinas. It both deliver strategic guidance on how developing small Adriatic ports in a homogeneous way, as well as collecting relevant experiences and feedbacks coming from best practices and piloting experiences along the Adriatic coasts. This could be obtained through a strong cross-border cooperation meant to develop new and more effective planning processes, enforcement of new business models and innovative management and environmental protection tools. In order to facilitate this process, there is a wide range of past and on-going projects with various addresses as:

- improving ports capacity and maritime accessibility (ADRIAMOS, NAPADRAG, NAPAPROG, NAPA4CORE, Trelleborg-Swinoujscie MoS services);
- developing innovative IT solutions for a more efficient multimodal integration (ITS Adriatic Multiport Gateway, MOS4MOS, B2MOS, ANNA);
- improving accessibility and multimodality (SEE Programme: ADB Multiplatform, SETA, WATERMODE, GIFT, NEWADA; ADRION: SUPAIR; GREENBERTH, MEDNET, MEDITA; IVC: CASTLE, SUGAR, POLITE; IPA: EASYCONENCTING, INTERMODADRIA; ITALY-CROATIA: PROMARES, DIGLOGS, TRANSPOGOOD, ICARUS and CHARGE that focused on improving PCSs and related interoperability and security services.

In order to create a harmonized and more efficient development for Adriatic small ports and marinas, the project proposes through cooperation a collection, storage and then use of data to make a photograph of small ports and marinas, dealing with its own characteristics and enlarged to a geographical perspective. Thus, is created through a joint methodological framework and common survey tools to be applied in investigating different small ports characters. In particular, the data survey used to build the sustainable development of small ports and marinas deeps several aspects as contest characters, small port description, regulations, spatial and urban governance, transport topics, environmental data. The result is a common background mainly dealing with the delivery of concrete testing initiatives, where technical solutions and experimental initiatives are tested to identify innovative paths to solve existing problems and to address small ports and marinas towards a sustainable growth.

The data harvest has produced a database of 501 records that investigate seven different pillars (characteristic dimension, type of application and expected rates, technical services to the boat, services to the yachtsman within the tourist port, accessory services for the consumer, environmental services, services for the enhancement of the territory) that can offer some initial results on the role of small parts and marinas in development of tourism boating.

3. Small ports and marinas survey: topics of interest

In academic literature, topics related to commercial ports exist in a mixed-disciplinary space between engineering, business/tourism management and economy. A large number of papers are concentrated into design and operational/managment activities inside small ports and marinas as the project features, the maintenance of navigational access, efficiency of use, maximum allowable vessel size, etc. (De Langen et al., 2018; Green Marina Education and Outreach Project team, 2017; Martín & Yepes, 2019), many others focalize topics related to sustainability and resilience in relation to the impacts of sea level rise, heavy storms, etc. (Casas-Prat & Sierra, 2010; Nursey-Bray et al., 2013; Chhetri et al., 2014; Sierra et al., 2015; Christodoulou et al., 2018). Another important topic is referred to impacts on nature and to the efforts to regulate them (Poletan Jugović et al., 2022; Biondi, 2017; Darbra et al., 2009; Petrosillo et al., 2009; Di Franco et al., 2011). For the management, the topics are the evaluation of the future project's impact, the marina maintenance, facilities and habitat, the waste management and recycling (Green Marina Education and Outreach Project team, 2017; Berman et all., 2002).

The topic of small port in planning literature (spatial and urban planning and design) seem to receive little formal academic attention. In spite of port and waterfront literature where the bibliography is large and varied (Olivier & Slack, 2006; Woo et al., 2012, Sakalayen et al., 2022; Parola et al, 2021, Pagés Sánchez & Daamen, 2019; Garcia-Alonso et al., 2017; Hesse, 2017; Oniszczuk-Jastrząbek et al, 2018; Giovinazzi & Moretti, 2010; Üzümcüoğlu & Polay, 2022; Flynn & Valverde, 2019; Ragheb & EL-Ashmawy, 2020; De Ciutiis, 2009; Russo & Formato, 2014; Fonti et al., 2009; Giampaola, 2009; Leonardi, 2009; Giannì, 2009, Falzetti, 2009), focusing the attention on topics as fragility and threatened environments, rapid urbanization processes, relationship among port and city, maritime infrastructure and inland one, the role of the port in the coastal landscape and in processes of urban regeneration. The common result to all these treats of the topic port & city is the prevalence of design on planning, the importance of the interventions at various scales, the practical approach and the role of urban processes in defining physical form and articulation of socio-economic strategies. Water quality, public and free access and to water, public spaces, gradual and flexible development and shared participation in the entire process as well as a mix of functions and uses and the collaboration between public and private entities are some of the key aspects that needs to be taken into account in new interventions.

But marinas need to deal with coastal tourism and recreation development that can create great pressure on coastal ecosystems and resources such as energy, land, landscape, and water. The case of port shows as main feature the importance of shipping or commercial trade, while marinas might provide the bare essentials, such

as fuel and fresh water, but it may offer also an integrated onshore complex of luxury amenities, including hotel suites, dining, and shopping, literally above and beyond its utilitarian services for vessel repair, maintenance, and provisioning (European Commission, 2016). Then the principal function of a marina is hospitality, and the main object of interest is tourism.

As shown by La Rocca (2014), "The challenge that tourist cities have to face consists exactly in their ability to find a balance between promotion and safeguard of their (historical, cultural, architectural, territorial, environmental) resources. From a town planning point of view, this condition requires intervening through actions and policies targeted to the optimization of urban liveability. Moreover, a good quality of urban life is an unavoidable condition for building the future smart cities. At the same time, one of the factors of urban smartness consists exactly in making city attract tourists (investments, enhancement, image promotion, attractions of tourist flows, and so on)". So, the most important approach in planning (strategically) and promoting the tourism in small ports and marinas seems to be able to create a holistic vision of the relationship port/city, identifying the structural features towards a complex system of elements able to increase the tourist experience on which to build policies/strategies of development and promotion of the territory in tourist key.

For this reason, in this paper we tried to adopt the exploratory research approach for assessing the main services existing in the small Italian and Croatian ports. First of all, we analyzed the data available in the survey to understand which were the most interesting to study the relationship between place, marina and tourism. The evaluation has been articulated defining as references the theme of environmental sustainability, touristic appeal and accessibility. In the following figure it is possible to see how parameters have been evaluated: each group of available information has been categorized according to their possible consideration respect to the nautical tourism activities. This analysis leads to the subsequent selection of certain data for the marinas' sustainability assessment.

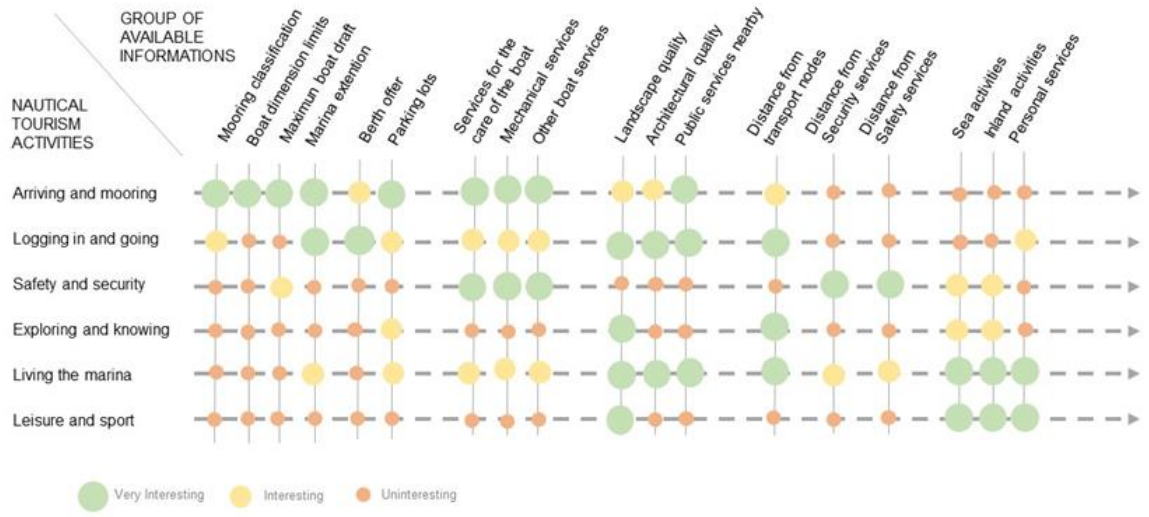


Fig.1 Incidence of the marinas' characteristics in relation to the nautical tourism activities

4. Some evidence on small port and marinas in the Adriatic Sea

Starting from the previous analysis, the small ports and marinas represent the interface between land and water of coastal communities and are used for trade, transport, fishing and boating. There are many urban centers coastal areas that have developed and enriched over time thanks to the functions of the port, in particular role of stopover for tourists with and without boat. The degree of attractiveness of a port strongly depends on the environmental context within which it is inserted, by the position and purpose for which it was conceived, which will make it the destination of a specific customer. A port can also bring various criticalities, if the structure is in contrast with the surrounding landscape or even, since the presence of the same may

cause damage to the nearby coast, may affect or damage other tourist modes connected to the sea, such as beach tourism. Moreover, small ports and marinas are the last link in the long and varied chain of the nautical chain and are, together with boat moorings, the biggest indicator of the offer of boating tourism: here the boaters have the opportunity to call and enjoy the many services offered both inside of the port area and in the immediate hinterland. So that, small ports and marinas may be considered may consider as complex bidding systems, systems with which they interact and where relationships between the human and natural elements of an area. In this perspective, the users of the ports have different needs and objectives and must coexist in the same space, thus a specific offer on this tourist targets may be developed: leisure facilities, links with the cities or other inland services (for examples transport services), are examples of this necessities.

Another aspect of interest is related to environmental sustainability. The transformation of a portion of coastline should be positive and not cause discomfort to the environment, to the landscape and to the community of the place; that is why the planning policies and monitoring is essential to integrate these works with the environment. The problems related to the possible environmental alterations caused by the nautical activities can be traced back to two different aspects: the movement of the boats and the bases nautical. As for the first, the oil and fuel spills are the first danger to the marine environment and its fragile ecosystem, because it deposit on the surface and prevent the normal exchange of oxygen between air and water; moreover weighs the still rampant uncivility of many boaters who do not care to dispose of bilge sewage or toilet waste water in ports, throwing everything in the sea despite being forbidden in the first 3 miles from the coast.

This make a strict relationship between small ports and marinas and their water and land hinterland that can be at the basis of line coast crisis due to the loss of landscape quality as the excess of fixed installations at sea (as piers, docks, dams, artificial reefs) or the dams and the ground plants alter with time the coastal morphology and affect the cover-up both inside the port and in the mouth. These lasts aspects have not been considered in this contribute, because it is necessary to collect other details of the theme and carry out further investigation. However, this issue will soon be analyzed in other related publications through Life Cycle Assessment and other ratings systems.

The study design adopts the exploratory research approach for assessing the main services existing in the small Italian and Croatian ports. The questionnaire was submitted on a voluntary basis but with different methods: in Croatia the ministry was involved, while in Italy the trade associations. The result was that in Croatia more questionnaires were filled in and in a short time.

The data have been collected from the connected people in the small ports and marinas and initially divided according to the dimension. Indeed, the 501 records have been divided between mooring, with less than ten berths and no presence of a toilet, and ports, the remaining records. In Fig.1 it is possible to see the results in a map and to notice as the Croatian area has a lot of moorings, probably for his insular territory and because moorings are used by specific tourism sectors like the island destination, resorts, or hotels. In this manner, a different social services distribution it is possible to notice; indeed, in Croatia dockings are primarily an infrastructure for navigation, while in Italy small ports and marinas are used also for social activities, can be found also in following maps.

For this study, only the number of small ports and marinas, in this manner selected, have been considered. In the database, different types of berths have been inserted according to the available dimension in ports (from 2.5x7.0 m to 8.0x36.0 m), with the biggest total dimension in Italy with 80.000 square meters while in Croatia the biggest have a size of 33.000 square meters. In Fig.2, it is possible to see the division of ports between four different ranges based on the number of available berths. In Italy, ports normally have more than 50 number of berths (from 10 to 1,205 with an average of 263), while in Croatia the dimension of ports is smaller (from 10 to 898 with an average of 146). Furthermore, Croatian small ports and marinas are inserted in the 420 moorings that aren’t considered.

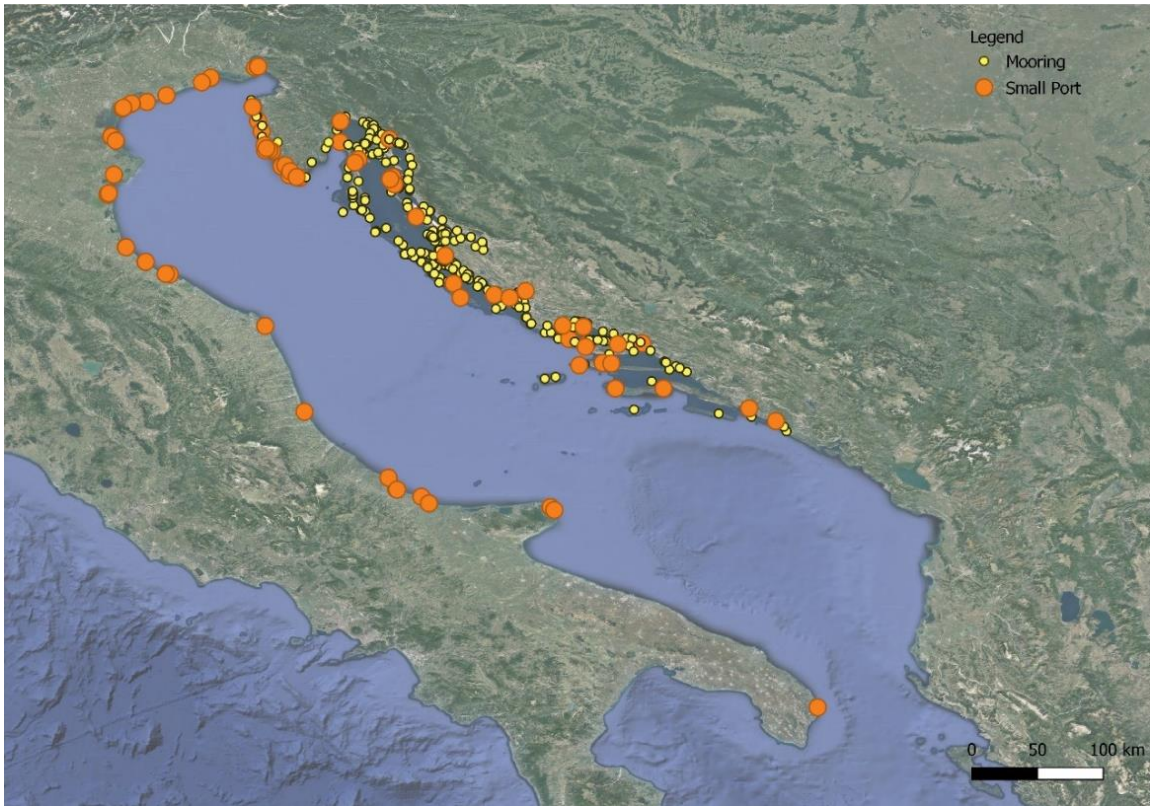


Fig.2 The study area with the arrangement of 420 mooring (small yellow circle) and 81 ports (orange circle)

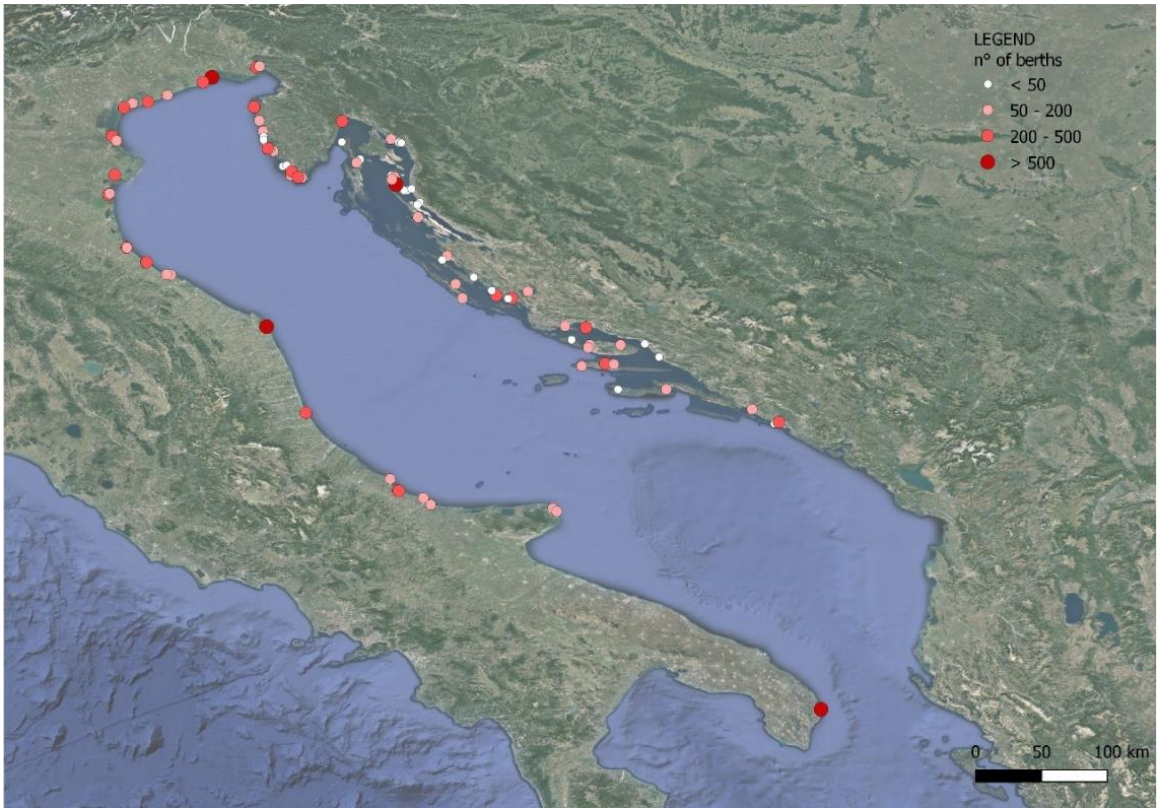


Fig.3 The study area with the 81 ports divided according to four different ranges about the number of berths. It is possible to see that major are in Italy

To satisfy the tourist request on water sports and activities and to develop the competitiveness, some ports insert the possibility to do and learn some sports like wind surf, sailing or diving (Fig.3). Almost all Italian ports offer nautical activities (almost two per port) unlike Croatian ports (less than one per port). These results

probably find an explanation in ports dimensions to see in Fig.2; indeed, with the ratio of water sports and activities to berths it is possible to find the same value (1.13) both for Italy and Croatia. In the same manner, the data about place for other sports available, inside or in proximity, has been collected (Fig.4).

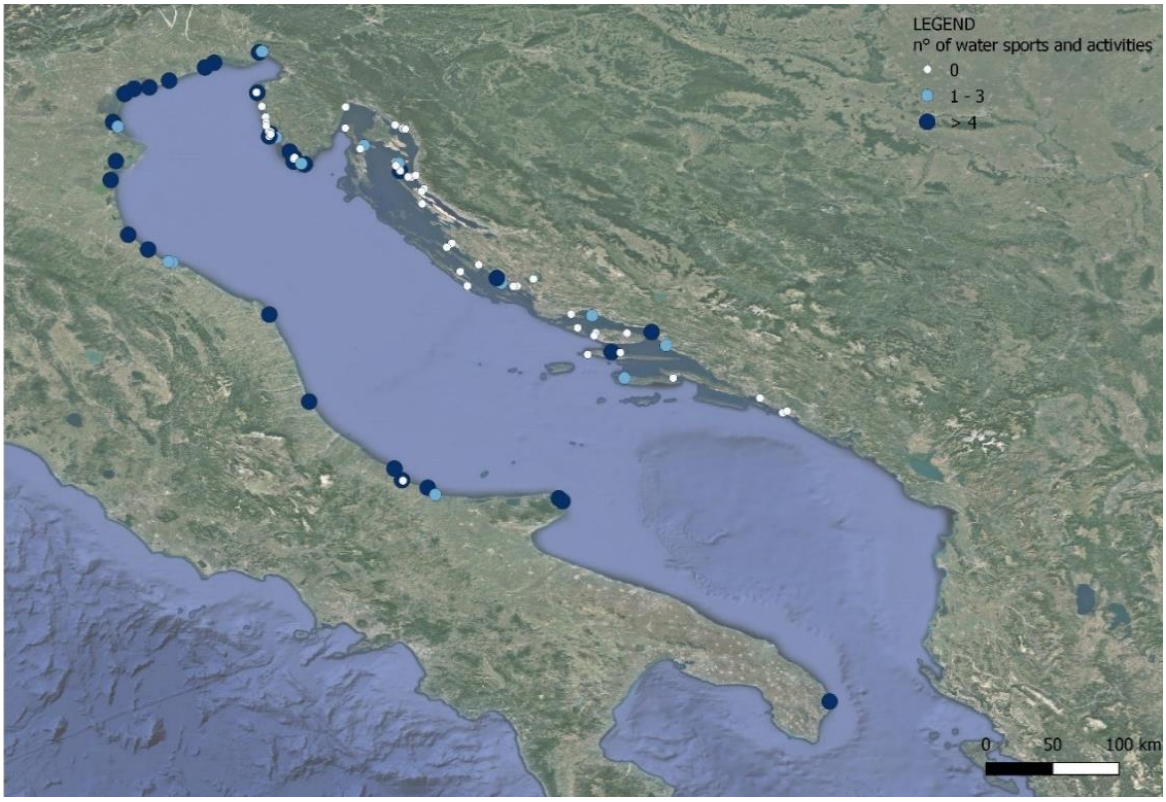


Fig.4 The 81 ports divided according to the number of possible water sports and activities. It is possible to see that Italian ports are better provided.

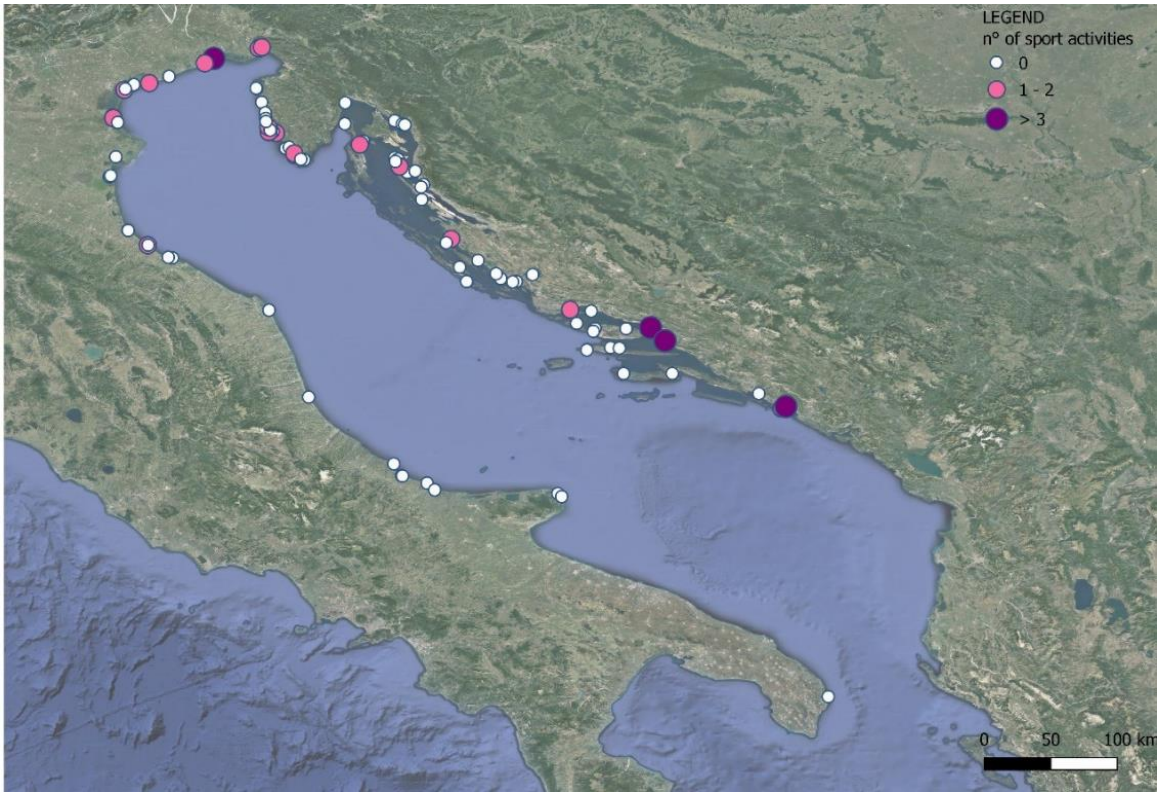


Fig.5 The 81 ports divided according to the number of possible sport activities. It is possible to see that Croatian ports are better provided.

The sports facilities reported are, for example, tennis court, football pitch, swimming pool, riding school, golf course and gym. Conversely to the Fig.3, in Italy almost no one proposes other activities beyond nautical activities.

The same analysis about personal care services inside or in proximity of the port, like wellness centers, beauty centers, hairdresser, barber shop or SPA, where Italian ports are more equipped than Croatian (Fig.5).

To attract tourist inland, it is necessary that the port is well connected to other infrastructure. Distance from train station and bus stop are analyzed with the average of data (1).

$$D = \frac{distance\ from\ station\ [km] + distance\ from\ bus\ stop\ [km]}{2} \quad (1)$$

In Fig.6 it is possible to see the results and that Italian ports are closer and better connected, with only 6 km of distance on average, than Croatian, with 21 km.

In the same manner, distances from hospitals, fire brigade and police stations are evaluated. In this case, small Croatian and Italian ports have similar results approximately 8 km of average distance.

About the possibility to have information with digital or paper documentation of the inland, the results show that small Croatian ports are more virtuous, with the 73% of yes answers, than Italian (only 50%).

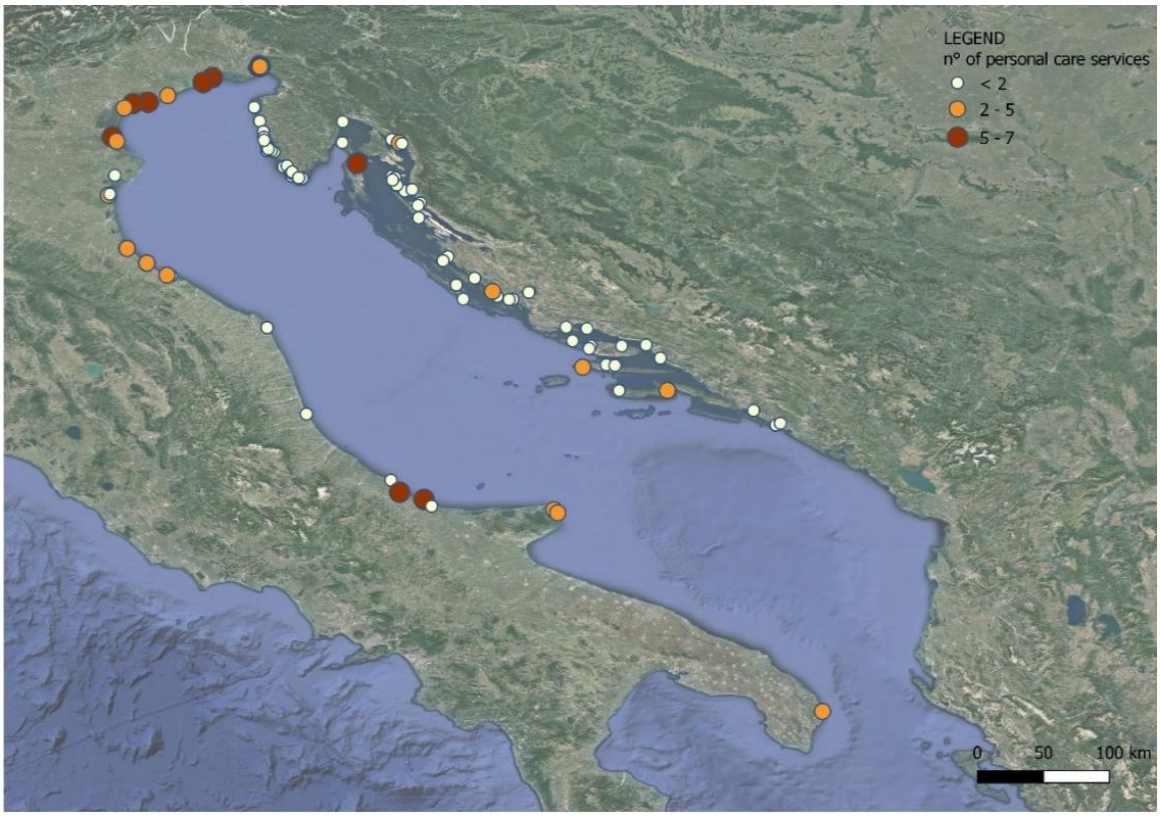


Fig.6 The 81 ports divided according to the number of possible personal care services. It is possible to see that Italian ports are better provided.

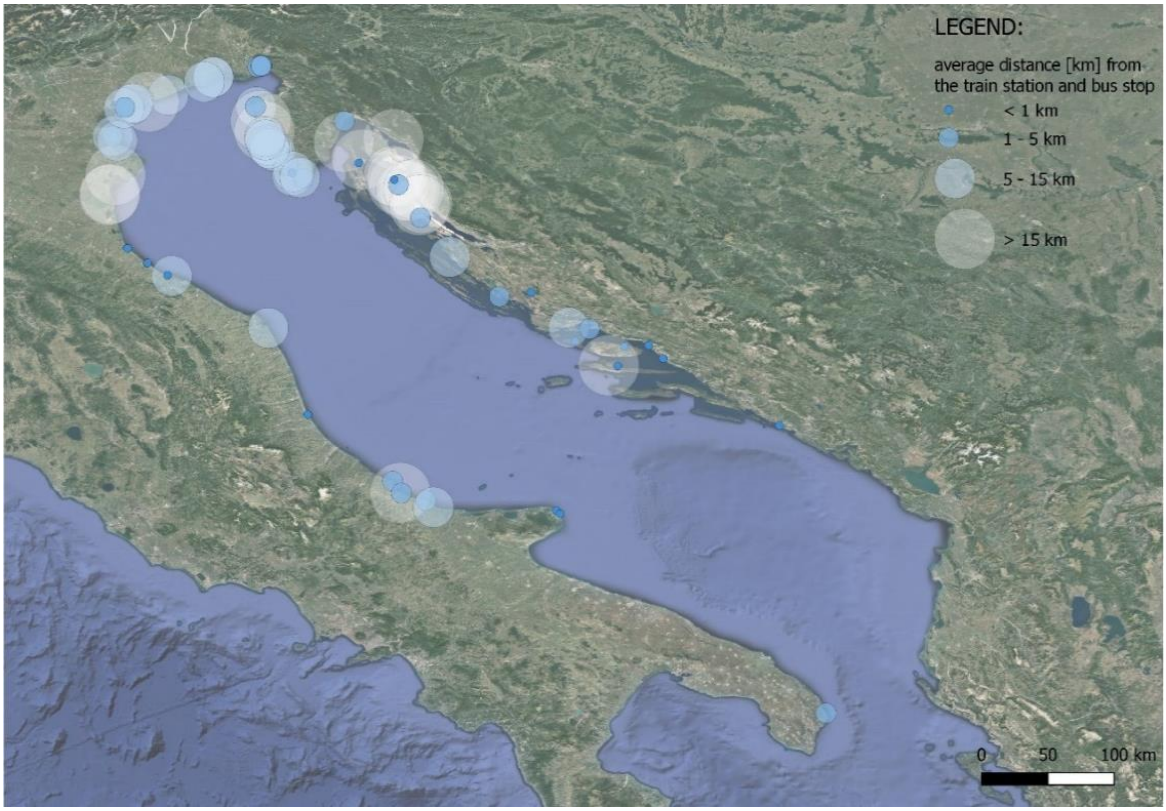


Fig.7 The 81 ports divided according to the average distance from the train and the bus stop. Italian ports are closer than Croatian

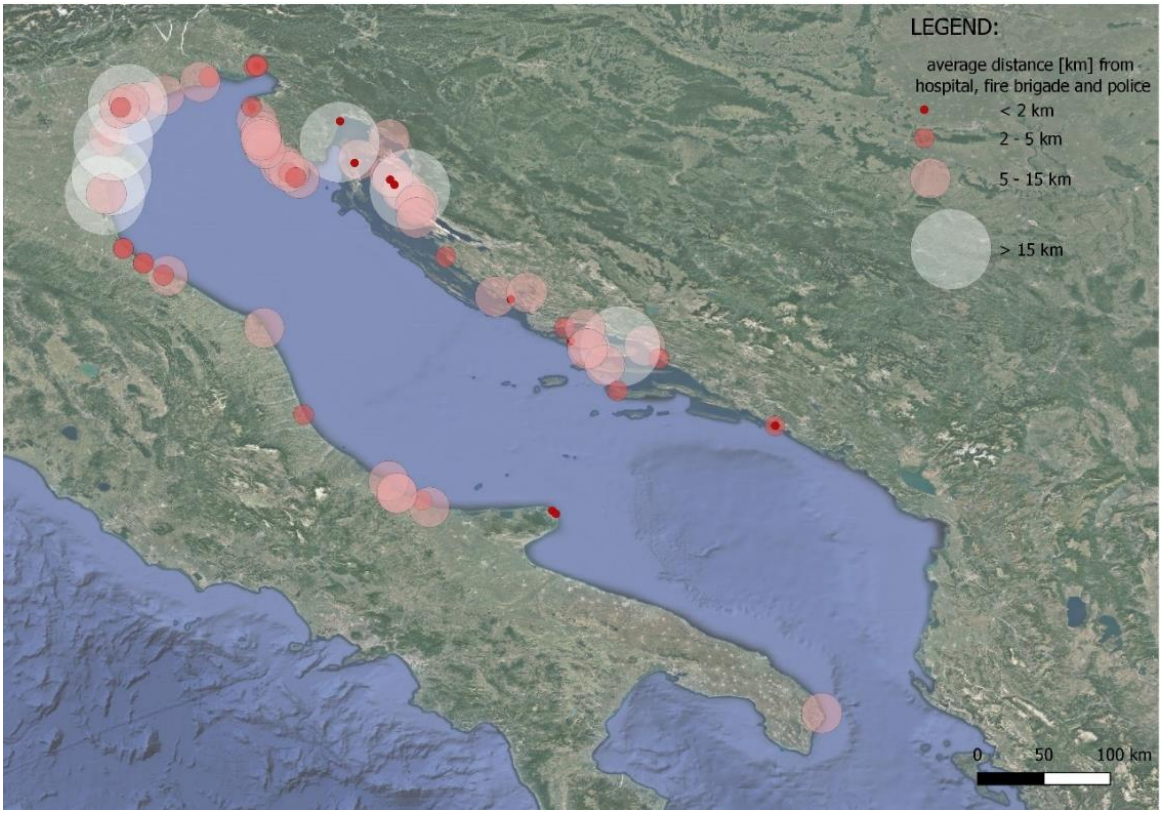


Fig.8 The 81 ports divided according to the average distance from hospitals, fire brigade and police stations

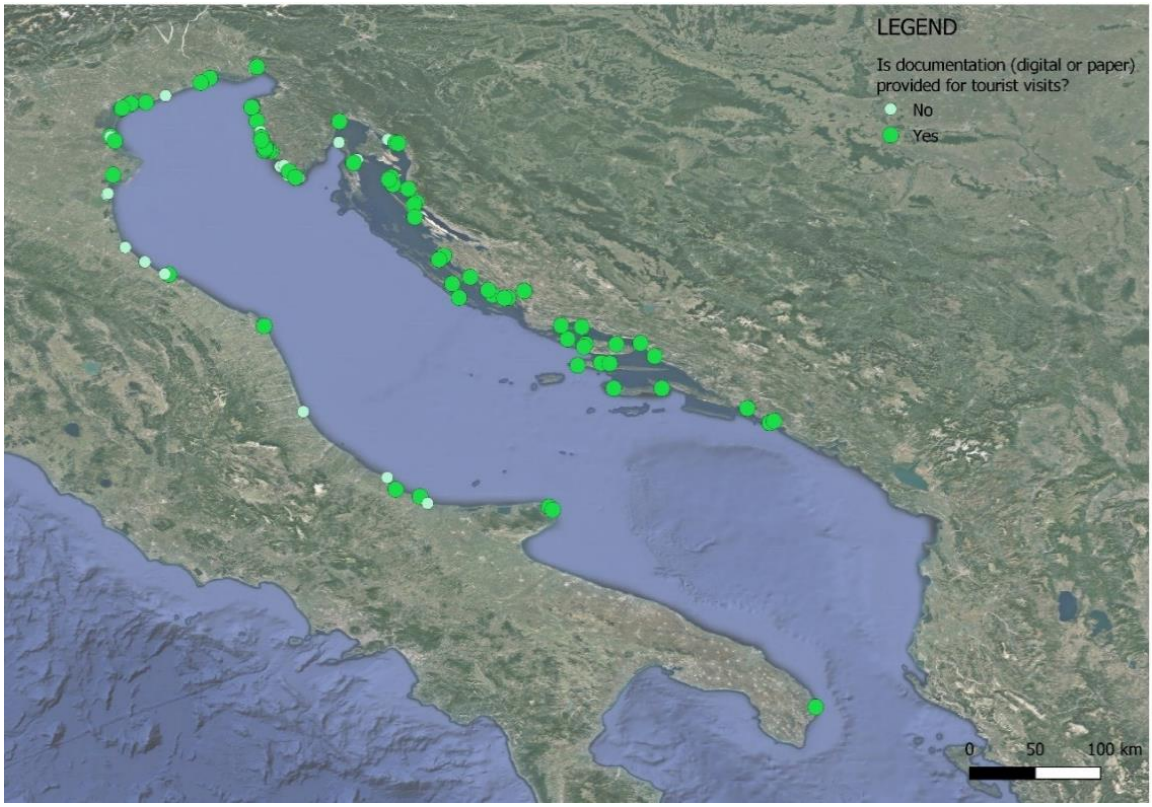


Fig.9 The ports divided according to the possibility to have digital or paper documentation available

5. Conclusion

Planning and designing a small port/marina needs a multicriteria/holistic approach because, as shown in the paper, there are many aspects, from environmental one, to engineering, to aspects related to operational activities, that influence the choices that are taken. Moreover, it seems important emphasizing that the key factors to deal with can change in relationship with the expected results or the enhancement strategies that marina authority/management intend to pursue. One of these key factors is certainly the nautical tourism. Reading the planning/design of a marina through the lens of nautical tourism is a way to address choices related with services offered to the nautical tourist, not only referred to the principal nautical aspects (i.e., all the activities related to the maintenance of the boat of the mooring activity), but also all the elements that can qualify the offer, as the landscape quality, as the cultural interest of town and inland territories, as all services to the person like the offer of leisure activities should be considered. So, it seems possible to conclude that the best marina is the one that avoids most of its potential negative impacts by siting and design, and further incorporates social and environmental features as part of the value of the project itself. This is the result of a multiple-purpose design approach, which endures that the social design elements are fully integrated and contribute synergistically to the project objectives, as opposed to forced add-ons resulting from the negation of nautical tourism necessities. As seen in the case study of Italian and Croatian marinas, this multiple-purpose design approach requires a particular attention to the general management of the whole tourist area, integrating the aspects of accessibility and living the nautical experience as a part of the place, not only referred to the marina. In this way it seems to be possible to attract new clients as well as to offer a new variety to regular customers. On the other hand, neighboring resorts with similar or complementary supply, transport infrastructures and cultural touristic offer must be combined to organizational units so that it is possible to create a sort of 'wider catchment area'. The necessity of an integral management of whole tourist region and the planning to manage resources and prevent environmental problems, the strictly

consideration of the territory and his conformation for all the future development of existing marinas, the use of web to inform and describe the possibilities, etc., demonstrate that.
That means that marinas with its specific infrastructures and characteristics those can be subjected to an adequate conversion towards the function of improving nautical tourism, developing specific services which require a certain level of knowledge and specific technologies which are not represented often with existing one.

References

Agarwal, S. (2002). Restructuring seaside tourism. *Annals of Tourism Research, 29*(1), 25–55. https://doi.org/10.1016/s0160-7383(01)00002-0

Aronsson, L. (1994). Sustainable tourism systems: The example of sustainable rural tourism in Sweden. *Journal of Sustainable Tourism*, 2(1–2), 77–92. https://doi.org/10.1080/09669589409510685

Benevolo, C. (2010). Turismo nautico. Una sfida per il destination management, *Rivista di Scienze del Turismo*, n. 3, p. 105-129.

Benevolo, C. (2011) Problematiche di sostenibilità nell'ambito del turismo nautico in Italia, *Impresa Progetto Electronic Journal of Management*, n. 2

Berman, M., Havens, K. H., Rudnicky T., Barnard, T.A. (2002). Marina site suitablity tool: final project report https://doi.org/10.21220/V5HJ0J

Biondi E. L. (2017). "Working with Nature" - Planning Sustainable Marinas. Pianc-Smart Rivers 2017

Bramwell, B., & Lane, B. (1993). Sustainable Tourism: An Evolving Global Approach. *Journal of Sustainable Tourism*, 1(1), 1–5. https://doi.org/10.1080/09669589309450696

Bossel, H. (2002). Assessing Viability and Sustainability: a Systems-based Approach for Deriving Comprehensive Indicator Sets. Conservation Ecology, 5(2). https://doi.org/10.5751/es-00332-050212

Burns, P. M. & Holden, A. (1995). *Tourism: A New Perspective*, Prentice Hall.

Candela, G., & Figini, P. (2003). *Economia del turismo e delle destinazioni*, *McGraw-Hill*, Milano

Carter, E. (1993). Ecotourism in the Third World: problems for sustainable tourism development. *Tourism Management* (April), 14(2), 85–90. https://doi.org/10.1016/0261-5177(93)90040-r

Casas-Prat, M., & Sierra, J. P. (2010). Trend analysis of wave storminess: wave direction and its impact on harbour agitation. Natural Hazards and Earth System Sciences, 10(11), 2327–2340. https://doi.org/10.5194/nhess-10-2327-2010

Chandy, J., & Rajesh, R. (n.d.) Environmental Impact of tourism on Vembanad Lake

Chen, C.F., & Tsai, D. (2007). How destination image and evaluative factors affect behavioral intentions? *Tourism Management* 28(4): 1115–1122. https://doi.org/10.1016/j.tourman.2006.07.007

Chhetri, P., Corcoran, J., Gekara, V., Maddox, C., & McEvoy, D. (2014). Seaport resilience to climate change: mapping vulnerability to sea-level rise. *Journal of Spatial Science, 60*(1), 65–78. https://doi.org/10.1080/14498596.2014.943311

Chiu, W., Zeng, S., & Cheng, P. S. T. (2016). The influence of destination image and tourist satisfaction on tourist loyalty: a case study of Chinese tourists in Korea. *International Journal of Culture, Tourism and Hospitality Research*, 10(2), 223–234. https://doi.org/10.1108/ijcthr-07-2015-0080

Christensen, N. A. (1994). Sustainable community-based tourism and host quality of life. *General Technical Report - Intermountain Research Station, USDA Forest Service*: 63-68

Christodoulou, A., Christidis, P., & Demirel, H. (2018). Sea-level rise in ports: a wider focus on impacts. *Maritime Economics &Amp; Logistics, 21*(4), 482–496. https://doi.org/10.1057/s41278-018-0114-z

Cole, S. T., & Scott, D. (2004). Examining the Mediating Role of Experience Quality in a Model of Tourist Experiences. *Journal of Travel &Amp; Tourism Marketing*, 16(1), 79–90. https://doi.org/10.1300/j073v16n01_08

Darbra, R., Pittam, N., Royston, K., Darbra, J., & Journee, H. (2009). Survey on environmental monitoring requirements of European ports. *Journal of Environmental Management, 90*(3), 1396–1403. https://doi.org/10.1016/j.jenvman.2008.08.010

De Ciutiis, F. (2009). Urban practices: Integrated Planning Port-City into Urban Plan and Projects. *TeMA - Journal of Land Use, Mobility and Environment, 2*(3). https://doi.org/10.6092/1970-9870/95

De Langen, P., Turró, M., Fontanet, M., & Caballé, J. (2018). *The infrastructure investment needs and financing challenge of European ports. Report prepared for the European Seaports Organisation (ESPO)*. Retrieved from: https://www.espo.be/media/Port%20Investment%20Study%202018_FINAL_1.pdf

Di Franco, A., Graziano, M., Franzitta, G., Felline, S., Chemello, R., & Milazzo, M. (2011). Do small marinas drive habitat specific impacts? A case study from Mediterranean Sea. *Marine Pollution Bulletin, 62*(5), 926–933. https://doi.org/10.1016/j.marpolbul.2011.02.053

European Commission. (2016). *Study on specific challenges for a sustainable development of coastal and maritime tourism in Europe*. Report EA-04-16-261-EN-N. Retrieved from: http://publications.europa.eu/resource/cellar/ab0bfa73-9ad1-11e6-868c-01aa75ed71a1.0001.01/DOC_1

European Commission. (2017). *Commission Staff Working Document on Nautical Tourism.* Retrieved from: http://ec.europa.eu/maritimeaffairs/documentation/studies_en

European Commission. (2021). The EU Blue Economy Report. https://s3platform.jrc.ec.europa.eu/w/the-eu-blue-economy-report-2021

Fachrudin, H. T., & Lubis, M. D. (2016). Planning for Riverside Area as Water Tourism Destination to Improve Quality of Life Local Residents, Case Study: Batuan – Sikambing River, Medan, Indonesia. *Procedia - Social and Behavioral Sciences, 234*, 434–441. https://doi.org/10.1016/j.sbspro.2016.10.261

Falzetti, A. (2009). Design and Infrastructure: the Transformations of Senigallia's Interface among Town, Port and Canal. *Tema. Journal of Land Use, Mobility and Environment, 2 (3)*. https://doi.org/10.6092/1970-9870/90

Flynn, A., & Valverde, M. (2019). Planning on the Waterfront: Setting the Agenda for Toronto's 'smart city' Project. *Planning Theory &Amp; Practice, 20*(5), 769–775. https://doi.org/10.1080/14649357.2019.1676566

Fonti, L., Masiello, D., & Pagano, C. (2009). Fiumicino: nuova città portuale e porta di Roma. *Tema. Journal of Land Use, Mobility and Environment, 2*(3). https://doi.org/10.6092/1970-9870/91

Fortezza, F. (2008). *Processi strategici e di marketing nel settore della nautica da diporto*. Franco Angeli.

Fraser, E. D., Dougill, A. J., Mabee, W. E., Reed, M., & McAlpine, P. (2006). Bottom up and top down: Analysis of participatory processes for sustainability indicator identification as a pathway to community empowerment and sustainable environmental management. *Journal of Environmental Management*, 78(2), 114–127. https://doi.org/10.1016/j.jenvman.2005.04.009

Garcia-Alonso, L., Monios, J., & Vallejo-Pinto, J. N. (2017). Port competition through hinterland accessibility: the case of Spain. *Maritime Economics &Amp; Logistics, 21*(2), 258–277. https://doi.org/10.1057/s41278-017-0085-5

Giampaola, D. (2009). Archaeology and the City: the Waterfront Redevelopment. *Tema. Journal of Land Use, Mobility and Environment, 2*(3). https://doi.org/10.6092/1970-9870/86

Giovinazzi, O., & Moretti, M. (2010). Port Cities and Urban Waterfront: Transformations and Opportunities. *Tema. Journal of Land Use, Mobility and Environment, 2*(3). https://doi.org/10.6092/1970-9870/123

Giannì, R. (2009). The Waterfront of Naples in the New Master Plan. *Tema. Journal of Land Use, Mobility and Environment, 2*(3). https://doi.org/10.6092/1970-9870/89

Green Marina Education and Outreach Project team. (2017). *Great Lakes clean marina. Best management practices Guide – for State program managers and coordinators*.

Hall, C. (2001). Trends in ocean and coastal tourism: the end of the last frontier? *Ocean &Amp; Coastal Management*, 44(9–10), 601–618. https://doi.org/10.1016/s0964-5691(01)00071-0

He, X., & Luo, J. M. (2020). Relationship among Travel Motivation, Satisfaction and Revisit Intention of Skiers: A Case Study on the Tourists of Urumqi Silk Road Ski Resort. *Administrative Sciences, 10*(3), 56. https://doi.org/10.3390/admsci10030056

Hesse, M. (2017). Approaching the Relational Nature of the Port-City Interface in Europe: Ties and Tensions Between Seaports and the Urban. *Tijdschrift Voor Economische En Sociale Geografie, 109*(2), 210–223. https://doi.org/10.1111/tesg.12282

Jennings, S. (2004). Coastal tourism and shoreline management. *Annals of Tourism Research, 31*(4), 899–922. https://doi.org/10.1016/j.annals.2004.02.005

John, R. M. (2018). A study on the houseboat tourism on water environment and fish production in Kumarakom. International Journal of Fauna and Biological Studies, 5(5), 39–41. Retrieved from: https://www.faunajournal.com/archives/2018/vol5issue5/PartA/5-5-9-136.pdf

Joseph, L. C., Soundararajan, V., & Parayitam, S. (2021). The relationship between attraction, perception of service, opportunities and tourist satisfaction in backwater tourism in Alappuzha district of Kerala in India. *Tourism and Hospitality Research, 22*(3), 314–335. https://doi.org/10.1177/14673584211044087

Kokkranikal, J., & Morrison, A. (2002). Entrepreneurship and Sustainable Tourism: The Houseboats of Kerala. *Tourism and Hospitality Research, 4*(1), 7–20. https://doi.org/10.1177/146735840200400102

Kozak, M., & Rimmington, M. (2000). Tourist Satisfaction with Mallorca, Spain, as an Off-Season Holiday Destination. *Journal of Travel Research, 38*(3), 260–269. https://doi.org/10.1177/004728750003800308

La Rocca, R. A. (2014). The Role of Tourism in Planning the Smart City. *Tema. Journal of Land Use, Mobility and Environment, 7(3)*, 269–284. https://doi.org/10.6092/1970-9870/2814

Lee, S., Jeon, S., & Kim, D. (2011). The impact of tour quality and tourist satisfaction on tourist loyalty: The case of Chinese tourists in Korea. *Tourism Management, 32*(5), 1115–1124. https://doi.org/10.1016/j.tourman.2010.09.016

Leonardi, R. (2009). The Waterfront Project in Naples. *Tema. Journal of Land Use, Mobility and Environment, 2*(3). https://doi.org/10.6092/1970-9870/87

Martín, R. M., & Yepes, V. (2019). The concept of landscape within marinas: Basis for consideration in the management. *Ocean & Coastal Management, 179, 104815*. https://doi.org/10.1016/j.ocecoaman.2019.104815

McIntyre, G. (1993). Sustainable tourism development: guide for local planners. *Sustainable Tourism Development: Guide for Local Planners*.

Murphy, L., Moscardo, G., Benckendorff, P., & Pearce, P. (2011). Evaluating tourist satisfaction with the retail experience in a typical tourist shopping village. *Journal of Retailing and Consumer Services, 18*(4), 302–310. https://doi.org/10.1016/j.jretconser.2011.02.004

Murphy, P. E. (1995). Tourism and Sustainable Development, *Global Tourism: the next decade*, 274-290.

Naidoo, P., Ramseook-Munhurrun, P., & Seegoolam, P. (2011). AN ASSESSMENT OF VISITOR SATISFACTION WITH NATURE-BASED TOURISM ATTRACTIONS. *International Journal of Management and Marketing Research, 4*(1), 87–98. https://econpapers.repec.org/RePEc:ibf:ijmmre:v:4:y:2011:i:1:p:87-98

Nguyen Viet, B., Dang, H. P., & Nguyen, H. H. (2020). Revisit intention and satisfaction: The role of destination image, perceived risk, and cultural contact. *Cogent Business &Amp; Management, 7*(1), 1796249. https://doi.org/10.1080/23311975.2020.1796249

Nursey-Bray, M., Blackwell, B., Brooks, B., Campbell, M. L., Goldsworthy, L., Pateman, H., Rodrigues, I., Roome, M., Wright, J. T., Francis, J., & Hewitt, C. L. (2013). Vulnerabilities and adaptation of ports to climate change. *Journal of Environmental Planning and Management, 56*(7), 1021–1045. https://doi.org/10.1080/09640568.2012.716363

Okello, M. M., & Yerian, S. (2009). Tourist satisfaction in relation to attractions and implications for conservation in the protected areas of the Northern Circuit, Tanzania. *Journal of Sustainable Tourism, 17*(5), 605–625. https://doi.org/10.1080/09669580902928450

Olivier, D., & Slack, B. (2006). Rethinking the Port. *Environment and Planning A: Economy and Space, 38*(8), 1409–1427. https://doi.org/10.1068/a37421

Oniszczuk-Jastrząbek, A. Pawłowska B., & Czermański, E. (2018). Sea port as an element of a city sustainability based on city-port of Gdańsk, *SHS Web of Conferences* (58). https://doi.org/10.1051/shsconf/20185801021

Pagés Sánchez, J. M., & Daamen, T. A. (2019). Using Heritage to Develop Sustainable Port–City Relationships: Lisbon's Shift from Object-Based to Landscape Approaches. *Adaptive Strategies for Water Heritage*, 382–399. https://doi.org/10.1007/978-3-030-00268-8_20

Parola, F., Satta, G., & Vitellaro, F. (2021). "Port Hinterlands". In Roger Vickerman (Ed.), *International Encyclopedia of Transportation* (3): 305-309.

Pearce, P. L., Moscardo, G., & Ross, G. F. (1996). Tourism community relationships. *Emerald Group Publishing Limited EBooks, 4*. https://books.emeraldinsight.com/page/detail/Tourism-Community-Relationships/?K=9780080423951

Petrosillo, I., Valente, D., Zaccarelli, N., & Zurlini, G. (2009). Managing tourist harbors: Are managers aware of the real environmental risks? *Marine Pollution Bulletin, 58*(10), 1454–1461. https://doi.org/10.1016/j.marpolbul.2009.06.013

Poletan Jugović, T., Agatić, A., Gračan, D., Šekularac – Ivošević, S. (2022). Sustainable activities in Croatian marinas – towards the "green port" concept, *Multidisciplinary Scientific Journal Of Maritime Research* (36): 348-327. https://doi.org/10.31217/p.36.2.15

Puczko, L. & Ratz, T. (2000). Tourist and residential perceptions of the physical impacts of tourism at Lake Balaton, Hungary: issues for sustainable tourism management. *Journal of Sustainable Tourism, 8* (6), 458-478. https://doi.org/10.1080/09669580008667380

Quintal, V. A., & Polczynski, A. (2010). Factors influencing tourists' revisit intentions. *Asia Pacific Journal of Marketing and Logistics, 22*(4), 554–578. https://doi.org/10.1108/13555851011090565

Ragheb, A., & EL-Ashmawy, R. (2020). Urban Waterfront Development for Designing Space in Coastal Cities. *International Journal of Sustainable Development and Planning, 15*(3), 345–352. https://doi.org/10.18280/ijsdp.150311

Report Linker. (2020) *The Global Boat Rental Market Is Expected to Grow from USD 17,620.57 Million in 2019 to USD 23,160.11 Million by the End of 2025 at a Compound Annual Growth Rate (CAGR) of 4.66%.* Retrieved from: https://www.globenewswire.com/news-release/2020/07/03/2057347/0/en/TheGlobal-Boat-Rental-Market-is-expected-togrow-from-USD-17-620-57-Million-in-2019-to-USD-23-160-11-Million-by-the-end-of-2025-at-a-Compound-Annual-Growth-RateCAGR-of-4-66.htm

Ritchie, J. R. B., & Crouch, G. I. (2003). *The Competitive Destination: A Sustainable Tourism Perspective*. CABI Pub.

Ruozi, R. (2005). *Sostenibilità e competitività nel settore turistico*. Economia & Management (2), 95.

Russo, M., & Formato, E. (2014). City/Sea Searching for a New Connection. Regeneration Proposal for Naples Waterfront Like an Harbourscape: Comparing Three Case Studies. *Tema. Journal of Land Use, Mobility and Environment*. https://doi.org/10.6092/1970-9870/2498

Sakalayen, Q., Shu-Ling Chen, P., Cahoon., S. (2022). A place-based approach for ports' involvement in regional development: A mixed-method research outcome, *Transport Policy* (119): 16-31.

Santoso, S. (2019). Examining relationships between destination image, tourist motivation, satisfaction, and visit intention in Yogyakarta. *Expert Journal of Business and Management* (7), 82–90. https://www.zbw.eu/econis-archiv/handle/11159/3847

Shamim, A. S. (2012). Tourism and Lake Sustainability: A Case Study of Dal Lake, *International Journal of Environmental Sciences* (1), 230-234.

Sierra, J. P., Casas-Prat, M., Virgili, M., Mösso, C., & Sánchez-Arcilla, A. (2015). Impacts on wave-driven harbour agitation due to climate change in Catalan ports. *Natural Hazards and Earth System Sciences, 15*(8), 1695–1709. https://doi.org/10.5194/nhess-15-1695-2015

UNCTAD - United Nations Conference on Trade and Development. (2020). COVID-19 and Tourism Assessing the Economic Consequences. https://unctad.org/system/files/official-document/ditcinf2020d3_en.pdf

Üzümcüoğlu, D., & Polay, M. (2022). Urban Waterfront Development, through the Lens of the Kyrenia Waterfront Case Study. *Sustainability, 14*(15), 9469. https://doi.org/10.3390/su14159469

Vijayakumar, B. (2009). Tourism in Kerala – an Overview, in Vijayakumar. *Sustainable Development of Tourism in Kerala: Issues and Strategies*, 1: 5-20

Wall, G. (1997). Sustainable Tourism: Unsustainable Development. *Tourism Development and Growth: The Challenge Of Sustainability*:33-49

Weeden, C. (2013). *Responsible Tourist Behavior*. Routledge.

Woo, S. H., Pettit, S., Beresford, A., & Kwak, D. W. (2012). Seaport Research: A Decadal Analysis of Trends and Themes Since the 1980s. *Transport Reviews, 32*(3), 351–377. https://doi.org/10.1080/01441647.2012.660996

World Tourism Organization. (n.d.). https://www.unwto.org/glossary-tourism-terms, last access 2/08/2022

Zacharias, S., Manalel, J., & Jose, M. C. (2010). Back Water Tourism in Kerala: Challenges and Opportunities. *International Journal of Research* (1), 542-551

Zhang, H., Cho, T., Wang, H., et al. (2018). The influence of crosscultural awareness and tourist experience on authenticity, tourist satisfaction and acculturation in world cultural Heritage sites of Korea. *Sustainability* 10(4): 927–934

Author's profile

Alessandro Bove

He is a researcher in urban planning and technics at the department ICEA of Padua University. He is building engineer with expertise in urban and spatial planning and special interest in resilience and sustainability planning. He had his PhD in Building and Territorial Engineering (Bologna University, 2009). His research experiences are characterized by a practical approach because He always tried to combine theoretical research with design. The main themes of interest regard the sustainable urban transformation/regeneration, with a specific attention to industrial areas, the reuse of abandoned infrastructure and the protection of landscapes. On these themes, He had the opportunity to participate to national researches, to international cooperation projects and to public and private initiatives with research interest as regional and urban plans, strategic projects, often as leader or as coordinator. He is actually the President of Padua Engineers Foundation, private body active in the innovation and continuous education for engineers.

Elena Mazzola

She is currently a researcher and an Assistant Professor in the faculty of Engineering in Padua (Italy). She obtained her PhD in Architecture, City and Design from Iuav of Venice University, published a number of papers in preferred journals, and presented various academic as well as research-based papers at national and international conferences. Her research activities are currently twofold: while the first research activity is set to explore the efficiency of buildings, the second major research theme is focused on the develop of sustainable urban cities.

TeMA Journal of Land Use, Mobility and Environment

TeMA 1 (2023) 83-104
print ISSN 1970-9889, e-ISSN 1970-9870
DOI: 10.6093/1970-9870/9290
Received 4th July 2022, Accepted 30th January 2023, Available online 30th April 2023

www.tema.unina.it

Identifying spatial variation in the values of urban green at the city level

A case study in Thessaloniki, Greece

Antonia Giannakidou [a], Dionysis Latinopoulos [b*]

[a] School of Spatial Planning and Development
Aristotle University of Thessaloniki, Thessaloniki, Greece
e-mail: antwgian11@gmail.com

[b] School of Spatial Planning and Development
Aristotle University of Thessaloniki, Thessaloniki, Greece
e-mail: dlatinop@plandevel.auth.gr
ORCID: https://orcid.org/0000-0003-2184-9268
* Corresponding author

Abstract
Analyzing the benefits/values of urban green spaces (UGS) to local citizens is necessary in order to make these areas more visible, as well as to support future planning decisions related to the development of new green infrastructure in the urban environment. This paper aims to examine the values associated with the UGS in the city of Thessaloniki, Greece, by using a Hedonic Pricing Method, which examines the effect of urban green areas and amenities on housing prices. Furthermore, the study attempts to examine if the proximity to green spaces has a fixed/homogenous effect on residential property values across the city. A global regression analysis was first applied to explore which structural, locational and green/environmental characteristics are likely to have a statistically significant effect on housing prices. Then, a semi-parametric geographically weighted regression analysis, was applied to identify how the implicit prices of the environmental/green attributes vary within the city. The study revealed that the values of several environmental attributes vary significantly spatially, having in most cases a positive influence on home sale prices. These findings reveal that when making planning decisions about urban green spaces, it is necessary to consider the heterogeneity of citizens' preferences, facilitating thus a more targeted planning for new green infrastructures.

Keywords
Economic valuation; Spatial hedonic pricing model; Urban green spaces; Urban sustainability; Geographically weighted regression.

How to cite item in APA format
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.
http://dx.doi.org/10.6093/1970-9870/9290

1. Introduction

By their nature, cities are particularly vulnerable to natural hazards and climate change impacts. Furthermore, cities are exposed to several human pressures caused by the continuous growth in the size and the population of the urban areas. Specifically, according to data of the United States Department of Economic and Social Affairs, in 2007 for the first time in human history, 50% of the entire global population lived in urban areas and it is now predicted to reach 69% by 2050 (Zali et al., 2016). Consequently, the living conditions in cities deteriorate, and several problems are encountered. It has to be noticed that even though the cities represent only the 4% of the Earth's land, they consume about the 67% of the global primary energy and, due to urban lifestyle and economy, they are responsible for more than the 70% of greenhouse gas (GHG) emissions (Papa et al., 2015). Cities are also highly vulnerable to climate change, as they represent concentrations not only of people but also of assets and infrastructures (De Gregorio Hurtado et al., 2015). Thus, the sustainability and the resilience of cities are increasingly challenged and the necessity to find solutions and to take action is more urgent than ever.

Furthermore, urban density is now commonly considered as a fundamental characteristic of sustainable urban form and thus a prime goal of urban planning. Namely, compact cities have the potential to reduce the use of land and optimize the flow of people, energy, and good, while they may increase the proximity between dwellings, workplaces, and public facilities. Consequently, compact cities are likely to demand fewer resources and produce fewer greenhouse gases (Palacio et al., 2018). Even though compact cities are trying to solve the problems of rapid urbanization and urban sprawl, some negative effects may also exist (e.g. overcrowding, lower living quality, etc.). A major issue which is necessary to be addressed is the lack of urban green space in densified urban areas and the removal of green space when densifying an urban area (Haaland & Van den Bosch, 2015).

Hence, the development of green spaces is likely to strengthen the resilience of the cities, enabling them to overcome many future shocks and pressures. Furthermore, urban green spaces (UGS) are integral elements of cities' living environment, ensuring a higher quality of everyday life, as well a safe and friendly environment for citizens. Therefore, beyond the environmental benefits that citizens could gain from green infrastructures, there are also benefits related to many other sectors such as the economic, the social, and the cultural ones. Some examples are the management of the stormwater through the green and blue roofs (Foster et al., 2011) and the mitigation of the urban heat island effect (Onishi et al., 2010; Tsilini et al., 2015). Other advantages include the reduction of air pollutants (Foster et al., 2011), the cooling of the interior of buildings, especially during summer months (Wang et al., 2014), the improvement of the urban and peri-urban ecosystems' health and ecosystems' services (Tzoulas et al., 2007), as well as the contribution to the mental and physical health by creating positive feelings (Chiesura, 2004). All these benefits have been widely recognized but they are even more important in compact cities.

Finally, as a result of the above-mentioned benefits, proximity to green spaces increases property values, although this increase varies depending on the type of green space and the type of properties (Skouras & Arvanitidis, 2008). For all these reasons, several recent movements in urbanism, such as ecological urbanism, ecological landscape urbanism and landscape urbanism, emphasize that it is vital for the quality of life of cities to prioritize nature and ecological considerations (Latinopoulos, 2022).

The present study highlights the value of green spaces in the urban fabric, by using the hedonic pricing approach. In particular, a spatial hedonic analysis model was used in order to determine the value of green spaces with housing prices, as well as to examine how the proximity to green space influences the value of a property in the study area. Another question that the study attempt to answer, is whether this influence is homogeneous throughout the study area, or if there are regions/neighborhoods where urban green has a more significant (positive) impact on property values (i.e. if there are regions/neighborhoods where the value of green infrastructure is higher as compared to the rest of the city). For the spatial analysis, the Municipality

of Thessaloniki in Greece was selected as a study area, which has up to now a very low rate of proportional green space per capita.

2. Literature Review

2.1 UGS and Green Infrastructure

The term "green areas" is used in various ways even within the same discipline and the same culture, based on the research question (and on their interpretation/expression), as well as on the characteristics of those areas (Taylor & Hochuli, 2017). The classification of green spaces could be done with many different criteria, such as according to: 1) their size (Choi et al., 2020); 2) the quality and the quantity of the provided services; 3) the accessibility (Panduro & Veie, 2013); 4) their dominant functions; 5) the different kind of administration (Liu et al., 2020). Even though at the national level (i.e. in Greek legislation) there is no strict distinction between the concepts of "UGS" and "free public spaces", in the study area (Municipality of Thessaloniki), green spaces are considered according to the city's "Green Regulation" as: urban spaces covered by vegetation, including: public parks, gardens, cemeteries, planted trees in historic sites, green belts, street/sidewalk trees, and groves (Municipality of Thessaloniki, 2017).

A new term for urban green is that of green infrastructure, the definition of which varies among studies, according to the context, the stakeholders, and/or the spatial scale in which it is examined (Salata & Yiannakou, 2016). Green infrastructures are usually considered as an interconnected network of green space that conserves natural ecosystem functions and provides associated benefits to human populations (Benedict & McMahon, 2002). Respectively to green spaces, green infrastructure can be also classified into categories. The simplest classification is the urban, peri-urban and rural division, while several attributes/criteria can be used for this purpose: a) land uses; b) accessibility; c) land ownership (public/private); d) physical characteristics (e.g. morphology); e) spatial configuration (Koc et al., 2016), scale (Barker et al., 2019), etc.

Recent studies tend to use classified land cover (CLC) data, from satellite imagery to measure greenspace in urban areas. Other studies are measuring vegetation's health and density by means of vegetation indices, which are based on the biophysical functions of plants, as well as on high-resolution aerial photos (Li et al., 2015). One of the most well-known indices is the Normalized Difference Vegetation Index (NDVI), which is usually obtained from Landsat imagery (with a 30m resolution) to quantify green areas and to show the status (density and condition) of green vegetation on the landscape.

2.2 Economic valuation of UGS

Many reasons make necessary the estimation of the economic value of UGS. First of all, despite their multiple benefits, the critical role of UGS is often neglected or overlooked in the urban/regional development and planning policies (Sandstrom et al., 2006; Latinopoulos et al., 2016). Besides, as pointed out by More et al. (1988), UGS are subject to development pressures because planners have been more or less unable to articulate its value in economic terms. Furthermore, the valuation of UGS is also necessary in order to understand/assess the economic benefits of the various ecosystem services provided by these areas.

When market prices are not available for environmental and natural resource valuation (as in the case of the valuation of UGS), the value is measured by the citizens' (direct or indirect) willingness to pay (WTP) for the goods and/or services (whether or not actual transactions take place). The valuation of such non-market benefits of UGS are not a simple task, as it necessitates to assess various social and ecological services. Several economic valuation techniques have been developed to quantify such values. These techniques are rigorously based on either stated preferences (SP) in surveys with respect to the non-marketed goods/services or on observed behavior towards some marketed goods/services (revealed preference - RP) (Navrud, 2000).

Stated preferences (SP) techniques, such as the contingent valuation method, are trying to infer the value of non-market goods by asking people to state their WTP for a benefit in a hypothetical scenario (Bouma & Van Beukering, 2015). These techniques are the most frequently cited for the valuation of environmental values as they enable the estimation of both use and non-use values. As a consequence, they are also very commonly used within the context of UGS and urban parks. On the other hand, there is a great controversy over whether people would actually pay the amounts stated in the survey responses (Barbier et al., 1997) and they are also prone to several biases questioning their applicability in decision making processes (Mitchell & Carson, 1989; Venkatachalam, 2004).

On the other hand, revealed preference techniques are based on actual consumer (or producer) behavior and identify how non-marketed environmental services, influence the actual market for some related economic goods (Bouma & Van Beukering, 2015). Therefore, these techniques are mainly applied to elicit preferences for direct and indirect use, as revealed in complementary or surrogate markets. The most important indirect methods are the travel cost method, the hedonic pricing method, and the averting behavior method (Mendelsohn & Olmstead, 2009).

The present work focuses on the application of the hedonic pricing method (RP technique), which is based on the assumption that people's demand for composite marketed goods (e.g. housing prices), which among others, incorporates environmental characteristics is likely to reveal the value that people attach to each particular environmental characteristic (Pearce & Özdemiroglu, 2002). According to Gargiulo & de Ciutiis (2009), the market value of residential houses depends on many neighborhood/location characteristics, such as the accessibility, the density of services in the vicinity and the urban quality (i.e. the quality of the urban environment). Regarding the latter, the role of urban green spaces (UGS) is fundamental and for this reason there is an increasing literature on their effect on housing prices (e.g. Tyrväinen, 1997; Luttik, 2000; Morancho, 2003; Kong et al, 2007; Donovan & Butry, 2011; Saphores & Li, 2012; Liebelt et al., 2017).

For example, according to the U.S. Environmental Protection Agency (EPA), green infrastructure can contribute to land value increases up to 30% (Zucaro & Morosini, 2017). More specifically, Morancho, 2003 examined the effect of distance and size of UGS, in the city of Castellon in Spain, concluding that the most important factor affecting property prices is the distance from green spaces. Cho et al (2006) and Poudyal et al (2009) estimated the price increase with respect to the property's distance from the nearest park. In a similar study in the district of Salo in Finland, Tyrväinen and Miettinen (2000) estimated that increasing the distance of a property from an urban forest by 1 km, reduces its value by 5.9%. Other studies, focused on how property prices are affected by: the UGS size (e.g. park size) (e.g. Hoshiro & Kuriyama, 2010), the aggregate UGS area within a radius from home, as a landscape metric (e.g. Kong et al., 2007), the percentage of a town district covered by forested land (Tyrvainen, 1997), the diversity of UGS (e.g. Kong et al., 2007), the view of a green space (Morancho, 2003; Jim & Chen, 2006; Tyrväinen & Miettinen, 2000). All this information, coming from the valuation of different UGS variables/characteristics is likely to provide valuable insights into the values that citizens attain from these spaces and may thus support future urban planning processes and decisions (Panduro & Veie, 2013).

3. Methodology

3.1 Hedonic pricing method

The hedonic pricing method measures the implicit price (i.e. the value of an individual characteristic) of an environmental good or service, which is not traded on a market, as revealed through the observed price of a product that is traded on markets (Bouma & Van Beukering, 2015). Hedonic pricing may be used to estimate economic benefits or costs associated with environmental quality (e.g. air pollution, noise) and/or environmental amenities (e.g. aesthetic views, proximity to recreational sites). It is usually applied to variations

in housing prices that reflect - among others - the value of local environmental attributes. Houses are multi-attribute goods, so their price is determined by characteristics, which can be classified into the following categories:

$$P = f(S, N, L, E) \quad (1)$$

P is the vector of the rent or the price of the house; S is the matrix of the property-related (structural) attributes (e.g. number of rooms, age, floor, size, etc.); N is the matrix of neighborhood's socio-economic characteristics (e.g. quality of services, quality of the schools, quality of transport system, etc.); L is the matrix of locational variables (e.g. distance to schools, distance from the central business district, distance from bus/metro stations, etc.); E is the matrix of environmental characteristics (e.g. UGS variables), which are usually considered as a separated category (Saphores & Li, 2012).

In most studies, the market price is considered to be the selling price and not the rent value, because rent values are problematic since different apartments may have different terms in the rental agreement. For example, some might include heat and hot water supply or parking spaces (Sopranzetti, 2010). The partial derivative of P (Eq. 1) with respect to any of the selected attributes (dP/dz_i) is an implicit price, that equals its marginal contribution to the housing price, representing thus consumers' marginal willingness to pay for the corresponding characteristic/attribute (Saphores & Li, 2012). According to Gómez-Baggethun & Barton (2013) the hedonic pricing method is widely used for the assessment of the UGS (e.g. open spaces, parks, trees in public spaces) through a regression analysis (Herath & Maier, 2010). The most common method for estimating the function above is the application of a linear regression model, which is solved by means of an ordinary least squares (OLS) method (Latinopoulos, 2018):

$$P_i = \alpha + \beta Z_{i,j} + e_i \quad (2)$$

P_i is the price of house i, α is the intercept term; β is the vector of regression coefficients, Z is the Matrix of j attributes of each house and e is the random error, which is assumed that it follows the normal distribution. The functional form of the hedonic regression equation can either be linear, semi-log, or log-log form (Herath & Maier, 2010), thus differentiating the way the results are interpreted (Mallios et al., 2009). For example, in the case of the linear model, any coefficient β_j represents the marginal value of the *j-th* characteristic while in the log-linear model the same coefficient β_j represents the elasticity of demand for this specific characteristic (Mallios et al., 2009). Thus, log-linear models are commonly used to make better interpretation of the results, as well as to minimize the problem of heteroskedasticity.

3.2 Geographically weighted regression

Traditional OLS hedonic pricing models are based on various assumptions. For example, it is assumed that there is sufficient information about the conditions in the market, as well as about the environmental issues (people are supposed to be aware of the link between the environmental good and their welfare). It is also assumed that when using an OLS model, the random error e in Eq.2 follows a normal distribution with mean zero and constant variance, so there is no autocorrelation in the data. However, in some cases, there is (spatial) autocorrelation between the values of a variable due to the spatial nature of the sampling (e.g. property values are dependent on property values of neighboring locations) and this may violate the assumption of independence of observations in the traditional hedonic price model (Latinopoulos, 2018).

Another drawback of traditional hedonic-pricing models is that the fail to detect and account for the non-stationarity of the effects of space/location on real estate prices. Spatial non-stationarity means that the relationship between the variables is not constant across the study area (Páez & Wheeler, 2009), indicating thus a heterogeneous relationship between dependent and independent variables across the geographic

space. As non-stationarity is not taken into account when using a traditional OLS model, the resulting statistics/estimations are assumed to be constant across space (Brunsdon et al., 1996). This means that wherever a house is located, the value added for an additional floor or for a closer proximity to an UGS, for instance, will be the same (global estimate) in the whole study area. However, this may not be the case and it might be more reasonable to assume that price determinants are spatially varying parameters with different marginal price functions across space. And this clarifies why a global (OLS) model is not always possible to explain the relationships between all sets of variables (Brunsdon et al., 1996). Hedonic regression models, in order to better explain the real estate prices across space, integrate new approaches for modeling spatial heterogeneity. The most popular ones are the following: a) spatial error models, which are appropriate if it appears to be structure in the residual term, b) spatial lag models which are appropriate when a spatial structure is present in the model's variables (Charlton & Fotheringham, 2009), c) OLS models using dummy variables to represent distinct geographic areas/submarkets, and d) geographically weighted regression (GWR) models, which allow the regression parameters to vary over space, being also able to explore the issue of spatial parametric non-stationarity.

In this study, a geographically weighted regression (GWR) model was developed to take into account the variable nature of relationships in geographical space. There is a good reason to expect that the price of housing attributes will exhibit spatial heterogeneity within large metropolitan areas (i.e. large housing markets) due to different preferences (demand by households based on socioeconomic characteristics), location attributes and neighborhood characteristics (supply of certain types of housing and neighborhood characteristics. So, it is very likely that supply and demand imbalances may result in spatial heterogeneity within a large metropolitan area (Bitter et al., 2007). In fact, recent applications of GWR models demonstrated that property prices premiums varied in terms of the effect and magnitude across space for the demand of explanatory variables that are spatial in nature (Dziauddin et al., 2015).

The basic difference between the traditional OLS models and the GWR model is the fact that the latter (a) assumes that the association between the property price and the independent variables can be spatially variant and (b) provides a set of equations to estimate the coefficients at any given location (local coefficients). In other words, the GWR model aims to capture spatial variations (i.e. to address spatial heterogeneity and spatial autocorrelation) in the relations between housing prices and the selected attributes. The geographically weighted regression model is expressed as follows:

$$P_i = \alpha(u_i, v_i) + \Sigma_j \beta_j(u_i, v_i) Z_{i,j} + \varepsilon_i \quad (3)$$

All the elements are the same with the Eq. 2 above, but the only difference is that they are location specific. Namely, P_i is the dependent variable (price of house) at location i, the coefficients α and β are non-stationary but also correspond to the location i of each observation (where u_i and v_i are the x-y coordinates at location i) and ε_i is the random error at location i. Data located near to point i are assumed to have more influence in the estimation of the *j-th* attribute's β-coefficient [$\beta(u_i, v_i)$] than data located farther from i. Thus, in GWR an observation is weighted in accordance to its proximity to point i so that the weighting of β-coefficients is no longer constant in the calibration but varies with i, that is (Fotheringham et al., 1998):

$$\hat{\beta}(u_i, v_i) = [X^T W(u_i, v_i) X]^{-1} X^T W(u_i, v_i) P] \quad (4)$$

where the bold type denotes a matrix, $\hat{\beta}$ represents an estimate of β and $W(u_i, v_i)$ is a n×n matrix whose off-diagonal elements are zero and whose diagonal elements denote the geographical weighting of observed data for point i. Usually these weights (for any given observation) are estimated by means of a kernel function (based on the rule that closer observations have a higher effect on the estimation of the coefficients than

those further apart). The most commonly used kernel functions are the fixed Gaussian and the adaptive bi-square kernel functions[1].

There are different formations of GWR, one of which is the semi-parametric. The semi-parametric models allow to mix simultaneously some globally fixed variables (i.e. effects that are independent of location) and some locally varying variables (Nakaya, 2007). In this way, the analysis can be separated into global (stationary) and local (non-stationary), instead of the traditional OLS regression analysis where all variables are considered to be global. In this case, the geographically weighted regression model is expressed as follows:

$$P_i(u_i, v_i) = \alpha(u_i, v_i) + \Sigma_j \gamma_j Z_{i,j} + \Sigma_j \beta_j(u_i, v_i) Z_{i,j} + \varepsilon_i \quad (5)$$

It should be also noted that spatial heterogeneity can also be captured by means of other non-parametric (e.g. local polynomial regression models) or semi-parametric methods (e.g. generalized additive model) which allow a more flexible modeling between the regressor and the predictor without any a priori assumptions regarding the underlying data generating process. These models expand the traditional hedonic model by identifying nonlinear effects and thus, by allowing covariates to take nonlinear functional form in order to enhance the model quality (Cajias & Ertl, 2018). However, this kind of analysis has large computation and data requirements to achieve reliable estimation, so its attractiveness is limited in our study due to the limited dataset availability. Besides, the type of the methodology to be employed depends on the research problem, the research objectives, the data availability and not on the merits of a particular research approach, as no particular approach is superior to others (Creswell, 2007).

4. Study area description, data collection and pre-processing

4.1 Study area description

The Municipality of Thessaloniki was selected as the study area for the present study. It is the second most populated municipality in Greece (according to the 2011 Greek census the population is about 325,000 inhabitants) while its total area is equal to 19.31 km^2. It is also the center of the metropolitan area of Thessaloniki (Fig.1), where the historic city center is located. Consequently, it is a typical compact city facing various environmental problems (e.g. air quality, traffic noise), and particularly, facing a lack of open and green spaces.

The urban form of the metropolitan area of Thessaloniki has undergone several changes, and the most important reasons for these changes were the natural disasters and the refugee crises that had occurred from time to time. According to the current General Urban Plan, some areas have been characterized as "purely residential" especially in the southeastern part and others as "general residence". In the northwestern part, the main public transport hubs (port and railway station) are located close to the sub-urban and peri-urban industrial zone/sites. Finally, the Metropolitan area of Thessaloniki has on average 2.6m^2 of green area per person, while the World Health Organization (WHO) recommends having 10 to 12 square meters.

Especially for the UGS, the Municipality of Thessaloniki has developed an "Observatory of Urban Green Siting" under the Geospatial Information Infrastructure. In this Observatory, the location of green spaces and trees are recorded with the aid of Geographical Information System (G.I.S.), while the green adequacy index is calculated through the normalized vegetation index from Sentinel-2 satellite data (Municipality of Thessaloniki, 2016). According to the index data, only two neighborhoods ("Upper Town" and "Troxiodromikon") appear to have high adequacy index values, while in the rest of the study area the index values are significantly low,

[1] A Gaussian function assigns the weight as a continuous function of distance, while the adaptive bi-square kernel function uses the same number of nearby points for modeling, and therefore, it does not coerce the bandwidth into a constant but permits the spatial extent (bandwidth) to vary across space (Yang et al., 2020).

and in many cases, a critical green deficit is identified. Additionally, it is important to mention that the share of green area per person – which was estimated based on census data on the population from the Hellenic Statistical Authority (www.statistics.gr) and on land-use data from the Urban Atlas (https://land.copernicus.eu/) – is slightly higher than the average share of the Metropolitan area (3.14m^2/person) but still quite low. It should be noted that according to a ministerial order, the need for green spaces on Greek cities has been set to 8 m^2/resident. So, there is a deficit of such spaces of 4.86 m^2/resident, based on the Greek legislation or equal to 6.86 m^2/resident, based on WHO standards.

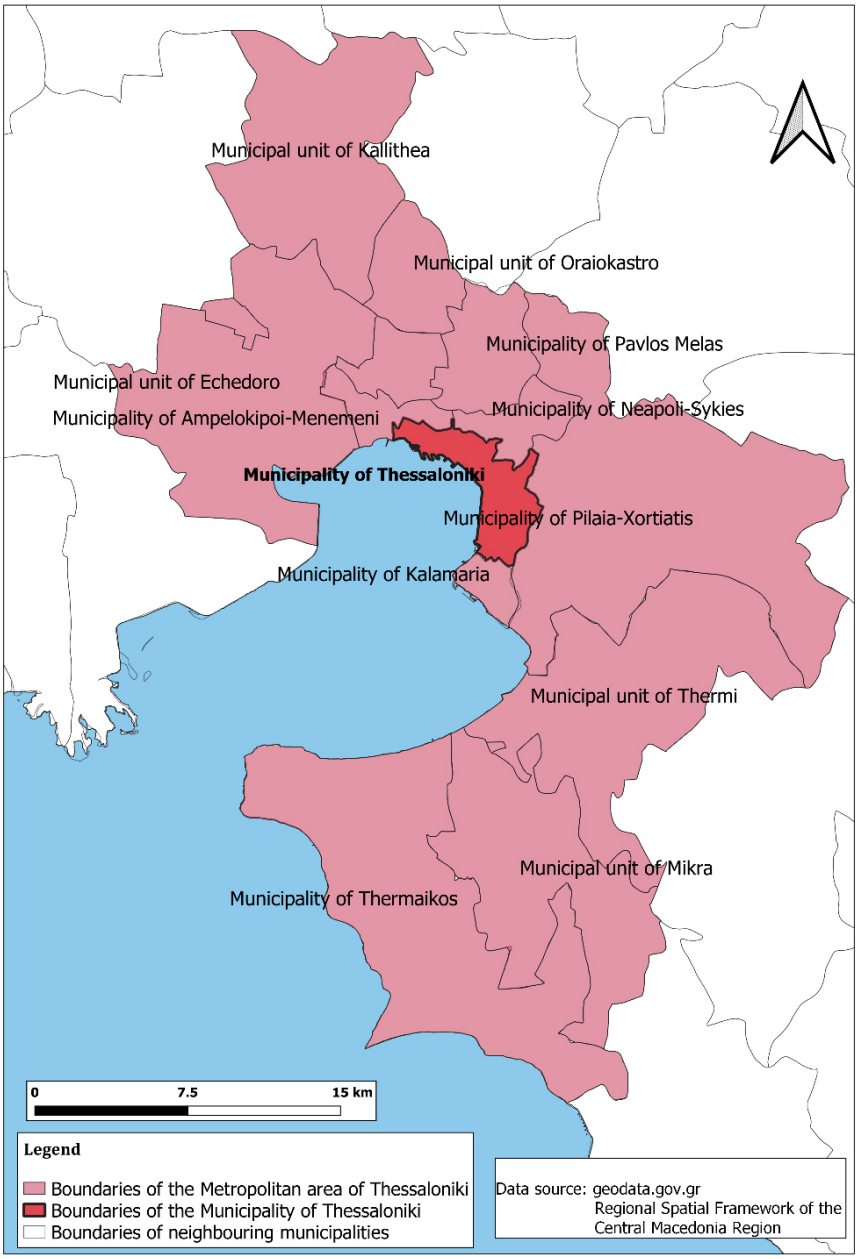


Fig.1 Location of the Municipality of Thessaloniki within the Metropolitan area

In this context, a study has been conducted by Latinopoulos et al. (2016), aiming to value (through a contingent valuation method) the benefits of an urban park regeneration project in the location of the Thessaloniki International Fair (TIF). The survey proved that on average households would be willing to pay significant amounts of money for the regeneration of the TIF area and the creation of a large metropolitan park.

4.2 Data collection

The data for this study were collected from a real estate online database (www.spitogatos.gr), over a one-month period, aiming to identify properties under the same demand conditions and thus to exclude any seasonal variation. We used a data collection method aiming to select (from the available database) only the properties that met the following criteria:

- properties had to be for sale and not for rent (i.e. we only examined property values and not rental values);
- only residential properties have been considered;
- properties had to be in the boundaries of the Municipality of Thessaloniki and their location (coordinates) should be available;
- properties had to be well (evenly) distributed over the study area;
- properties should have been entered into the database no later than six months earlier than the data collection period.

Following these criteria, a sample of 295 apartments were collected. All properties were then imported in the GIS environment (QGIS 3.18 software), for visualization (Fig.2) and for further analysis. Subsequently, by using the Urban Atlas database (edition 2012), land-use and land cover data were extracted for the green spaces in the study area. The Urban atlas distinguishes 21 thematic classes of land cover, including diverse classes of open/green spaces. In our study area, we initially used the following categories of land uses to classify the available green spaces: (1) Urban Green Spaces (UGS), (2) Arable Land, (3) Pastures, (4) Forests, (5) Herbaceous vegetation associations (natural grassland, moors, etc.), (6) (rows/corridors of) Trees (e.g. street trees).

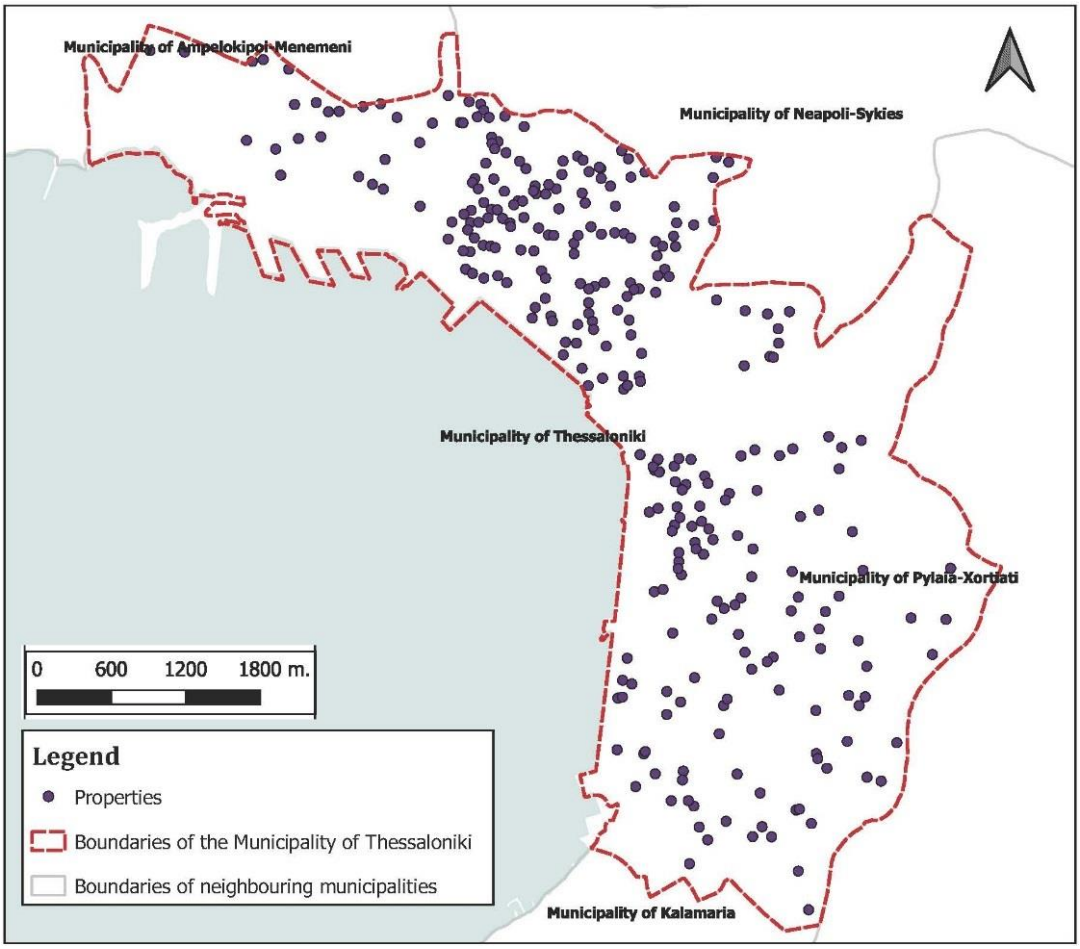


Fig.2 Map of the spatial distribution of properties

Some of these categories were combined to avoid using categories with very small number of cases, to obtain more efficient estimates and thus, to have a well-fitted model. So, urban green spaces, which are bordered by suburban natural areas and/or forests were studied as a separate category (Green other spaces). Arable land, pastures, forests, and herbaceous vegetation associations were also included in this category. A separated category was also used for the case of trees, which include contiguous rows or patches of trees, covering 500m² or more and with a minimum width of 10 m over "Artificial surfaces" (Rows of trees). All the rest were considered as UGS (Fig.3).

Then, for each individual property, the shortest (Euclidean) distance was calculated from: (a) all the above-mentioned categories of green spaces, (b) the coastline, (c) the historic center (the historic center was mapped in QGIS, according to the ministerial order: "Characterization as a historical place of the historical center of Thessaloniki", which describes in detail the city's districts.

Finally, we calculated, by using the QGIS software the vegetation index (NDVI) all over the study area and we assigned the corresponding value to each observation (according to the location of each property). The reasoning for using NDVI index is to represent vegetation's health and density in the study area, as well as to evaluate green space regardless of the land-use type (and then to use this evaluation as an attribute to the hedonic model). For the NDVI calculation the satellite Landsat 8 images were used from Landsat Collection 1 Level-1 and Landsat 8OLI/TIRS C1 Level 1. The date those images were taken was 20/6/2020 and their analysis was 30m, which were both considered very satisfactory. NDVI values range from [-1,1]. Low NDVI values indicate moisture-stressed vegetation and higher values indicate a higher density of green vegetation (Gessesse & Melesse, 2019). According to Fig.4, it is obvious that most of the study area represents a sparse and moderate vegetation, while there are only few areas where the vegetation index values are high.

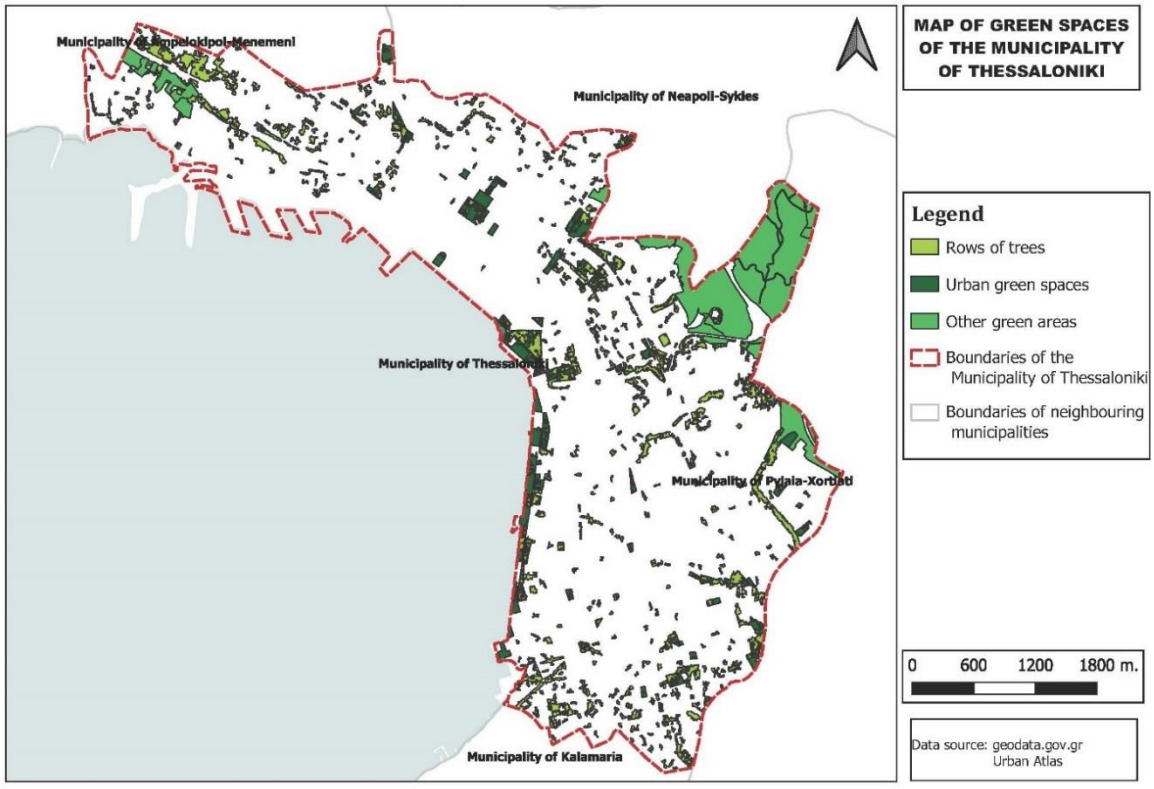


Fig.3 Map of green spaces of the Municipality of Thessaloniki

Explanatory variables were selected based on previous relevant studies, as well as on the suggested data availability for the study area. Accordingly, 13 attributes were finally selected as factors that may affect the dependent variable (i.e. the housing prices).

Most of these factors are related to the structural characteristics of the housing units/observations in the data, while four different factors were used to fully consider the role of green areas on residential property (real estate) values. Tab.1 lists and describes each of the selected variables and Tab.2 provides the summary statistics and the expected sign (effect of each variable on housing prices).

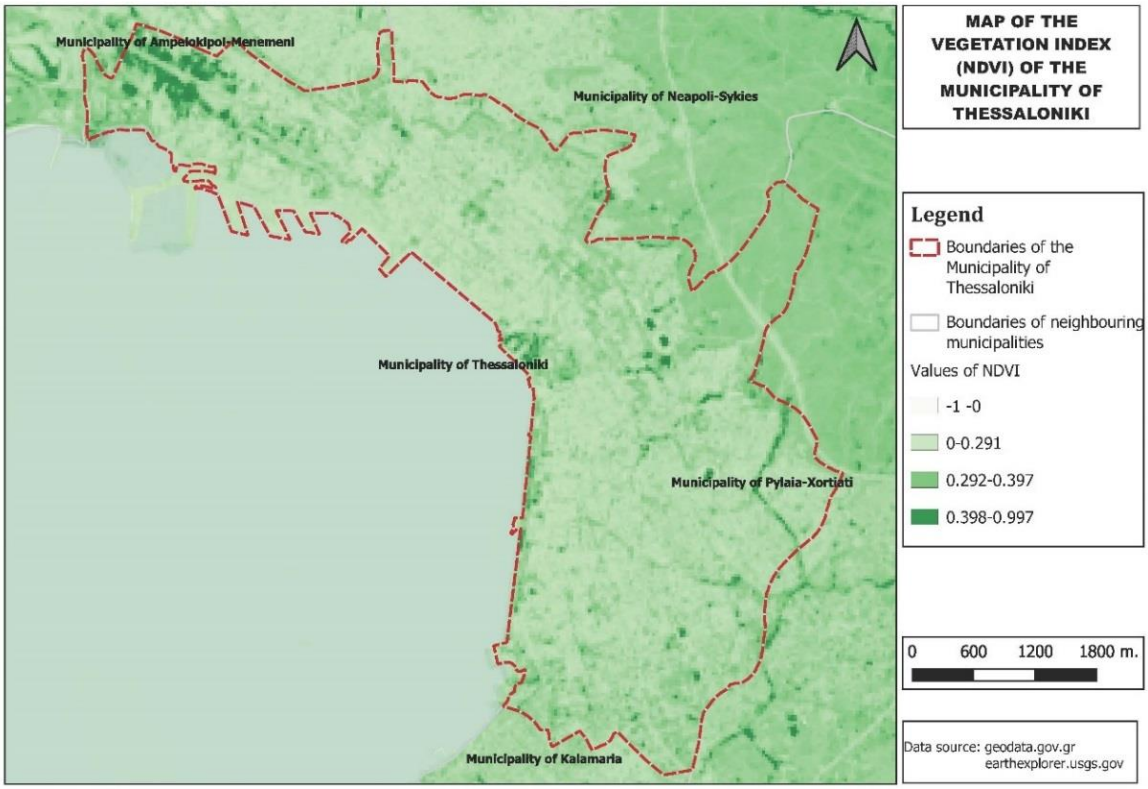


Fig.4 Map of the vegetation index (NDVI) of the Municipality of Thessaloniki

Variable	Category	Description
PRICE	Dependent variable	- Offered price of each housing unit/apartment (in €) – used as dependent variable in the OLS model - Offered price per square meter of each housing unit (€/m2) – used as dependent variable in the GWR model
AREA	Structural	Usable area of a flat (m^2)
AGE	Structural	Age of the apartment
FLOOR	Structural	Floor level on which the apartment is situated
NBEDROOM	Structural	Number of bedrooms in the apartment
TYPEHEAT	Structural	Type of apartment's heating system 0: Heating with all types of fuel except gas, 1: Heating with gas
ELEVATOR	Structural	(Dummy) - 1: The elevator is available
ORIENT	Structural	Apartment's orientation 0: North orientation, 1: All other orientations (except the north)
UGSDIST	Environmental	Distance to the closest urban green space (m)
TREESDIST	Environmental	Distance to the closest rows of trees (m)
OGADIST	Environmental	Distance to the closest "other green area" (m)
CENTDIST	Accessibility	Distance to the city center (m)
COASTDIST	Environmental	Distance to the coastline (m)
NDVI	Environmental	Vegetation index values [ranging from -1 to 1]

Tab.1 Attributes used in the analysis and descriptions

Variable	Mean value	Standard deviation	Min value	Max value	Expected sign
PRICE	122,289	79,908	6,000	530,000	DV[1]
PRICE per m²	1574.73	627.70	142.86	4,240.00	DV[2]
AREA	76.65	33.69	25	240	+
AGE	43.25	19.45	0	120	-
FLOOR	2.61	1.93	-1	8	+
NBEDROOM	1.81	0.77	1	4	+
TYPEHEAT	0.63	0.48	0	1	-
ELEVATOR	0.70	0.45	0	1	+
ORIENT	0.99	0.09	0	1	-
UGSDIST	238.62	244.84	1.16	2,047.83	-
TREESDIST	86.34	76.35	0.43	453.47	-
OGADIST	1,364.04	698.40	10.77	3,250.02	-
CENTDIST	1,196.64	1,192.20	0.00	4,581.48	-
COASTDIST	947.36	542.40	51.06	2,659.31	-
NDVI	0.11	0.06	0.03	0.39	?

[1]= Dependent variable in the OLS model, [2]=Dependent variable in the GWR model

Tab.2 Descriptive statistics of the selected variables

5. Results

5.1 OLS regression model results

Before implementing the regression analysis, the correlation between independent variables was checked by using a correlation table (with threshold value r > 0.70). In our sample of observations, the variables of AREA and *NBEDROOM* were found to be positively correlated as the value of the correlation coefficient was found equal to +0.79. Consequently, the variable *NBEDROOM* was not used in the regression analysis. For the rest of the independent variables the values of the correlation coefficient range from -0.01 to +0.36, well below the threshold value, indicating thus, that the regression models will not suffer from multicollinearity.

The next step was to import the data into the GEODA software tool (Anselin et al., 2006) to apply the regression analysis. Tab.3 represents the results for the OLS regression analysis, which corresponds to a global model with fixed (in space) coefficients. According to Tab.3, the variables "*ORIENTATION*", "*ELEVATOR*" and "*TREESDIST*" were not found statistically significant, thus, in contrast with all the other variables they do not affect the price variance. Concerning the environmental attributes, it is interesting to note that 3 out of 4 variables were found to be statistically significant at the 1% level, with the expected sign. Namely, the *UGSDIST* (distance from green urban spaces) coefficient reveals a strong negative relationship, according to which housing prices are likely to decrease by 71.6€ if the distance between the residential area and the nearest UGS increases by 1 meter. Respectively, for an-one-meter increase in distance to other green areas (*OGADIST*) the housing price is likely to decreased by 16.2€, indicating that the implicit value of UGS is more than 4 times higher than the implicit value of other green areas (OGAs). It is also worth mentioning that, the NDVI variable is statistically significant with a positive coefficient, which shows that residential areas with higher NDVI values are expected to have higher property values. It should be underlined that the extreme value of the *NDVI*'s β-coefficient is mainly due to the low mean value of NDVI in the study area, as well as to the small variance around this value. The fact that the vegetation index is statistically significant indicates that except for the distance from green spaces, the environmental quality of those spaces (e.g. vegetation cover, tree cover, etc.) is also important. Finally, concerning the structural characteristics, the findings are consistent with previous research and expectations. Specifically, higher prices are expected in bigger, newer and higher floor level apartments.

Variable[1]	Coefficient	Probability
Constant	-29,985.5	0.358
AREA	1,469.0	0.000
AGE	-360.89	0.038
FLOOR	5,321.98	0.001
ELEVATOR	17,463.1	0.011
TYPEHEAT	27,177.9	<0.001
ORIENT	39,295.9	0.144
TREESDIST	68.171	0.133
UGSDIST	-71.561	<0.001
OGADIST	-16.166	<0.001
CENTDIST	25,210.4	<0.001
COASTDIST	-20.408	0.002
NDVI	185,291	0.001
Number of observations	295	
R-squared	0.682	
Adjusted R-squared	0.669	
F-statistic	50.51	

[1] Dependent variable = PRICE

Tab.3 Results of the linear regression analysis

5.2 Geographically Weighted Regression (GWR) model results

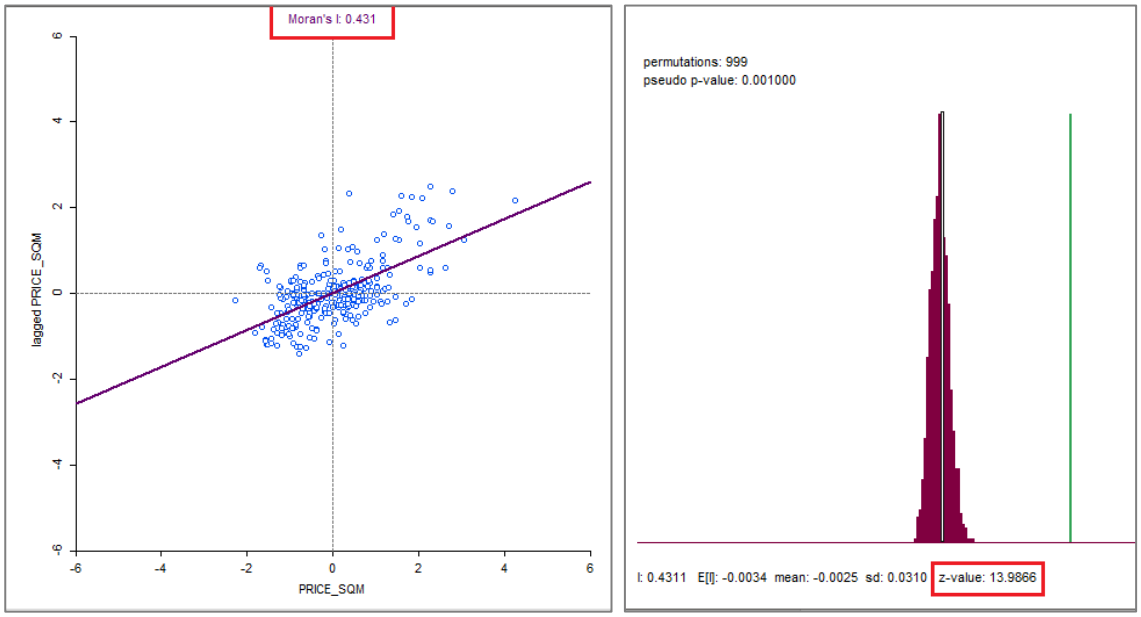
As aforementioned, spatial autocorrelation refers to the correlation of a variable's values due to spatial closeness (Griffith, 2003). The purpose of this study was to check if spatial autocorrelation exists between the dependent variable's values.

Specifically, it was checked if the variations in the properties' prices are the same in the whole study area or if there are areas where some (local) characteristics may affect more or less these prices. In order to additionally control for a possible non-linearity regarding the 'living space', we use the 'housing price per square meter' as a dependent variable (Gröbel, 2019). The first step was to test for spatial autocorrelation by using the GEODA software tool in order to perform a Moran's I test.

For this purpose, nearest neighbor weights were used, as the sample of the properties consisted only of points that didn't have a natural neighbor (after running lots of tests, the 6-nearest neighbors were considered). The Moran's I value is found equal to 0.43 which indicates the existence of spatial autocorrelation (Fig.5a). Also, according to Fig.5b, the Moran statistic is found significant ($z= 13.99$, $p<0.001$) so that the null hypothesis of no spatial pattern of residuals was rejected. This is an indication that the coefficients have been incorrectly specified, maybe as a result of non-stationarity and that a local modeling framework may result to a better specification.

The existence of spatial autocorrelation was further examined through the Local Indicators of Spatial Autocorrelation (LISA), by creating the corresponding thematic map in the environment of GEODA (Fig.6). As it can be observed in Fig.6, spatial autocorrelation (statistically significant) is observed in two areas in the study area. The first area is located in the historic center of Thessaloniki, where the house units (observations) have a positive spatial autocorrelation, in the High-High (HH) LISA category (red points).

The second area is located in the western part of the Municipality, at the entrance of the city and near the two main transportation hubs (port, railway station) and quite close to the industrial zone. In this cluster, the observations are included in the Low-Low (LL) LISA category, implying thus a negative spatial autocorrelation. It would be interesting thus to further examine the impact of the selected attributes in these High-High and Low-Low clusters.



(a) (b)

Fig.5 Moran's I test: (a) scatter plot, (b) z and pseudo-p value for the Moran's index

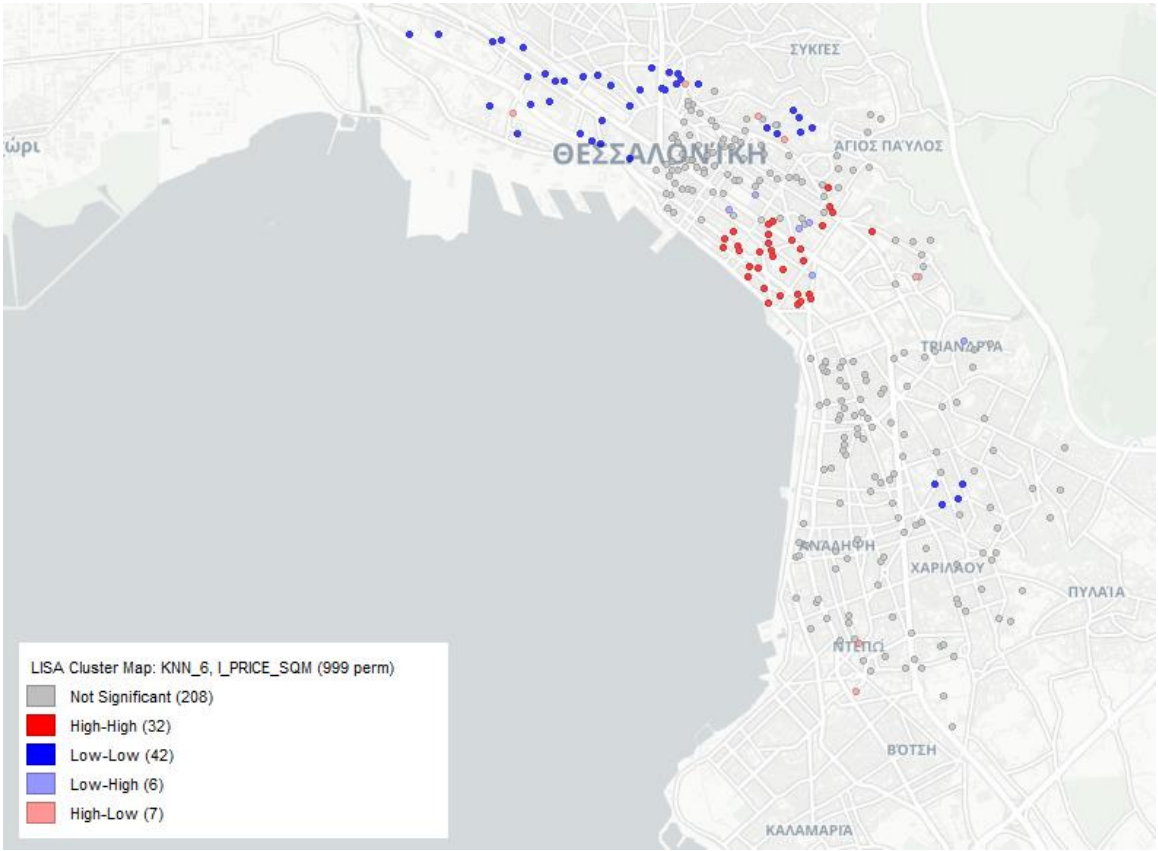


Fig.6 Local Indicators of Spatial Autocorrelation (LISA) cluster map

Having confirmed the existence of spatial autocorrelation, the next step was to examine which variable(s) influence(s) this autocorrelation. In this framework we used the GWR 4.0 software for spatial modeling and analysis (Nakaya et al., 2009).

Namely, a geographically weighted regression analysis with a fixed Gaussian kernel weighting function was used and the fitting technique for automated variable selection model, called "local to global" (L to G), was chosen. In this technique (L to G), all the variables are initially considered to present variation in space and are included in the local field, and then with successive iterations, the variables that remain constant are

considered global (following a similar concept to the stepwise regression models). The independent variables that were included in this procedure were the same as in the case of the OLS model.

Tab.4 represents the GWR results for the "L to G" model (mean, median, lower quartile, and upper quartile for local variables, as well as the estimated coefficients for the global variables). It should be noticed that all environmental attributes were found as non-stationary variables, varying across space, while only two structural attributes were considered as fixed in space (stationary): i.e. *FLOOR* and *TYPEHEAT*. The mean coefficients of the environmental attributes reflect the following overall effects: a) a 1-meter increase in the distance from an UGS will decrease the housing price by 0.36€/m^2; b) a 1-meter increase in the distance from "rows of trees" will decrease the price by 0.59€/m^2; while c) a 1-meter increase in the distance from the coastline will decrease the housing price by 0.21€/m^2.

In Tab.4, it is also interesting to notice that all the mean and median values have the expected sign (as in the OLS results). However, by observing the lower (25^{th}) and upper (75^{th}) quartile coefficients some of them seem to be counterintuitive. Specifically, despite the fact that most of the local coefficients of *OGADIST* (distance from other green areas), *COASTDIST* (distance from the coastline) and *CENTDIST* (distance from the city center) are negatively correlated with housing prices, there is also a positive relationship for some properties (corresponding to the upper quartile).

	Non – stationary variables				Stationary variables
Variable[1]	**Lower Quartile**	**Mean**	**Median**	**Upper Quartile**	**coefficients**
Intercept	1,866.79	2,516.77	2,483.27	3,330.47	
UGSDIST	-0.725	-0.356	-0.342	-0.025	
TREESDIST	-0.879	-0.586	-0.362	-0.036	
OGADIST	-0.552	-0.0896	-0.279	0.223	
COASTDIST	-1.108	-0.211	-0.271	0.275	
CENTDIST	-0.561	-0.228	-0.205	0.200	
AREA	-4.774	-3.003	-3.160	-1.405	
AGE	-10.135	-6.969	-7.192	-3.177	
TYPEHEAT	-	-	-	-	222.39***
FLOOR	-	-	-	-	70.30***
Number of observations		295			
R-squared		0.523			
Adjusted R-squared		0.483			
AIC_c		4,524.6			

***=statistically significant at the 1% level [1]Dependent variable = PRICE per m^2

Tab.4 Results of geographically regression analysis

The estimated local regression coefficients (for the selected attributes) and their associated t-test values can be also mapped by using a GIS-software.

In this study, we used the QGIS software and the Inverse Distance Weighted (IDW) interpolation method[2] in order to visualize the local coefficients of the environmental/green attributes. Fig.7 illustrates the spatial distribution of the parameter estimates for the UGSDIST (distance from UGS) variable and the associated interpolated t-test variables.

There are two areas where the proximity to UGS was found to have a significant impact on housing prices (i.e. the local coefficients were statistically significant at the 10% level or higher). Specifically, the first area is located in the city center (between Aristotelous Square and the Courthouse area), while the second one is located in the southeastern part of the Municipality, where small and medium green urban spaces are scattered

[2] IDW interpolation method weights the points of the sample according to the distance. In this way, as the distance increases from unknown points, the influence from the sample points tends to decrease. Comparatively with the Triangulated Irregular Network (TIN) interpolation method, which is mainly used for calculating elevation, the first was chosen as it fitted better in the sample.

throughout the urban environment (according to Fig.3). Particularly, in both areas, an increase of a property's distance from an UGS by 1-meter is likely to decrease the housing price on a range from 0.72€/m^2 to 1.18€/m^2 (while in all other areas/neighborhoods the price effect is insignificant and much lower).

Fig.8 shows a similar map for the attribute TREESDIST (distance from trees). This variable is found statistically significant at the local level only in a neighborhood, situated in the southern part of the Municipality. In this neighborhood, according to Fig.3, there is a higher (as compared to the study area) density of street trees. Proximity to trees in that particular neighborhood has a strong influence on housing prices (e.g. a 1-meter increase of a property's distance from street trees, could decrease the housing price from 0.87€/m^2 to 4.94€/m^2).

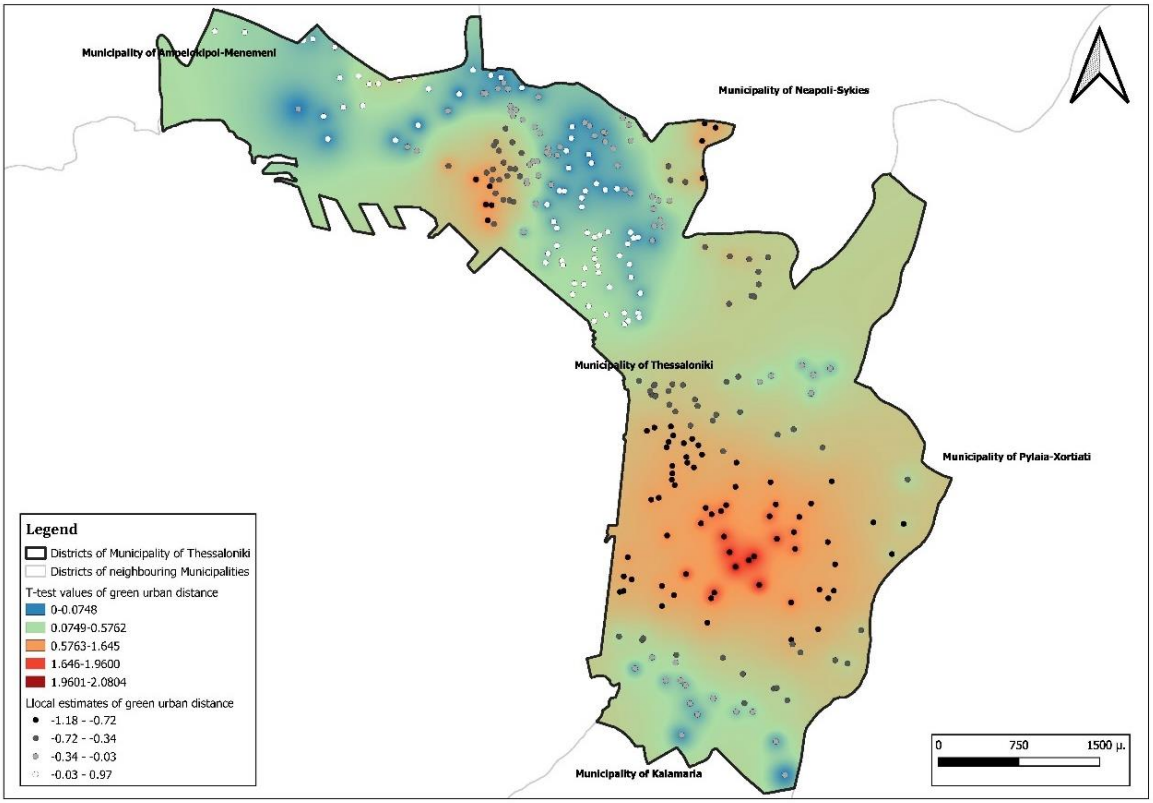


Fig.7 Map of local estimates and t-test values for green urban distance variable

Another variable with spatially heterogenous impacts on the properties' values of the study area is the distance from the coastline (*COASTDIST*). In Fig.9, is obvious that this attribute has a statistically significant effect in the historic city center, where the proximity to the "Old Waterfront" has an important and statistically significant impact on housing (e.g. a 1-meter increase of a property's distance from the coastline, is likely to decrease the property's value from 1.13€/m^2 up to 1.51€/m^2).

Something similar is not observed in the areas near the "New Waterfront", where the local parameters were not found statistically significant. Based on the previous maps (Fig.7 and Fig.8), property values of houses which are close to the "New Waterfront" (southern coastal regions) are likely to be more affected by their proximity to green spaces.

This may be attributed to the fact that the "New Waterfront" is structured by the coastline and the linear zone of green spaces that develops along the coastline. In this zone green spaces/areas are dense (as compared to the rest of the study area), causing thus some collinearity at the local level with the COASTDIST attribute. Therefore, in that part of the city, it is likely that our results may ultimately underestimate the implicit price of properties' proximity to the sea (coastline).

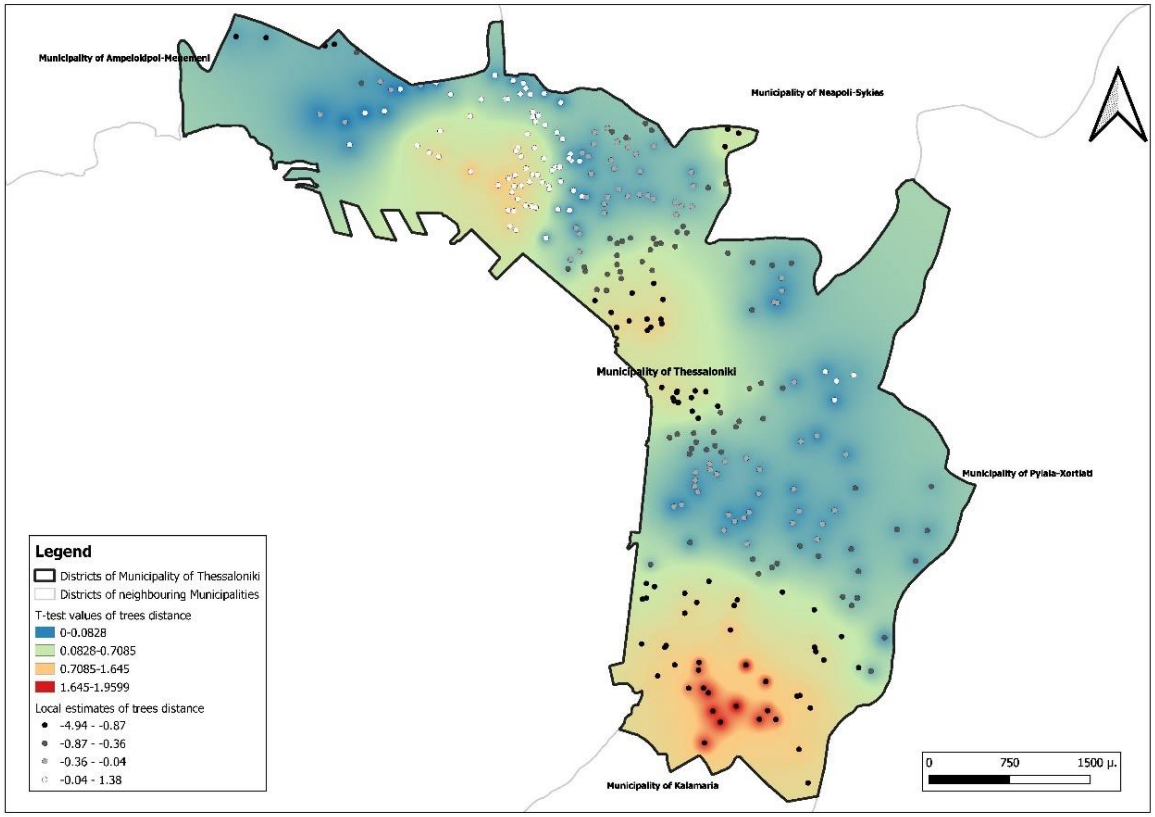


Fig.8 Map of local estimates and t-test values for trees distance variable

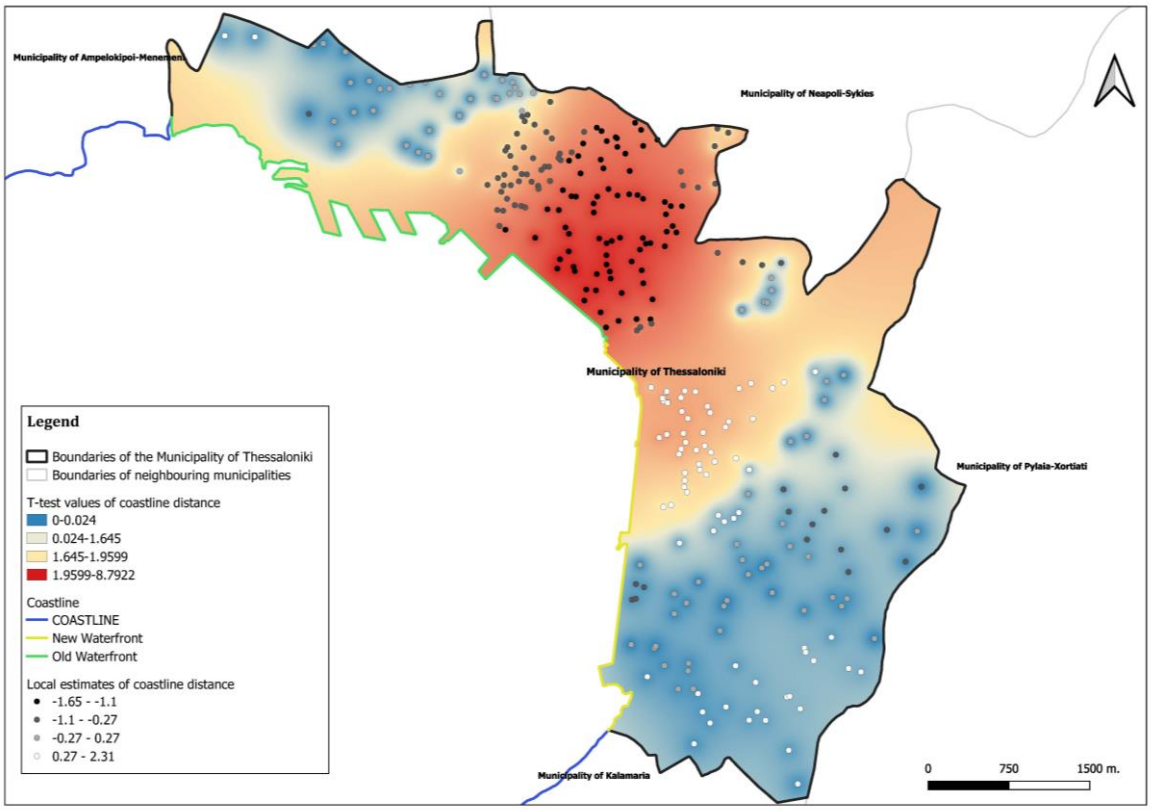


Fig.9 Map of local estimates and t-test values for coastline distance variable

6. Discussion and conclusions

In this study, a hedonic pricing model based on Geographically Weighted Regression (GWR) analysis is used to explore the spatial heterogeneity of environmental/location characteristics on properties values. A semi-parametric tool, such as the mixed GWR model was applied aiming to understand how different characteristics and different locations of green areas/amenities may affect the price of houses at the city level. An OLS analysis was also performed, but not for comparison purposes, but only in order to initially distinguish the main structural characteristics, as well as the green/environmental characteristics that are likely to have a statistically significant marginal effect on the selected property values. Both linear regression (OLS) and GWR models' results reveal that there is a proximity effect between urban green amenities and housing prices, with differences across space and across different typologies of green areas/amenities. Urban green amenities were found to have a positive and spatially heterogeneous impact on the residential real estate market in the Municipality of Thessaloniki. According to the OLS model, the distance from UGS, as well as the distance from other green areas/amenities (OGAs) (e.g. peri-urban green areas, arable land, herbaceous vegetation associations, etc.) can negatively affect the housing prices. Namely, as distance from the nearest UGS or OGA increases by one meter, the (average) housing price is expected to decrease by 71.56€ and 16.16€ respectively. Furthermore, it should be mentioned that in the OLS model, a statistically significant premium was estimated for the "vegetation index" (NDVI) variable, highlighting thus, the necessity to maintain/improve the quality (extent and health) of green vegetation in the urban area (e.g. the vegetation cover, the tree cover, etc.). As already stated, according to the GWR results, the impact of green/environmental attributes on housing prices is not constant over the study area. Particularly, the proximity to UGS was found to significantly increase the property values in the south-eastern regions/neighborhoods of the study area, as well as in a small neighborhood in the city center. Concerning the proximity to (rows of) street trees, the marginal impact on housing prices seems to be more intense in the southern part of the Municipality, on the border with the Municipality of Kalamaria. It is also important to mention that property values in the western part of the municipality, are not impacted by the proximity to any category of green areas. Apart from the green areas/amenities, the present study also examined the marginal price effects due to the properties' proximity to the coastline. According to the GWR results, the "distance from the sea (coastline)" attribute seems to have a significant influence on the real estate market, mainly in the area of the "Old Waterfront", located in the city center. Namely, a one-meter distance increase from the coastline of the "Old Waterfront" is expected to decrease the housing price on a range from 1.13€/m^2 to 1.51€/m^2. On the other hand, in neighborhoods situated near the "New Waterfront", the proximity to green areas/amenities seems to have a more significant effect on housing prices than the distance from the coastline, maybe due to the fact that in those neighborhoods UGS are mostly located in the waterfront (representing thus a local collinearity effect).

It is interesting also to note that in the Low-Low cluster areas (i.e. areas with negative spatial autocorrelation of the dependent variable) the environmental attributes have no significant impact on property values, while in the High-High clusters (i.e. areas with positive spatial autocorrelation of the dependent variable) the property values are significantly affected by the coastline distance and in some cases by the distance to green areas. Therefore, the implicit prices for the environmental attributes were found higher (and significant) in neighborhoods with higher residential prices.

The analysis highlights the importance of green infrastructures and the urgent need to integrate them into the urban fabric of Thessaloniki. Their potential benefits, such as the mitigation of the phenomenon of urban heat island, the air filtration, the (flood)water management, and the improvement of citizens' health and quality of life, are expected to be huge. Some of these benefits can be also internalized by the market values of houses, offering thus an economic incentive to city planners, especially in areas where land values are higher (and the associated UGS development costs may be initially considered to be too expensive). Furthermore, as the concept of compact cities is gaining popularity, it is even more urgent to include green spaces in the urban

planning procedure, because this concept is based on the belief that public spaces and parks can lead to the flourish of neighborhoods (Zali, 2016). At the same time ensuring proximity, access and exposure to UGS is usually considered of great importance for health and well-being in the design of compact urban environment (Lennon, 2021). In this context, citizens of Thessaloniki have already expressed the need for new UGS and are very supportive of the development of new green projects (Latinopoulos, 2022). Certainly, the integration of new green projects into the urban fabric should take into consideration the potential gentrification effects that may arise, in terms of increasing property values that could result to higher rental prices, and therefore, to the displacement of economically vulnerable residents. Hence, hedonic pricing methods should be used as a monitoring tool for future green infrastructure development goals, aiming to examine both positive (in real estate markets) and negative (in terms of gentrification) externalities.

Future research efforts could focus on adding more cases in the initial dataset of housing prices in order to achieve greater spatial heterogeneity among the location attributes, which would also allow more explanatory variables/attributes to be used (e.g. view on green areas, size of UGS, socioeconomic characteristics of the neighborhood, etc.). Future studies could also broaden the typologies of urban green areas/amenities and take into account accessibility and fairness/equity considerations with regard to urban green spaces.

References

Anselin, L., Syabri, I. & Kho, Y. (2006). GeoDa: An introduction to spatial data analysis. *Geographical Analysis, 38* (1), 5-22. https://doi.org/10.1111/j.0016-7363.2005.00671.x

Barbier, E.B., Acreman, M. & Knowler, D. (1997). *Economic valuation of wetlands: a guide for policy makers and planners.* Gland: Ramsar Convention Bureau. Retrieved from: https://www.ramsar.org/sites/default/files/documents/pdf/lib/lib_valuation_e.pdf

Barker, A., Clay, G., Morrison, R., Payne, S., Gilchrist, A., Rothwell, J. & Tantanasi, I. (2019). *Understanding Green Infrastructure at Different Scales: A signposting guide*. University of Manchester.

Benedict, M.A. & McMahon, E.T. (2002). Green infrastructure: smart conservation for the 21st century*. Renewable resources journal*, *20* (3), 12-17.

Bitter, C., Mulligan, G.F. & Dall'erba, S. (2007). Incorporating spatial variation in housing attribute prices: a comparison of geographically weighted regression and the spatial expansion method. *Journal of geographical systems*, *9* (1), 7-27. https://doi.org/10.1007/s10109-006-0028-7

Bouma, J. & Van Beukering, P. (2015). *Ecosystem services: from concept to practice*. Cambridge University Press. https://doi.org/10.1017/CBO9781107477612.002

Brunsdon, C., Fotheringham, A.S. & Charlton, M.E. (1996). Geographically weighted regression: a method for exploring spatial nonstationarity. *Geographical Analysis*, *28*, 281–298. https://doi.org/10.1111/j.1538-4632.1996.tb00936.x

Cajias, M. & Ertl, S. (2018). Spatial effects and non-linearity in hedonic modeling: Will large data sets change our assumptions? *Journal of Property Investment & Finance*, *36* (1), 32-49. https://doi.org/10.1108/JPIF-10-2016-0080

Charlton, M. & Fotheringham, A.S. (2009). Geographically weighted regression. White paper. National Centre for Geocomputation. National University of Ireland Maynooth, 2. Retrieved from: https://gwr.maynoothuniversity.ie/wp-content/uploads/2016/01/GWR_WhitePaper.pdf

Chiesura, A. (2004). The role of urban parks for the sustainable city*. Landscape and urban planning*, *68* (1), 129-138. https://doi.org/10.1016/j.landurbplan.2003.08.003

Cho, S. H., Bowker, J.M. & Park, W.M. (2006). Measuring the contribution of water and green space amenities to housing values: An application and comparison of spatially weighted hedonic models. *Journal of agricultural and resource economics*, *31* (3), 485-507. https://ageconsearch.umn.edu/record/8630

Choi, D.A., Park K. & Rigolon, A. (2020). From XS to XL urban nature: Examining access to different types of green space using a 'just sustainabilities' framework. *Sustainability*, *12* (17), p.6998. https://www.mdpi.com/2071-1050/12/17/6998

Creswell, J.W. (2007). *Qualitative Inquiry and Research Design: Choosing Among Five Approaches*. Thousand Oaks CA, Sage Publications.

De Gregorio Hurtado, S., Olazabal, M., Salvia, M., Pietrapertosa, F., Olazabal, E., Geneletti, D., D'Alonzo, V., Si Leo, S. & Reckien, D. (2015). Understanding how and why cities engage with climate policy. An analysis of local climate action in Spain and Italy. *TeMA: Journal of Land Use, Mobility and Environment*, *8* (Special Issue ECCA 2015), 23-46. https://doi.org/10.6092/1970-9870/3649

Donovan, G.H. & Butry, D.T. (2011). The effect of urban trees on the rental price of single-family homes in Portland, Oregon. *Urban Forestry and Urban Greening*, *10* (3), 163-168. https://doi.org/10.1016/j.ufug.2011.05.007

Dziauddin, M.F., Powe, N. & Alvanides, S. (2015). Estimating the Effects of Light Rail Transit (LRT) System on Residential Property Values Using Geographically Weighted Regression (GWR). *Applied Spatial Analysis*, *8*, 1-25. https://doi.org/10.1007/s12061-014-9117-z

Foster, J., Lowe, A. & Winkelman, S. (2011). *The value of green infrastructure for urban climate adaptation*. Center for Clean Air Policy, 750, no.1: 1-52, Washington. Retrieved from: http://ggi.dcp.ufl.edu/_library/reference/The%20value%20of%20green%20infrastructure%20for%20urban%20climate%20adaptation.pdf

Fotheringham, A.S., Charlton, M.E. & Brunsdon, C. (1998). Geographically weighted regression: a natural evolution of the expansion method for spatial data analysis. *Environment and planning A*, *30* (11), 1905-1927. https://doi.org/10.1068/a301905

Gargiulo, C., & De Ciutiis, F. (2008). Urban Transformations and Property Values Variation: The Role of HS Stations. *TeMA - Journal of Land Use, Mobility and Environment*, *1* (1), 65-84. https://doi.org/10.6092/1970-9870/189

Gessesse, A. & Melesse, A. (2019). Temporal relationships between time series CHIRPS-rainfall estimation and eMODIS-NDVI satellite images in Amhara Region, Ethiopia. In *Extreme Hydrology and Climate Variability* , 81-92*,* Elsevier:Amsterdam, The Netherlands. https://doi.org/10.1016/B978-0-12-815998-9.00008-7

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

Griffith, D. (2003). *Spatial autocorrelation and spatial filtering.* Springer, Berlin, Heidelberg. https://doi.org/10.1007/978-3-540-24806-4

Gröbel S. (2019). Analysis of spatial variance clustering in the hedonic modeling of housing prices. *Journal of Property Research, 36* (1), 1-26. https://doi.org/10.1080/09599916.2018.1562490

Haaland, C. & van den Bosch, C.K. (2015). Challenges and strategies for urban green-space planning in cities undergoing densification: A review. *Urban Forestry & Urban Greening*, *4* (14), 760-771. https://doi.org/10.1016/j.ufug.2015.07.009

Herath, S. & Maier, G. (2010). *The hedonic price method in real estate and housing market research. A review of the literature* (No. 2010/03), SRE-Discussion Papers. WU Vienna University of Economics and Business. https://research.wu.ac.at/ws/portalfiles/portal/30983294/sre-disc-2010_03.pdf

Hoshino, T. & Kuriyama, K. (2010). Measuring the benefits of neighbourhood park amenities: Application and comparison of spatial hedonic approaches. *Environmental and Resource Economics*, *45* (3), 429-444. https://doi.org/10.1007/s10640-009-9321-5

Jim, C.Y. & Chen, W.Y. (2006). Impacts of urban environmental elements on residential housing prices in Guangzhou (China). *Landscape Urban Planning*, *78*, 422–434. https://doi.org/10.1016/j.landurbplan.2005.12.003

Koc, C.B., Osmond, P. & Peters, A. (2016). A green infrastructure typology matrix to support urban microclimate studies. *Procedia Engineering*, *169*, 183-190. https://doi.org/10.1016/j.proeng.2016.10.022

Kong, F., Yin, H. & Nakagoshi, N. (2007). Using GIS and landscape metrics in the hedonic price modeling of the amenity value of urban green space: A case study in Jinan City, China*. Landscape Urban Planning*, *79*, 240-252. https://doi.org/10.1016/j.landurbplan.2006.02.013

Latinopoulos, D. (2018). Using a spatial hedonic analysis to evaluate the effect of sea view on hotel prices. *Tourism Management*, *65*, 87-99. https://doi.org/10.1016/j.tourman.2017.09.019

Latinopoulos, D. (2022). Evaluating the importance of urban green spaces: a spatial analysis of citizens' perceptions in Thessaloniki. *Euro-Mediterranean Journal for Environmental Integration*, *7* (2), 299-308. https://doi.org/10.1007/s41207-022-00300-y

Latinopoulos, D., Mallios, Z. & Latinopoulos, P. (2016). Valuing the benefits of an urban park project: A contingent valuation study in Thessaloniki, Greece. *Land Use Policy*, *55*, 130–141. https://doi.org/10.1016/j.landusepol.2016.03.020

Lennon, M. (2021). Green space and the compact city: planning issues for a 'new normal'. *Cities & Health*, *1* (5), 212-215. https://doi.org/10.1080/23748834.2020.1778843

Li, W., Saphores, J.D.M. & Gillespie, T.W. (2015). A comparison of the economic benefits of urban green spaces estimated with NDVI and with high-resolution land cover data. *Landscape Urban Planning*, *133*, 105–117. https://doi.org/10.1016/j.landurbplan.2014.09.013

Liebelt, V., Bartke, S. & Schwarz, N. (2018). Hedonic pricing analysis of the influence of urban green spaces onto residential prices: the case of Leipzig, Germany. *European Planning Studies*, *26* (1), 133-157. https://doi.org/10.1080/09654313.2017.1376314

Liu, Q., Ullah, H., Wan, W., Peng, Z., Hou, L., Sanam, S., Rizvi, Dr.S., Ali Haidery, S., Qu, T. & Muzahid, A.A.M. (2020). Categorization of Green Spaces for a Sustainable Environment and Smart City Architecture by Utilizing Big Data. *Electronics 9* (6), p.1028. https://doi.org/10.3390/electronics9061028

Luttik, J. (2000). The value of trees, water and open space as reflected by house prices in the Netherlands. *Landscape Urban Planning*, *48*, 161–167. https://doi.org/10.1016/S0169-2046(00)00039-6

Mallios, Z., Papageorgiou, A., Latinopoulos, D. & Latinopoulos, P. (2009). Spatial hedonic pricing models for the valuation of irrigation water. *Global Nest Journal*, *11*, 575-582. https://doi.org/10.30955/gnj.000500

Mendelsohn, R. & Olmstead, S. (2009). The economic valuation of environmental amenities and disamenities: Methods and applications. *Annual Review of Environment and Resources*, *34* (1), 325-347. https://doi.org/10.1146/annurev-environ-011509-135201

Mitchell, R.C. & Carson, R.T. (2013). *Using surveys to value public goods: the contingent valuation method*. Rff press: New York, USA. https://doi.org/10.4324/9781315060569

Morancho, A.B. (2003). A hedonic valuation of urban green areas. *Landscape Urban Planning*, *66*, 35-41. https://doi.org/10.1016/S0169-2046(03)00093-8

More, T.A., Stevens, T. & Allen, P.G. (1988). Valuation of urban parks. *Landscape Urban Planning*, *15*, 139-152. https://doi.org/10.1016/0169-2046(88)90022-9

Municipality of Thessaloniki (2017). *Green Regulation.* Green and environment management directorate. Retrieved from https://thessaloniki.gr [accessed 1.6.2022]

Municipality of Thessaloniki (2016). *Open Data Portal*, https://opendata.thessaloniki.gr/en [accessed 1.6.2022]

Nakaya, T. (2007). Geographically Weighted Regression (GWR). *Encyclopedia of Geographical Information Science*, 179-184.

Nakaya, T., Fotheringham, A.S., Charlton, M. & Brunsdon, C. (2009). Semiparametric geographically weighted generalised linear modelling in GWR 4.0. In B. Lees, & S. Laffan (Eds.), *10th international conference on GeoComputation*. Sydney, Australia: UNSW. Retrieved from: http://www.geocomputation.org/2009/PDF/Nakaya_et_al.pdf

Navrud, S. (2000). Strengths, weaknesses and policy utility of valuation techniques and benefit transfer methods. In OECD (2001): *Valuing rural amenities*. Proceedings from OECD-USDA workshop: Value of rural amenities: Washington D.C.

Onishi, A., Cao, X., Ito, T., Shi, F. & Imura, H. (2010). Evaluating the potential for urban heat-island mitigation by greening parking lots. *Urban Forestry and Urban Greening*, *9* (4), 323-332. https://doi.org/10.1016/j.ufug.2010.06.002

Páez, A. & Wheeler, D.C. (2009). Geographically Weighted Regression, in: Kitchin, R., Thrift, N. (Eds.), *International Encyclopedia of Human Geography,* 407-414, Elsevier, Oxford. https://doi.org/10.1007/978-3-642-03647-7_22

Palacio, H.F., Scherzer, S. & Froyen, Y. (2018). The Value of Urban Density. An exploratory of the relationship between urban density and housing prices in Trondheim, Norway. *TeMA: Journal of Land Use, Mobility and Environment*, *11* (2), 213-230. https://doi.org/10.6092/1970-9870/5484

Panduro, T. & Veie, K. (2013). Classification and valuation of urban green spaces—A hedonic house price valuation. *Landscape Urban Planning*, *120*, 119-128. https://doi.org/10.1016/j.landurbplan.2013.08.009

Papa, R., Galderisi, A., Vigo Majello M.C. & Saretta E. (2015). Smart and resilient cities. A systemic approach for developing cross-sectoral strategies in the face of climate change. *TeMA: Journal of Land Use, Mobility and Environment*, *8* (1), 19-49. https://doi.org/10.6092/1970-9870/2883

Pearce, D.W. & Özdemiroglu, E. (2002). *Economic valuation with stated preference techniques: Summary guide*. London: Department of Transport, Local Government and the Regions. Retrieved from: https://assets.publishing.service.gov.uk/

Poudyal, N.C., Hodges, D.G. & Merrett, C.D. (2009). A hedonic analysis of the demand for and benefits of urban recreation parks. *Land Use Policy*, *26* (4), 975–983. https://doi.org/10.1016/j.landusepol.2008.11.008

Sandstrom, U.G., Angelstam, P. & Khakee, A. (2006). Urban comprehensive planning: identifying barriers for the maintenance of functional habitat networks. *Landscape Urban Planning*, *75* (1-2), 43-57. https://doi.org/10.1016/j.landurbplan.2004.11.016

Salata, K. & Yiannakou, A. (2016). Green infrastructure and climate change adaptation. *TeMA Journal of Land Use Mobilily and Environment*, *9* (1), 7-24. https://doi.org/10.6092/1970-9870/3723

Saphores, J.D. & Li, W. (2012). Estimating the value of urban green areas: A hedonic pricing analysis of the single-family housing market in Los Angeles, CA. *Landscape and Urban Planning*, *104* (3-4), 373-387. https://doi.org/10.1016/j.landurbplan.2011.11.012

Skouras, D.B. & Arvanitidis P.A. (2008). Urban green and housing values: exploring the links using empirical evidence from the UK. In Conference proceedings: *Urban green spaces-a key for sustainable cities,* 45-48, Sofia 17-18 April 2008.

Sopranzetti, B. (2010). Hedonic Regression Analysis in Real Estate Markets: A Primer. In Lee, C.F., Lee, A.C. & Lee, J. (eds) *Handbook of quantitative finance and risk management*, 1201-1207, Springer, Boston, MA. https://doi.org/10.1007/978-0-387-77117-5_78

Taylor, L. & Hochuli, D.F. (2017). Defining greenspace: Multiple uses across multiple disciplines. *Landscape Urban Planning, 158*, 25-38. https://doi.org/10.1016/j.landurbplan.2016.09.024

Tsilini, V., Papantoniou, S., Kolokotsa, D.D. & Maria, E.A. (2015). Urban gardens as a solution to energy poverty and urban heat island. *Sustainable Cities and Society*, *14*, 323-333. https://doi.org/10.1016/j.scs.2014.08.006

Tyrväinen, L. (1997). The amenity value of the urban forest: an application of the hedonic pricing method. *Landscape Urban Planning*, *37* (3-4), 211-222. https://doi.org/10.1016/S0169-2046(97)80005-9

Tyrväinen, L. & Miettinen, A. (2000). Property Prices and Urban Forest Amenities. *Journal of environmental economics and management*, *39* (2), 205-223. https://doi.org/10.1006/jeem.1999.1097

Tzoulas, K., Korpela, K., Venn, S., Yli-Pelkonen, V., Kaźmierczak, A., Niemela, J. & James, P. (2007). Promoting ecosystem and human health in urban areas using Green Infrastructure: A literature review. *Landscape Urban Planning*, *81* (3), 167-178. https://doi.org/10.1016/j.landurbplan.2007.02.001

Venkatachalam, L. (2004). The contingent valuation method: a review. *Environmental impact assessment review*, *24* (1), 89-124. https://doi.org/10.1016/S0195-9255(03)00138-0

Wang, Y., Bakker, F., de Groot, R. & Wörtche, H. (2014). Effect of ecosystem services provided by urban green infrastructure on indoor environment: A literature review. *Building and Environment*, *77*, 88-100. https://doi.org/10.1016/j.buildenv.2014.03.021

Yang, L., Chu, X., Gou, Z., Yang, H., Lu, Y. & Huang, W. (2020). Accessibility and proximity effects of bus rapid transit on housing prices: Heterogeneity across price quantiles and space. *Journal of Transport Geography*, *88*, 102850. https://doi.org/10.1016/j.jtrangeo.2020.102850

Zali, N., Gholami, N., Karimiazeri, A.R. & Azadeh, S.R. (2016). Planning according to new urbanism: the Ostadsara neighborhood case study. *TeMA: Journal of Land Use, Mobility and Environment*, *9* (3), 323-341. https://doi.org/10.6092/1970-9870/4023

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

Image Sources

Fig.1: Location of the Municipality of Thessaloniki within the Metropolitan area;

Fig.2: Map of the spatial distribution of properties;

Fig.3: Map of green spaces of the Municipality of Thessaloniki;

Fig.4: Map of the vegetation index (NDVI) of the Municipality of Thessaloniki;

Fig.5: Moran's I test: (a) scatter plot, (b) z and pseudo-p value for the Moran's index;

Fig.6: Local Indicators of Spatial Autocorrelation (LISA) cluster map;

Fig.7: Map of local estimates and t-test values for green urban distance variable;

Fig.8: Map of local estimates and t-test values for trees distance variable;

Fig.9: Map of local estimates and t-test values for coastline distance variable.

Authors' profile

Antonia Giannakidou

Antonia Giannakidou is an engineer and researcher. She received her diploma from the School of Rural and Surveying Engineering, Faculty of Engineering, Aristotle University of Thessaloniki. She received a master's degree in Spatial Planning for Sustainable and Resilient Development in the School of Spatial Planning and Development, Faculty of Engineering, Aristotle University of Thessaloniki. Her M.Sc. thesis research concerns the topic of the economic evaluation of urban green spaces.

Dionysis Latinopoulos

Dr. Dionysis Latinopoulos is an associate professor of Rural Sustainable Development and Natural Resources Management at the School of Spatial Planning and Development, Aristotle University of Thessaloniki (AUTh). Diploma in Agriculture / Agricultural Economics (AUTh), MSc in Environmental and Resource Economics (Department of Economics, University College London), PhD (Department of Civil Engineering, AUTh) and Post-doc (Department of Economics, University of Macedonia). His teaching includes courses in environmental and natural resource economics, environmental spatial planning, sustainable development economics and environmental planning and management of tourism. His research interests include non-market valuation of environmental resources, environmental planning and decision-making, urban resilience and sustainability, planning and management of tourism. He has published articles in international peer reviewed journals on these topics.

TeMA Journal of Land Use, Mobility and Environment

TeMA 1 (2023) 105-120
print ISSN 1970-9889, e-ISSN 1970-9870
DOI: 10.6093/1970-9870/9353
Received 2nd August 2022, Accepted 13th April 2022, Available online 30th April 2023

www.tema.unina.it

Public perceptions of barriers to walk in urban areas of Lahore, Pakistan

Muhammad Ahsan [a], Nabeel Shakeel [b*], Farrukh Baig [c]

[a] Department of City and Regional Planning
Yildiz Technical University, Istanbul, Turkey
e-mail: ahsansaeedi04@gmail.com
ORCID: https://orcid.org/0000-0002-6114-5161

[b] Department of Geography, School of Earth and Environment, University of Canterbury, Christchurch, New Zealand
e-mail: nabeel.shakeel@pg.canterbury.ac.nz
ORCID: https://orcid.org/0000-0002-8576-0361
* Corresponding author

[c] School of Traffic and Transportation Engineering
Central South University, Changsha 410075, China
e-mail: farrukhbaig0304@hotmail.com
ORCID: https://orcid.org/0000-0002-5500-1989

Abstract
The development strategies in urban areas of the less developed world have predominantly focused on motorized-oriented planning, which influences the travel habits of individuals. However, there has been little research on walking as a mode of transport in Pakistani cities. In order to bridge this gap, this study examines the public's perception of barriers to walking in Lahore, Pakistan. Surveys were conducted online using structured questionnaires. To investigate pedestrians' perceptions of walking constraints, a valid sample of 277 responses was analyzed using a weighted factor and regression analysis. Findings show that pedestrians' dissatisfaction with existing infrastructure is due to the ignorance of walking as a travel mode in transport plans, policies, and strategies executed by government organizations. The integration of walking as a travel mode has been highly neglected by transport policymakers. Further, significant walking constraints have been elaborated that need to be resolved to enhance walking in urban areas.

Keywords
Walking; Pedestrian perceptions; Accessibility; Walking constraints, Lahore.

How to cite item in APA format
Ahsan, M., Shakeel, N. & Baig, F. (2023). Public perceptions of barriers to walk in urban areas of Lahore, Pakistan. *Tema. Journal of Land Use, Mobility and Environment*, *16* (1), 105-120.
http://dx.doi.org/10.6093/1970-9870/9353

1. Introduction

The environmental impact, efficiency, and overall feasibility of walking and driving are frequently compared in transportation planning research. Walking is one of the most fundamental active travel modes, yet it remains a relatively understudied aspect of transport research in developing countries. Where existing research considered public transport and cycling as travel modes for analysis, see, e.g. Aslam et al. (2018); Anwer et al. (2021); and Al-Rashid et al. (2021), walking as a travel mode has been given less attention. Walking is vital in transport research because it provides an opportunity to promote healthy and active lifestyles, reduce congestion, and improve accessibility. Cars, on the other hand, are major contributor to various environmental problems, including carbon emissions and air and noise pollution (De Nazelle et al.,2017; Mazzeo et al., 2019). Therefore, studying walking as a travel mode and its integration into the planning and designing of infrastructure helps to improve the design of cities, and make them more accessible, sustainable, and livable (Cecchini & Talu, 2011).

The extent to which walking is readily available as a safe, connected, accessible, and pleasant mode of transportation is an integral enabler of sustainable development (Bharucha, 2017; Gaglione et al., 2019).

There are several factors that make walking a convenient and comfortable mode of transportation, including density, diversity, safety, and connectivity (Southworth, 2005). Briefly explaining these factors, the more dense a neighborhood is, for example, the more destinations are within walking distance, and the streets are easier to navigate. Similarly, a diverse neighborhood is one with a variety of land uses, and because there are more things to do along the way, the built environment becomes more interesting and appealing for walking. Safety, in the same way, plays an essential role in making walking a pleasurable mode of travel by making streets more pedestrian-friendly (Lourenço & Rahaman, 2010). Traffic calming measures, speed limits, and pedestrian crossings help reduce the risk of accidents and make walking more enjoyable. Finally, connectivity makes different neighborhoods more connected and accessible on foot, which makes pedestrians' lives easier and less intimidating. In short features like density, diversity, safety, and connectivity are essential for making walking a comfortable and convenient mode of transport.

Looking at these features in the relevant literature, the study by Arvidsson et al. (2012) listed density, land-use patterns, and street connectivity as three major features of neighborhood walkability. The other studies, e.g. Balsas (2019); Bharucha (2017); Jun & Hur (2015); Bahari et al. (2014); Makki et al. (2012); and Southworth (2005), focused on such factors as built environment, safety, and the comfort level of pedestrians, destination connections with people and social environments, adjacent visual aesthetics, and connected infrastructure. Moreover, Clark et al. (2010) and Saelens et al. (2003) concluded that highly dense population areas and housing accumulation with efficient connectivity encourage walking more than less dense areas. The results further showed that the factors that encourage walking are high land use density, safety, connected infrastructure, and the aesthetics of the surroundings. Furthermore, Bahari et al. (2014) and Fonseca et al. (2022) elaborated on the influence of the built environment on walkability by considering features, including land use density and diversity, accessibility, street connectivity, safety, and security. In short, past studies indicated the importance of walking as a travel mode in association with the several features that need to be considered for transport policies to shift people towards active transportation.

There is no doubt that transport researchers from Pakistan have contributed to transport literature in several ways; however, literature on perceptions of walking constraints is still limited. Exiting studies, e.g. Aziz et al. (2018), examined the suitability of the integrated public transport system in Lahore and declared the system unharmonized. The study by Al-Rashid et al. (2022) modeled psychological barriers among older people in choosing public transport as a travel mode.

The study by Aslam et al. (2018) and Tariq & Shakeel (2021) explored the potential of cycling in Lahore as a travel mode and talked about its integration into the transportation network; however, the examination of walking as a travel mode and related components remains scarce. Therefore, this study aims to assess the

potential constraints of walking based on public perspectives in Lahore, Pakistan. For this purpose, this study has taken into consideration several built environments, safety features, and physical infrastructure-related features to analyze public perceptions of barriers to walking. The study's findings will help promote the integration of walking with motorized transport systems in Pakistan.

2. Case Study

The city of Lahore was selected as a case study area to evaluate the public perceptions, potential, and constraints of walking. Lahore is the second largest city in Pakistan and the provincial capital of Punjab province with a population of 11.13 million (PBS, 2017; Aslam et al.,2018). The city of Lahore has been developed as one of the most congested cities in Pakistan.

The urban population of the city of Lahore has grown by 3% from 5.20 million in 1998 to 11.13 million in 2017. Whereas, in the 20th century, Lahore was grown 25 times from 1901 to 1998 (Ahsan, 2019). The Spatial boundary of Lahore has expanded two times in the past two decades, from 220 km in 1995 to 336 sq. km in 2005 and 665 sq. km in 2015 (Ibrahim & Riaz, 2018). These development patterns in Lahore are augmented the car-based dependence of residents for commuting (Hameed and Anjum, 2013), resultantly in declining walking practices. In just one decade (from 2005 to 2015), a 268% increase in vehicle registration has steadily worsened the traffic congestion in Lahore (Gallup Pakistan, 2016). The project report on the urban transport master plan of Lahore conducted under the Punjab Transport Department showed that the walking modal share in the city was only 10% (JICA, 2012). Therefore, these empirical facts indicate the utmost need to study the decline of walking among individuals in the urban area of Lahore, making it the best case study for this research.

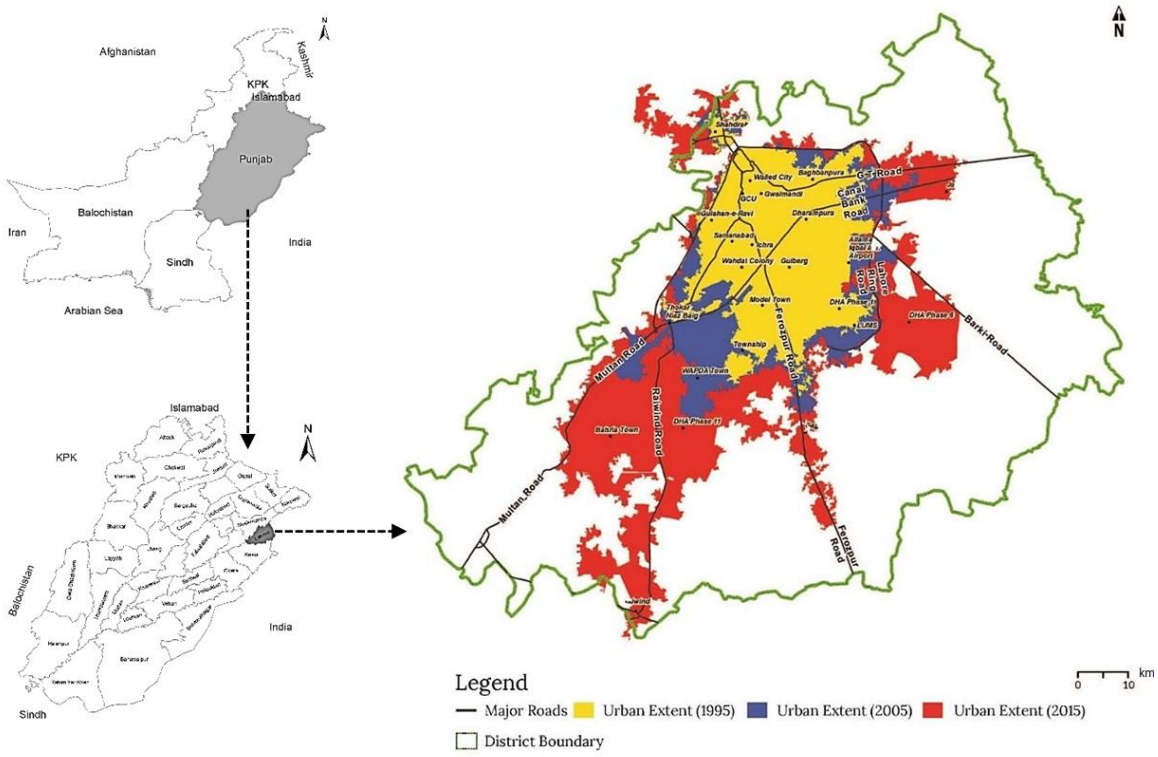


Fig 1. Spatial Extension of Lahore, Source: Ibrahim and Riaz, 2018

3. Methodology

3.1 Sample calculation and methodological considerations

The sample size for data collection was calculated with the help of Kohran's formula (Ahsan, 2019; Shakeel & Jahanzaib, 2019) as written in Eq. 1.

$$n = N/\ (1 + Ne\text{^}2\ ) \quad (1)$$

Where *n* is the sample size, *N* is the population of the city, and *e* is the marginal error rate of the sample. The sample size determined with this formula is 277, calculated by using the total population of 11.13 million with a marginal error of 5%. To collect the data, a structured questionnaire survey was conducted by using online social media platforms, i.e., Facebook, Twitter, and LinkedIn. The questionnaire was designed by using Google Forms and spread among the individuals living in different neighborhoods. The usage of these social media platforms for data collection is in line with past studies, including Zhang & Mu (2020); Liao et al. (2022); and Pak and Verbeke (2013). On these social media platforms, massive attention was paid to applying certain filters with the help of which the targeted population of Lahore was reached. This online survey in Lahore was administered and conducted during the months of January and February 2022 with an observed average response time of 7 to 10 minutes. Moreover, it was asked to share the coordinates by the respondent while filling out the questionnaire, which is spatially illustrated in Fig.2. This innovative method to collect the individual's response also helped to gain diversified data, gathered from all socio-economic classes, age and gender groups. Furthermore, before conducting the surveys, several studies related to the public perceptions of pedestrian's walking constraints were analyzed in terms of sample size, data collection method, and analysis techniques, as shown in Tab.1.

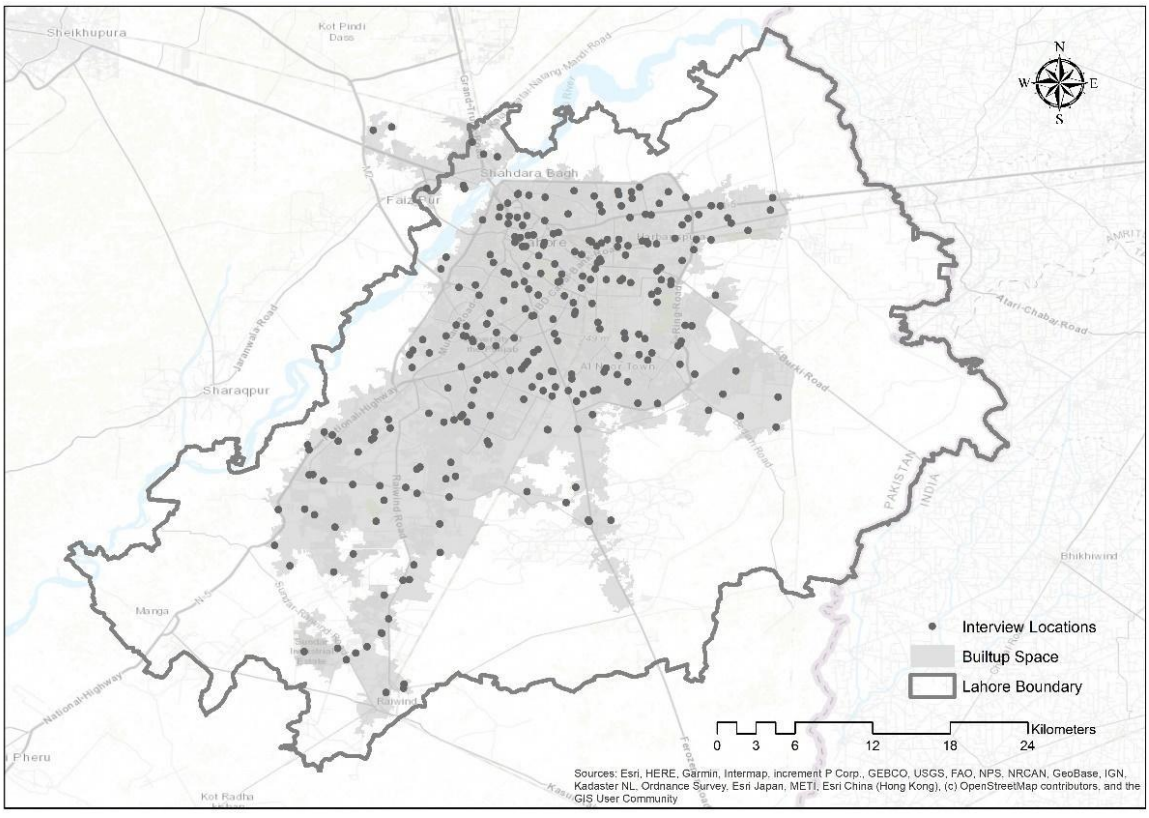


Fig.2 Spatial distribution of interview locations in Lahore

Study	Sample Size	Case Study Area	Data Collection Method	Data Analysis Technique
Bharucha (2017)	100 people from middle and lower income class	5 different districts of Mumbai city, India	Pedestrian interviews through structured questionnaire	Not specified
Bahari et al. (2014)	60 respondents	Jalan Tuanku Abdul Rahman and Central Market in Kuala Lumpur city	On street questionnaire survey	Simplified weighted factor analysis
Strohmeier (2016)	68 persons of old age	City of Vienna	Personal interviews with the help of questionnaire	Comparative analysis against several checklists
Clark et al. (2010)	17 participants were selected with the help of snow ball sampling technique	City of Edmonton	Semi- structured interviews	Interview recordings were transcribed verbatim then converted to meaning units
Grant et al. (2010)	53 participants with mean age of 75 years	Four Neighborhoods in Ottawa, Canada	Focus groups and individual interviews	A constant-comparative method was used while recordings were transcribed verbatim
Lockett et al. (2005)	13 people in photovoice session while 22 seniors participated in focused group session	Ottawa, Canada	Photovoice (a qualitative data collection method) was used followed by focus group sessions	Not specified
Ovstedal and Ryeng (2002)	1092 participants were interviewed	Six European countries: Belgium, Finland, France, Italy, Norway and Switzerland	On-street interview based on questionnaire was conducted at 22 different sites	Collected data was analyzed through correlation and regression analysis

Tab.1 Methodological consideration of similar past studies

3.2 Explanatory Variables

Tab.2 summarizes the variables along with their data types. Section 1 of the questionnaire included the characteristics of respondents, such as gender, age, and income, to assess socio-economic status, profession, and education level.

Section 2 indicated walking characteristics such as frequencies and purposes of using the walk as a travel mode, preferred traveling distance and consumed times while walking, provision of other facilities concerned with pedestrians, and their preferred mode of choice for daily travel.

Section 3 highlighted pedestrians' perception to evaluate their satisfaction level related to sidewalk conditions, street furniture, safety issues, aesthetics, and amenities.

Section 4 of the questionnaire emphasized the constraints and challenges of declining walking habits.

Variable	Variable Type	Categories
Personal Information		
Gender	Binary	Male, Female
Age	Categorical	Less than 20 years, 20–40 years, More than 40 years
Income	Categorical	None; <15,000 PKR; 15,001-50,000 PKR; 50,001 - 100,000 PKR; >100,000 PKR
Profession	Categorical	Student, Government Employee, Semi-Govt./ Private Employee, Private Business
Education	Categorical	Under Matric, Matriculation, Under-Graduate, Graduate, Post-Graduation
Walking Characteristics		
Do you walk?	Binary	Yes or No
If no, why not?	Open-ended	
Frequency of walking	Categorical	Daily, Once or twice a week, Occasionally
Purpose of walking	Categorical	Shopping, Leisure, Work, School, Access to public transportation, Health, Other (_____)
Prefer to walk rather motorized transport	Binary	Yes or No
Preferred mode of travel, other than walking	Categorical	Public Transport (Metro Bus/ train, Public Bus, Rickshaws etc.) Private Transport (Car, Motorbike, Bicycle etc.)
Travelled distance through walking	Categorical	<250 meters, 250 to 500 meters, 500 meters to 1 km, More than 1 km
Preferred Time Consumption for Walking	Categorical	<=10 min, 10 – 20 min, 20 – 30 min, > 30 min
Walking time without physical disconnectivity of walkways	Categorical	<=10 min, 10 – 20 min, 20 – 30 min, > 30 min
Footpaths free from encroachment	Binary	Yes or No
If no, reasons of encroachment	Categorical	Occupied by; hawkers, shopkeepers, utility infrastructure, parking, housekeepers, Other (___)
Availability of Zebra Crossing on intersections	Categorical	Availability of zebra crossing on; each, majority, and few intersections
Public Perception on Walking		
Shown in Tab.9	Likert scale	Highly Satisfied, Satisfied, Neutral, Dissatisfied, Highly dissatisfied
Walking Constraints		
Shown in Fig.5	Likert scale	1-Minor effects, 2- Sufficient effects, 3- Critical effects, 4-Prompt effects, 5- Devastating effects

Tab.2 Survey instrument for quantifying walking in Lahore

3.3 Analysis Techniques

Collected data were analyzed with quantitative methods and presented in the form of frequencies and percentages of binary and categorical statistics. Pedestrian satisfaction from several walking indicators was analyzed with simplified weighted factor analysis, converting the semantic values to numerical scale (Bahari et al. (2014); Kelly et al. (2011). The conversion of semantic to numerical values is shown in Tab.4. The weighted value of indicators is calculated by multiplying the weighting factor (converted numerical values) by the number of respondents, while the average weighted factor is calculated by dividing the weighted factor with the number of respondents (e.g. see Tab.3). The positive weighted factor indicates the satisfaction of pedestrians from the provided facility while negative values indicate dissatisfaction.

Scale of agreement	Weighing factors	No. of respondents	Weighted score
Highly Satisfied	2	5	10
Satisfied	1	6	6
Neutral	0	5	0
Dissatisfied	-1	8	-8
Highly dissatisfied	-2	7	-14
Total	-	31	-6

Tab.3 Weighted factor analysis and calculation example for satisfaction level determination

Scale of agreement	Numerical factor	Qualitative elucidation
Highly Satisfied	2	Highly satisfied with the walking conditions, and no further improvements are required.
Satisfied	1	Satisfied with the walking conditions but little modifications/improvements are required.
Neutral	0	Neither satisfied nor dissatisfied with walking conditions, while enough upgrading actions are necessary to be taken to make it satisfactory.
Dissatisfied	-1	Dissatisfied from walking conditions whereas plenty modifications/improvements are mandatory to be done to make the walking conditions sufficient and adequate.
Highly dissatisfied	-2	Extremely dissatisfied while walking conditions, either not existed or in worst conditions that needs proper renovation.

Tab.4 Converting semantic to numerical scale with qualitative elucidation

For walking constraints, regression analysis was used to determine the relationship between walking as a travel modes and other explanatory variables. This analysis also required numerical scale data which has been elaborated qualitatively based on the effecting scale, as shown in Tab.5.

Numerical factor	Qualitative elucidation
5	Has a devastating effect and extreme role in reducing walking habits, therefore must be resolved on highest priority.
4	Promptly effecting walking habits and is necessary to be solved abruptly.
3	Critically effecting the practices of walking habits and need to address on earliest.
2	Sufficiently effects the walking habits practices and the problems need to be address based long-term plans.
1	Have minor effects on walking habits and could be overcome while resolving the particular issues.

Tab.5 Qualitative elucidation with numerical factors of walking constraints

4. Results and Discussion

The survey sample was enriched with the male population, while a sufficient proportion of the other gender has also given their valuable input. Most of the respondents belong to the age category of 20 to 40 years. Determination of income level was mandatory to understand the socio-economic level of the interviewee, which demonstrates 28% population were unemployed or student having no income status, while 34% of people had income less than 50,000 being considered as a poor or lower-middle-income group (Ahsan, 2019; Arif et al., 2022). These people can not afford luxury cars but are still primarily dependent on motorized vehicles for mobility due to the presence of various walking constraints (Gargiulo et al., 2018).

With respect to Gender			**With Respect to Age**			**With Respect to Education**		
Type	Freq.	%	Categories	Freq.	%	Category	Freq.	%
Male	173	62%	Less than 20 years	45	16%	Under-Graduate or less	79	29%
Female	104	38%	20 - 40 years	166	60%	Graduate	125	45%
			More than 40 years	66	24%	Post-Graduation	73	26%
With Respect to Profession			**With Respect to Income**					
Categories	Freq.	%	Category	Freq.	%			
Student / unemployed	113	41%	None	77	28%			
Government Employee	48	17%	<15,000 PKR	24	9%			
Semi-Govt./ Private Employee	95	34%	15,001-50,000 PKR	70	25%			
Private Business	21	8%	50,001 - 100,000 PKR	75	27%			
			>100,000 PKR	31	11%			
Total No. of Respondents								**277**

Tab.6 Respondents' Characteristics

Indicators	**Classification**	**Descriptive Statistics**	
		Mean	**Std. Dev**
Walking habit	1= Yes 0=No	0.6101	0.4886
Frequency of Walking as a mode of transport	3= Daily 2= Once or twice a week 1= Occasionally	1.4657	1.2083
Intentions to Prefer Walking rather than Motorized Vehicles	1= Yes 0=No	0.4116	0.4930
Footpaths Free from Encroachments	1= Yes 0=No	0.2094	0.4076
Availability of Zebra Crossing lines on Intersections	1= Few 2= Major 3= All	1.3899	0.5770

Tab.7 Walking Characteristics

The results of exploratory analysis showed that the majority population have the habit of walking with mean values of 0.61. The population of developed and developing countries could have been surprised that how can someone answer whether they perform walking in yes or no. While conducting the surveys, this question was further elaborated to the interviewee to answer it based on their habits of walking as a mode of choice for travel. Moreover, keeping in view the climatical conditions, the case of Lahore is completely converse to the developed world because the population living in this city has to suffer from high temperature (Abbas et al., 2018) and the worst AQI (Pervaiz et al., 2019) in the different time span of the year. Besides this, the shortage of accessibility of public transport in different parts of Lahore forces the population to be dependent on motorized vehicles, thus minimizing the walking practices. The following questions were asked to those respondents who expressed earlier that they have a habit of walking. 31% of the population keeps the habit of walking daily while the majority population performs on a weekly basis or occasionally, having a mean value of 1.46. These results illustrate that a significant portion of people performs walking just on a need basis rather

than using it as a mode of travel. It demonstrates that walking constraints do not encourage people to walk as a mode of transportation, making them highly dependent on motorized vehicles. The population with walking habits is mainly concerned with health as a primitive indicator of walking purposes. Following health, work, and leisure are the prominent determinants of walking, as shown in Fig.3. The segment of the population reported not having regular walking habits was asked about the consequent reasons with open-ended questions where the lack of infrastructure for pedestrians, unsafe and unfriendly environment for walking, and encroached walkways in the city of Lahore was highlighted.

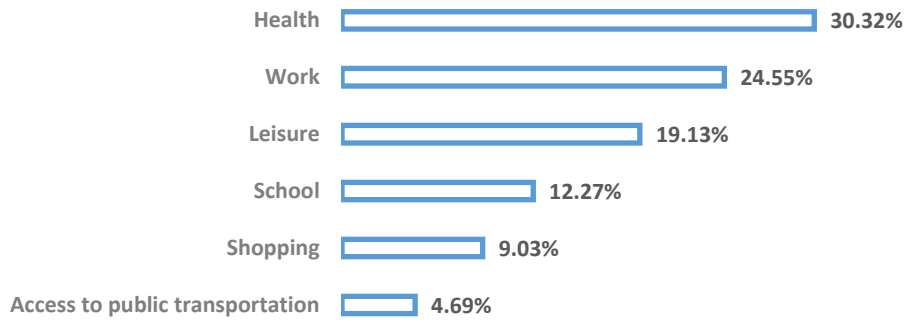


Fig.3 Purpose of Walking

Respondents were also asked whether they prefer walking as a mode of travel for accessing their desired destination or motorized vehicles. 59% of respondents refused walking as a preferred mode of choice for accessing multiple destinations with a mean value of 0.41. It's important to understand that the choice between walking and using motorized vehicles depends on a variety of factors, including distance, time, budget, personal preferences, and more. However, the predominant reasons behind preferring motorized vehicles to walk could be speed and efficiency, which allow people to cover greater distances in much less time, or the feeling of convenience as a mode of transportation.

Distance traveled			**Preferred Walking Time**			**Walking time without physical disturbance**		
Categories	No	%	**Categories**	No	%	**Categories**	No	%
<250 meters	57	21%	**<=10 min**	26	9%	**<=10 min**	108	38%
250 to 500 meters	55	20%	**10 - 20 min**	76	27%	**10 - 20 min**	46	29%
500 meters to 1 km	79	29%	**20 - 30 min**	84	30%	**20 - 30 min**	63	22%
More than 1 km	86	31%	**> 30 min**	91	33%	**> 30 min**	60	12%
Total No. of Respondents								**277**

Tab.8 Distance and Time Consumption Characteristics of Walking in Lahore

Travelled distance and time consumption characteristics of walking in Lahore are shown in Tab.8. Data demonstrates that almost 69% of people walk less than 1 Km while around 31% walk more than that. A significant number of people have intentions to walk for more than 20 minutes, but the physical disturbance and disconnectivity of walkways act as constraints reducing walking. 38% of the population faced physical disturbance within just 10 minutes, while 67% confronted it in less than 20 minutes of walking. This physical disturbance is examined as encroachment parameters and the non-availability of zebra crossing lines at intersections, as explained in perspectival. Non-availability of zebra crossing lines at an imperative road crossing section and intersections could be considered as discontinuity of pedestrian routes, which is often a major barrier to walking. The provision of zebra crossing lines could only be observed on a few major roads

or at some parts of planned communities, while most road sections and intersections are deprived of this facility, having a mean value of 1.39 (see Tab.7), leading pedestrians to unsafe environments. Another prominent parameter of physical nuisance is encroachment, i.e., only 21% of people observed footpaths free from encroachment, while 79% of the population confronts physical nuisance on walkways while walking (mean value of 0.20). Walkways and footpaths are mainly occupied by shopkeepers and vendors, using the walking infrastructure for profit-making on a personal basis, causing nuisances for the public at large. Besides this, permanent encroachment by households as stairs steps, and ramps, parking of private vehicles along the roadside, and installation of utility services on footpaths also act as a physical nuisance for pedestrians (shown in Fig.4).

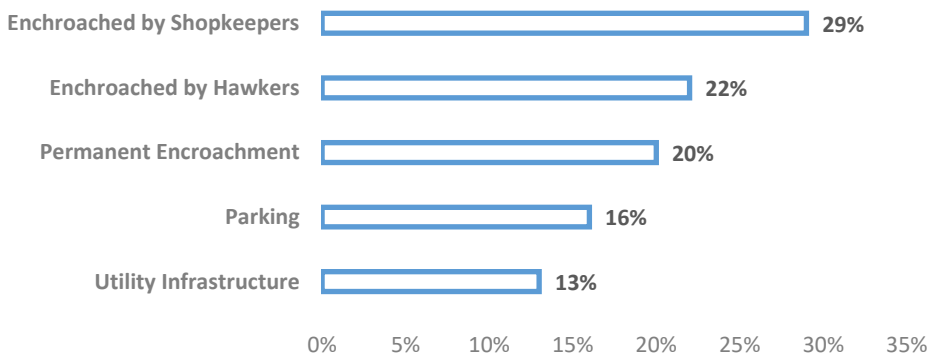


Fig.4 Reasons of Footpath Encroachment

4.1 Public Perception Determination

The public perception is evaluated by using average weighted factor analysis (as shown in Tab.9). The average weighted factor indicates the level of satisfaction or dissatisfaction as public perception, while negative or positive signs demonstrate the direction of perception. The value scale of the average weighted factor varies from 0 to 1, which indicates the least to the high level of satisfaction or dissatisfaction with public perception, where a positive sign illuminates public perception as satisfactory while negative signs as unsatisfactory.

Indicators	Weighted Factor	Average Weighted Factor
Infrastructural measures for Elders and Disabled	-302	-1.090
Environmental Qualities	-247	-0.892
Social Safety Concerns (Females)	-172	-0.621
Non-Existence of Encroachment on Footpaths	-139	-0.502
Driving Behaviour Concerns	-126	-0.455
Provision of Aesthetic and Amenities	-119	-0.429
Footpath Infrastructure Quality	-102	-0.368
Physical Connectivity/ Coherence of Walkways	-96	-0.347
Safety from Threat to Accidents	-83	-0.299
Walkways Cleanliness	-71	-0.256
Behaviour of Transport Officials	-42	-0.152

Tab.9 Average Weighted Factor Analysis Determining Pedestrian's Perception

It was observed that none of the indicators has a satisfactory public perception, which demonstrates the worst level of provided services and facilities for walking and non-consideration of walking parameters in urban policies and strategies. The highly criticized indicator is egregious convenience for elders and the disabled. It might be true that the problems and challenges associated with elders and disabled people have been considered in policymaking but not been implemented in their true spirit in real developmental projects, leading to diverse consequences. Following this, the most affecting indicator affecting walking is the air quality on the road. Other than this, safety concerns, particularly for females, are also an important concern. The existing literature on women's mobility in Lahore also declared the social environment unsafe and dangerous, e.g. the studies of (Malik et al., 2020; Jabeen et al., 2017) led to a barrier to inclusive mobility. Following these, the physical nuisance on pathways as encroached by shopkeepers or hawkers and uncontrolled parking is the most disparaged factor.

The adequate pedestrian planning highlighted in previous studies is just the provision of narrow footpaths in some parts of Lahore (Imran & Low, 2003), which are either encroached or poorly maintained, that reduced their operational capacity. Footpaths need to be free from encroachment and well maintained, infusing enthusiasm for walking in public (Haseeb et al., 2018; Tahir et al., 2015). Other factors, such as the provision of aesthetics and amenities along the walkways, are not even provided, but the heap of solid waste and garbage along footpaths are not properly removed and maintained. Bad smell from solid waste and garbage lying alongside roads and walkways establishes the unhappiest condition for walkers.

The findings highlight that the inhabitants of Lahore are dissatisfied with the walking infrastructure and its physical connectivity. On some major roads, walkways are available, but the connecting roads are deprived of this facility. Those who have the habit of walking face these problematic conditions. The unavailability of walkways increases the probability of pedestrians getting involved in crashes with other vehicles increased as they walk alongside the road.

To sum up, walking conditions were examined as dissatisfied due to the unavailability of infrastructure, social safety concerns, encroachment on footpaths, inadequate provision of aesthetics and amenities, insufficient physical connectivity/ coherence of walkways, and lack of management regarding cleanliness. Therefore, to encourage the public's walking practice, these indicators must be considered in plans and policymaking, while the collaboration of all stakeholders, predominantly the city walkers, must be considered.

4.2 Walking Constraints

Regression analysis also depicts an influential significance level of constraints as a barrier to declining walking practices. The analysis results (see Fig.5) reflect encroached footpaths, ignorance of pedestrian safety regarding accidents, excessive crime rate, and egregious weather conditions as extremely significant walking constraints. Besides encroached footpaths, pedestrian accidents because of safety ignorance by traffic movement are crucial walking constraints. Ignorance of pedestrian safety as a walking constraint refers to a lack of awareness or understanding of safe walking practices and pedestrian-friendly infrastructure. It can lead to a range of issues, including pedestrian accidents, pedestrian-vehicle conflicts, and a general lack of comfort and convenience for those who walk. Pedestrians' vulnerability on roads due to poor driving skills, incompatible pedestrian facilities, and inadequate driving education caused almost 26% of pedestrian accidents due to haphazard traffic management in Lahore (Minhas et al., 2016). Furthermore, as a walking constraint, "ignorance of pedestrian safety" can impede the creation of walkable communities. If people are unaware of the importance of pedestrian safety, they may not advocate for pedestrian-friendly infrastructure and amenities, such as well-lit sidewalks, pedestrian crossings, and pedestrian-friendly street designs.

Excessive crime in urban areas of Pakistan has a decisive impact on walking. A higher crime rate affects social dimensions of society, consequently reducing walking, while safer communities with efficient measures boost walking practices (Rad et al., 2014).

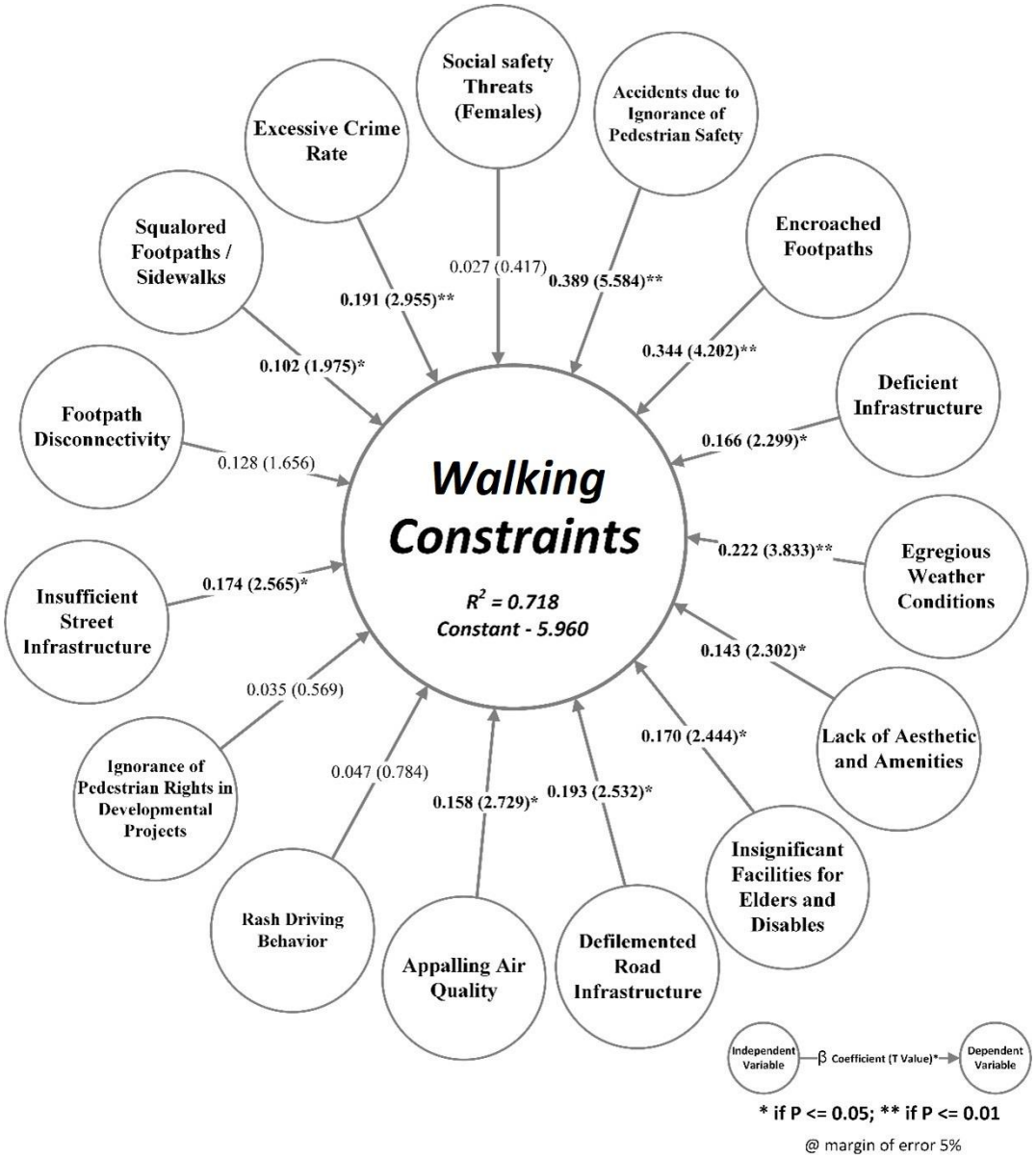


Fig.5 Walking Constraints and their Influential Significance

Egregious weather conditions in urban areas also influence walking. The built extent of Lahore lacks sufficient tact green spaces in it. Lesser provision of green spaces coupled with heavy traffic mobility has pessimistic effects on urban heat islands, which enhance the temperature in summer, causing a reduction in walking (Gray et al., 2012). Lahore suffers from high temperatures due to urban heat island effects caused by modifications in land cover, increased air pollution, lack of canopy, concrete infrastructure, and inadequate green spaces.

This study also indicates the significant effects of deficient walking infrastructure, squalor footpaths/sidewalks, insufficient street infrastructure, insignificant facilities for elders and disabled, absent road infrastructure, and lack of aesthetics and amenities on walking. Though few planned communities in Lahore have provided walking infrastructure for pedestrianization, plenty of areas are either deprived of these infrastructures, i.e., non-availability of footpaths, pedestrians' bridges, and Zebra crossing facilities, or possess poor maintenance characteristics. Street infrastructure, including streetlights for proper visibility at night, benches, and dustbins, either vanished from the streets or are insufficiently accessible. Other than this, walking is a key challenge for elders and the disabled. Insufficient time to cross the road or intersection, poor quality pavements, lack of curb ramps, the nonexistence of steps for visual impairments to find a way, etc., deprived special persons of

accessing opportunities through walking (Lo, 2010). Moreover, the lack of aesthetics and amenities has unpropitious influences on pedestrians' walking.

The crucial walking obstacles are social safety threats, particularly for females, physical disconnectivity on walkways, ignorance of pedestrian rights in developmental projects, and rash driving behavior of vehicular users. Apart from their decisive influence on pedestrians' walking, these indicators have insignificant impacts in the case of Lahore. All these walking constraints need to be resolved through long-term pragmatic plans with efficient stakeholder inclusion. Regardless of the analysed data for public perception and walking constraints determination in the settings of Lahore, further community-based in-depth understanding of respective issues is mandatory to form sustainable urban strategies leading to an inclusive mode of travel.

5. Conclusion

This study is conducted to analyze the impacts of indicators to assess public perceptions of constraints of walking in the city of Lahore. To conduct this study, a comprehensive set of data is collected from diversified socio-economic, age, and gender groups. The result of this study highlights that a minimal proportion of the population prefers walking as a mode of travel for everyday mobility. The utmost finding of this study shows extreme dissatisfaction of inhabitants with the provided urban infrastructure for walking, which was aggrandized by their poor maintenance. It is observed that none of the walking indicators have satisfactory public perception based on their beneficiary characteristics, thereby discouraging people from walking. Highly dissatisfying walking variables include the non-consideration of elders and disabled people in urban transport plans, bad environmental qualities surrounding walkways, poor infrastructural qualities, and social safety concerns. Moreover, this study has also enlightened us on the various walking constraints that act as a barrier for walkers in the built space of Lahore city. The constraints indicators that significantly impact walking are excessive crime rates, ignorance of pedestrian safety by vehicular traffic, egregious climatic conditions, and encroached footpaths for personal or profit-making business purposes. The number of other indicators, such as insufficient street infrastructure, degraded road infrastructure, a lack of aesthetics and amenities, and rash driving, also have their impacts on reducing walking practices. These elaborated walking constraints need to be resolved to make walking an efficient and viable transport mode for all age groups, genders, and socioeconomic classes.

This study is limited to people's perceptions about barriers to walking, in which factors related to infrastructure, weather, and safety have been analyzed. However, some important factors are out of the scope and this study and thus open for future research. For example, this study does not incorporate contextual factors, e.g. religion, culture, and social interaction to understand perceived barriers to walking. Similarly, how a specific group, e.g. gender or age, perceives walking can be an important avenue for future research. Other than this, the data used for analysis was collected from the city of Lahore and web-based, whereas, future studies can suggest to included cross cities comparisons to extend the current research. Finally, these findings arise from an online questionnaire. When using these tools, less educated, tech-savvy, and old people are more difficult to target, and therefore, their opinions could be underrepresented and should be included in future research.

Acknowledgement

The authors are thankful to anonymous reviewers and the Editor, Floriana Zucaro, for the valuable comments that helped to improve this research article.

References

Abbas, S., Shirazi, S. A., & Qureshi, S. (2018). SWOT analysis for socio-ecological landscape variation as a precursor to the management of the mountainous Kanshi watershed, Salt Range of Pakistan. *International Journal of Sustainable Development & World Ecology, 25*(4), 351-361.

Ahsan, M. (2019). Making Unaffordable to Affordable: Looking into Affordable Housing Issues and Its Remedies. *Architecture and Urban Planning, 15* (1), 22-29. https://doi.org/10.2478/aup-2019-0003

Al-Rashid, M. A., Goh, H. C., Harumain, Y. A. S., Ali, Z., Campisi, T. & Mahmood, T. (2021). Psychosocial barriers of public transport use and social exclusion among older adults: Empirical evidence from Lahore, Pakistan. *International journal of environmental research and public health, 18* (1), 185. https://doi.org/10.3390/ijerph18010185

Al-Rashid, M. A., Nadeem, M., Campisi, T., Shamsul Harumain, Y. A., & Goh, H. C. (2022). How Do Psychosocial Barriers Shape Public Transport Use? A Mixed-Method Study among Older Adults in Pakistan. *Sustainability, 14* (19), 12471. https://doi.org/10.3390/su141912471

Anwer, I., Masoumi, H., Aslam, A. B., & Asim, M. (2021). Logit and probit models explaining perceived cycling motives, barriers, and biking trip generation in Lahore, Pakistan. *TeMA Journal of Land Use, Mobility and Environment, 14* (3), 433-455. https://doi.org/10.6093/1970-9870/8113

Arif, M. M., Ahsan, M., Devisch, O., & Schoonjans, Y. (2022). Integrated Approach to Explore Multidimensional Urban Morphology of Informal Settlements: The Case Studies of Lahore, Pakistan. *Sustainability, 14*(13), 7788.

Arvidsson, D., Kawakami, N., et al. (2012). Physical activity and concordance between objective and perceived walkability, *Med Sci Sports Exerc, 44* (2). https://doi.org/ 10.1249/MSS.0b013e31822a9289

Aslam, S. A. B., Masoumi, H. E., et al. (2018). Cyclability in Lahore, Pakistan: Looking into Potential for Greener Urban Traveling. *TeMA Journal of Land Use, Mobility and Environment, 11* (3), 323-343. https://doi.org/10.6092/1970-9870/5806

Aziz, A., Nawaz, M. S., et al. (2018). Examining suitability of the integrated public transport system: A case study of Lahore. *Transportation Research Part A: Policy and Practice, 117,* 13-25. https://doi.org/10.1016/j.tra.2018.08.003

Bahari, N. I., Arshad, A. K., et al. (2014). Assessing pedestrians' perspective on the walkability of pedestrian environment under mixed-use development. In InCIEC 2013, pp. 355-367. Springer, Singapore. https://doi.org/10.1007/978-981-4585-02-6_31

Balsas, C. J. L. (2019). Walkable Cities: Revitalization, Vibrancy, and Sustainable Consumption. SUNY Press.

Bharucha, J. (2017). An investigation into the walkability problem in Indian cities. *Safer Communities ,16* (2), pp. 77-86. https://doi.org/10.1108/SC-02-2017-0010

Cecchini A., & Talu V. (2011). Walking (and cycling) to change the city. *TeMA - Journal of Land Use, Mobility and Environment, 4* (4), 99-108. https://doi.org/10.6092/1970-9870/605

Clark, M. I., Berry, T. R., et al. (2010). Key stakeholder perspectives on the development of walkable neighbourhoods. *Health & Place 16* (1), 43-50. https://doi.org/10.1016/j.healthplace.2009.08.001

De Nazelle, A., Bode, O., & Orjuela, J. P. (2017). Comparison of air pollution exposures in active vs. passive travel modes in European cities: A quantitative review. *Environment international, 99,* 151-160. https://doi.org/10.1016/j.envint.2016.12.023

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

Gaglione, F., Gargiulo, C., & Zucaro, F. (2019). Elders' quality of life. A method to optimize pedestrian accessibility to urban services. *TeMA-Journal of Land Use, Mobility and Environment, 12* (3), 295-312. https://doi.org/10.6092/1970-9870/6272

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

Grant, T. L., Edwards, N., et al. (2010). Neighborhood walkability: older people's perspectives from four neighborhoods in Ottawa, Canada. *Journal of aging and physical activity, 18* (3), 293-312. https://doi.org/10.1123/japa.18.3.293

Gray, J. A., Zimmerman, J. L., et al. (2012). Built environment instruments for walkability, bikeability, and recreation: Disability and universal design relevant?. *Disability and health journal, 5* (2), 87-101. https://doi.org/10.1016/j.dhjo.2011.12.002

Hameed, R., & Anjum, G. A. (2016). Improving the Environmental performance of bus-based public Transport system in Lahore-Pakistan. *Pakistan Journal of Engineering and Applied Sciences*.

Haseeb, A., Saleemi, A., et al. (2018). Spatial analysis for the identification of high-risk locations of road accidents with pedestrian fatalities in lahore. *Pakistan Journal of Science, 70* (4), 317. Retrieved from: https://www.proquest.com/scholarly-journals/spatial-analysis-identification-high-risk/docview/2348771590/se-

Ibrahim, M., and Riaz, S. (2018). Lahore growth-Past and future. Retrieved from: http://urbanunit.gov.pk/Upload/Photos/Urban%20Gazette%20Issue%202018.pdf (accessed at 27.04.2020).

Imran, M. & Low, N. (2003). Impact of global institutions on urban transport in Pakistan cities. In Proc. 39th ISoCaRP Congress.

Jabeen, T., Sunbal, M., et al. (2017). Relationship between Women Mobility and Sexual Harassment: Empirical Study of Metropolitan City of Lahore. *Pakistan Journal of Criminology, 9* (4), 90. Retrieved from: https://www.proquest.com/scholarly-journals/relationship-between-women-mobility-sexual/docview/2164962204/se-2

JICA. (2012). "The project for Lahore urban transport master plan "in the Islamic republic of Pakistan." Transport Department, Government of Punjab 2. Retrtieved from: https://www.urbanunit.gov.pk/Upload/Photos/103.pdf (accessed at 30.04.2020).

Jun, H. J., & Hur, M. (2015). The relationship between walkability and neighborhood social environment: The importance of physical and perceived walkability. *Applied Geography, 62*, 115-124. https://doi.org/10.1016/j.apgeog.2015.04.014

Kelly, C. E., Tight, M. R., et al. (2011). A comparison of three methods for assessing the walkability of the pedestrian environment. *Journal of Transport Geography, 19* (6), 1500-1508. https://doi.org/10.1016/j.jtrangeo.2010.08.001

Liao, B., van den Berg, P. E., van Wesemael, P. J., & Arentze, T. A. (2022). Individuals' perception of walkability: Results of a conjoint experiment using videos of virtual environments. *Cities, 125*, 103650. https://doi.org/10.1016/j.cities.2022.103650

Lo, C. (2010). What are the Main Problems Individuals with Mobility Issues Encounter Daily in the Kingston Galloway Orton Park Neighbourhood?.

Lourenço, J., & Rahaman, K. R. (2010). Pedestrian Planning in City Centers: a Study of Guimarães and Braga. *TeMA -Journal of Land Use, Mobility and Environment, 3* (1), 37–46. https://doi.org/10.6092/1970-9870/134

Lockett, D., Willis, A., et al. (2005). Through seniors' eyes: an exploratory qualitative study to identify environmental barriers to and facilitators of walking. *Canadian Journal of Nursing Research Archive, 37* (3).

Makki, S., Surat, M., et al. (2012). The importance of design characteristics in walking from student's perspective: a case study in Universiti Kebangsaan Malaysia. *Journal of Building Performance, 3* (1).

Malik, B. Z., Rehman, Z., et al. (2020). Women's mobility via bus rapid transit: Experiential patterns and challenges in Lahore. *Journal of Transport & Health, 17*, 100834.

Mazzeo, G., Zucaro, F., & Morosini, R. (2019). Green is the colour. Standards, equipment and public spaces as paradigm for the Italian sustainable city. *TeMA Journal of Land Use, Mobility and Environment, 12* (1), 31-52. https://doi.org/10.6092/1970-9870/5836

Minhas, M. K., Rehman, Z. U., et al. (2016). A study of factors influencing accidents on Lahore Islamabad motorway (m-2). *Pakistan Journal of Science, 68* (1), 63.

Newman, P., and Kenworthy, J. (1999). Sustainability and cities: overcoming automobile dependence. *Island press*.

Ovstedal, L., and Ryeng, E. (2002). Understanding pedestrian comfort in European cities: How to improve walking conditions. *In European Transport Conference, Cambridge, UK* (6).

Pak, B. & Verbeke, J. (2013). Walkability as a Performance Indicator for Urban Spaces. *Crowdsourcing and Sensing, 1*, 423-432. Retrieved from: https://www.researchgate.net/publication/279925396_Walkability_as_a_Performance_Indicator_for_Urban_Spaces_Strategies_and_Tools_for_the_Social_Construction_of_Experiences

Pervaiz, S., Javid, K., Khan, F. Z., Talib, B., Siddiqui, R., Ranjha, M. M., & Akram, M. A. N. (2019). Spatial analysis of vegetation cover in urban green space under new government agenda of clean and green Pakistan to tackle climate change. *Journal of Ecological Engineering, 20*(4).

Rad, V. B., Najafpour, H., et al. (2014). The Systematic Review on Safety in Urban Neighborhoods. *Life Science Journal, 11* (10).

Saelens, B. E., Sallis, J. F., et al. (2003). Environmental correlates of walking and cycling: findings from the transportation, urban design, and planning literatures. *Annals of behavioral medicine, 25* (2), 80-91. https://doi.org/10.1207/s15324796abm2502_03

Shakeel, N., & Jahanzaib, M. (2019). Influence of land use, socio-demographic and travel attributes on travel behaviour in City of Lahore. *Architecture and Urban Planning, 15* (1), 67-74. https://doi.org/10.2478/aup-2019-0009

Southworth, M. (2005). Designing the wa. lkable city. *Journal of urban planning and development, 131* (4), 246-257. https://doi.org/10.1061/(ASCE)0733-9488(2005)131:4(246)

Strohmeier, F. (2016). Barriers and their influence on the mobility behavior of elder pedestrians in urban areas: challenges and best practice for walkability in the city of Vienna. *Transportation research procedia, 14*, 1134-1143. https://doi.org/10.1016/j.trpro.2016.05.184

Tahir, M. N., Haworth, N., et al. et al. (2015). Observations of road safety behaviours and practices of motorcycle rickshaw drivers in Lahore, Pakistan. In Proceedings of the 2015 Australasian Road Safety Conference, Australian College of Road Safety (ACRS).

Tariq, F., & Shakeel, N. (2021). Modeling and Predicting Commuters' Travel Mode Choice in Lahore. Global Social Sciences Reviews VI(III), 106-118. https://doi.org/10.31703/gssr.2021(VI-III).12

Zhang, X. & Mu, L. (2020). Incorporating Online Survey and Social Media Data into a GIS Analysis for Measuring Walkability. In: Lu, Y., Delmelle, E. (eds) Geospatial Technologies for Urban Health. Global Perspectives on Health Geography. Springer, Cham. https://doi.org/10.1007/978-3-030-19573-1_8

Author's profile

Muhammad Ahsan

He is currently pursuing his master's degree in the Department of City and Regional Planning, Yildiz Technical University, Istanbul as Turkey Burslari Scholarship holder. He has recently completed his Erasmus+ Traineeship program in Katholieke Universiteit (KU) Leuven, Belgium in the faculty of Architecture. The author has completed his bachelor's degree in City and Regional Planning from University of Engineering and Technology (UET), Lahore and endowed with two gold medals based on excellent educational performance. Mr. Ahsan's research interests are related to affordable housing, urban regeneration of informal housing, urban transportation and walkability, and integration of spatial and statistical tools in urban planning.

Nabeel Shakeel

He is currently pursuing his PhD in Geography from the School of Earth and Enviornment, University of Canterbury, New Zealand. He is a forward-thinking transport planner and human geographer with specializations in the areas of travel behavior analysis, transport equity and accessibility, and spatial data analytics. The underlying goal of his research is to develop approaches for designing equitable and accessible transport services and analyze them with behavioral perspectives. He received his becholar's degree in Urban Planning and Master degree in Transportation Planning.

Farrukh Baig

He received the M.S. degree in transportation planning and management from the Dalian University of Technology, Dalian, Liaoning, China, in 2017. He is currently pursuing a Ph.D. degree in traffic engineering at Central South University, Changsha, Hunan, China. He has been an Associate Member of the American Society of Civil Engineering since 2020. He serves various International journals as a reviewer and has attended multiple international conferences. His research interests include automated vehicles, smart cities, road safety, transportation planning, transport policy, and urban management.

TeMA
Journal of
Land Use, Mobility and Environment

TeMA 1 (2023) 121-145
print ISSN 1970-9889, e-ISSN 1970-9870
DOI: 10.6093/1970-9870/9395
Received 13th September 2023, Accepted 13th April 2023, Available online 30th April 2023

www.tema.unina.it

Soil *de-sealing* for cities' adaptation to climate change

Planning of priority interventions in urban public space

Marianna Ceci [a]*, Barbara Caselli [b], Michele Zazzi [c]

[a] Department of Engineering and Architecture
University of Parma, Parma, Italy
e-mail: marianna.ceci@unipr.it
ORCID: https://orcid.org/0000-0003-2909-2204
* Corresponding author

[b] Department of Engineering and Architecture
University of Parma, Parma, Italy
e-mail: barbara.caselli@unipr.it
ORCID: https://orcid.org/0000-0002-3236-8681

[c] Department of Engineering and Architecture
University of Parma, Parma, Italy
e-mail: michele.zazzi@unipr.it
ORCID: https://orcid.org/0000-0001-5490-1558

Abstract
It is well known that extreme heat waves or weather events combined with the increased soil consumption and sealing processes are significantly affecting urban systems especially the most exposed and vulnerable. These urban challenges call for specific mitigation and adaptation actions; soil de-sealing (i.e., the removal of the impermeable surfaces for increasing green areas and restoring soil ecosystem functions) may be one of the possible solutions. However, this urban practice, to have meaningful outcomes, would need widespread and systematic application in urban areas that can be pursued only if supported by innovative programming and planning tools based on the construction of in-depth knowledge frameworks on the permeability and vulnerability of urban soils.
In this regard, the paper aims to outline a methodological approach, supported by GIS technology, to map in detail urban public soils and identify priority areas to be de-paved. In particular, the method assesses the permeability of public land in relation to hydraulic and heat island hazard exposure of potentially vulnerable urban systems. The methodological approach is applied to a pilot case in the city of Parma to test its potential and limitations, with the goal of creating a replicable procedure.

Keywords
Climate change; Urban planning; Adaptive measures; De-sealing; Public space.

How to cite item in APA format
Ceci, M., Caselli, B. & Zazzi, M. (2023). Soil *de-sealing* for cities' adaptation to climate change. *Tema. Journal of Land Use, Mobility and Environment*, *16* (1), 121-145. http://dx.doi.org/10.6093/1970-9870/9395

1. Introduction

The climate-regulating functions of the soil resource have long been known; however, data confirm that the slowdown in soil consumption has, in fact, ended moving further away from the European goals of 'no net land take' by 2050 (European Commission, 2011). Almost 98,000 km^2 (2.23% of the total NUTS3 area) of sealed soil was detected by the European monitoring programme 'Copernicus' in 2018 (Copernicus Land Monitoring Service, n.d.). More than 3,000 km^2 have been added to the count since 2012 (European Environment Agency, 2021). Urban growth, with the consequent transformations of agricultural and natural areas and a significant loss of biodiversity (Agenzia Europea dell'Ambiente, 2019), in Italy has achieved an average consumption of 77 km^2 per year reaching 7.13%, higher than the EU average of 4.2% (Munafò, 2022).

The trend of increased high air temperatures is growing as well. Temperatures in Europe are rising faster than the global average. Copernicus Climate Change data report that over the past ten years, the average annual temperature is 1.94 to 2.01°C warmer than in the 19th century (Simmons et al., 2017). In the main Italian cities, the average annual temperature has shown an increasing trend since 1971. In 2020, the average temperature is +16.3°C, an increase of 0.3°C over the corresponding average value for the decade 2006-2015 (Istat, 2022). Heavy rainfall events also increase, leading to higher flood risk. Urban layout with buildings, streets, and squares significantly affects the heat island phenomenon (European Commission, 2012), as well as the ability of urban soils to drain or retain water.

In the process of adapting to climate change, the European Union promoted the Covenant of Mayors (2008), an initiative that led many cities to sign a pact and draw up a specific Sustainable Energy and Climate Action Plan (SECAP), a planning tool that identifies mitigation and adaptation actions starting from a rigorous assessment of possible urban risks. Different risk levels derive from the combination of the probability of certain phenomena occurring (such as floods and heat waves), with the exposure and vulnerability of urban systems (World Health Organization, 2002). The increased awareness of the impacts of climate change on cities is also reflected in urban planning, as some local governments have recently complemented their urban plans with Climate Change Adaptation Plans (Pietrapertosa et al., 2018; Zucaro & Morosini, 2018). EU also funded projects, such as Urban GreenUP, to develop, apply and validate a methodology for implementing nature-based solutions (NBSs) in urban planning tools (Urban GreenUP, n.d.), to provide for new green infrastructures.

Studies carried out by several countries in the urban planning field and the good practices implemented by cities, show how this topic has become central in the debate on spatial planning (Oliveira et al., 2018; Zucaro & Morosini, 2018; Rota et al., 2019; Tardieu et al., 2021; Ventura et al., 2021; Pellicelli et al., 2022), with an increased awareness on environmental and social issues (Apreda, 2016). For these reasons, strong relationships must be established between the shape of cities and climate change adaptation strategies (Gerundo, 2018). By restoring nature to the city, proposing NBSs and permeable materials, there is an overall improvement in soil ecosystem services, as they help cool city temperatures, better manage water drainage, increase biodiversity, improve air quality and generate well-being (Dessì et al., 2016; Lehmann, 2019; Cortinovis et al., 2022). Urban regeneration, in addition to limiting soil consumption by recovering obsolete and/or degraded urban fabric, can also activate soil *de-sealing* interventions, i.e., the removal of the surface impermeable layer, to increase the permeability of soils, their ecological performance and their capacity to provide ecosystem services (Science for Environment Policy, 2016; Maienza et al., 2021; Garda, 2022). Various international de-sealing experiences are emerging in recent years, through associations and foundations, with the common aim of promoting urban regreening to adapt to climate challenges (Depave, s.d.; Stobbelaar et al., 2021). Indeed de-sealing practices contribute to microclimatic comfort (by increasing soil evapotranspiration resulting in a decrease in temperature and air cooling) and to the management of water runoff during heavy and prolonged rainfall (due to the increased capacity of permeable green areas to absorb

and filter water), thus improving urban quality and increasing the quality of life for the urban population (Directorate General for Environment - European Commission, 2012; Dessì et al., 2016; Garda, 2020; De Noia et al., 2022). Therefore, in the context of urban adaptation policies, an effective approach of spatial planning tools should address both effects of climate change by identifying a scale of intervention priorities, mapping both areas subject to the heat island phenomenon and those at risk of flooding (Musco & Fregolent, 2014, p. 93). The overlapping of high levels of criticality outlines a priority for intervention. Soil sealing, and the consequent choice of areas to be de-sealed, is, therefore, one of the key points to be addressed to measure the sustainable development of the city; but it is not always easy to find areas available and suitable to the purpose.

For instance, in the digital mapping of the 'Berlin Environmental Atlas', factors such as ownership, technical evaluation, technical effort, and feasibility in terms of time are considered as evaluation criteria for defining the priority levels of intervention of potential areas to be de-sealed[1]. Instead, in the 'SOS4life' project these areas were traced among those already classified for urban regeneration by the current urban plans of the participating cities, supplemented with areas that due to their degradation and poor environmental quality could provide for de-sealing actions (SOS4LIFE, 2018).

The paper aims to illustrate a practical method to map impermeable soils in public space and to analyse the priority areas for de-sealing interventions. The methodological approach, supported by GIS (Geographical Information System), aims at mapping non-permeable surfaces, identifying operable/transformable ones and interfacing them with hydraulic and heat island hazard maps to highlight potential intervention priorities. Indeed, de-sealing actions on public open spaces may have varying degrees of priority but should have immediate operability for the city government. A GIS database has been built with the double purpose of mapping impermeable/permeable surfaces and public space uses.

The contribution stems from a collaboration with the Municipality of Parma (Italy) interested in acquiring a tool to adequately respond to the new urban planning requirements of the Emilia-Romagna regional law no. 24/2017[2]. The study aims to support the public administration in the construction of a cognitive and analytical framework, and it is experimented on a residential neighbourhood in Parma to test its applicability.

The following chapters discuss in detail the methodology and lessons learnt from the case study. Section 2 develops a literature review on the relationship between urban planning and soil regulation and assessment, developing insight into the analysis of permeability in urban areas, also identifying indices used to assess the quality and ecological performance of urban soils. Section 3 introduces the research methodology for identifying areas to be de-paved, supported by a GIS database and the application of the method to a pilot case study. Finally, section 4 presents the results of the analysis and section 5 discusses the research outputs and sets some concluding remarks.

2. Urban planning studies on the permeability and quality of urban soils

Covering part of the land with non-draining materials (such as asphalt, concrete, etc.) for new construction means consuming soil and making it impermeable (Bencardino, 2015; Munafò, 2021). In the process of achieving zero soil consumption, envisaged in 2050 by the European Commission, some European countries have been integrating measures to limit soil consumption and compensate soil sealing into their strategic spatial planning processes (Science for Environment Policy, 2016). These are generally provided with specific environmental assessment tools on soil permeability and quality (SOS4LIFE, 2017; Juhola, 2018). These aspects will be addressed in the next sub-sections.

[1] https://www.berlin.de/umweltatlas/boden/entsiegelungspotenziale/fortlaufend-aktualisiert/methode/

[2] Urban Regional Law 'Regional regulations on the protection and use of land' refers to de-sealing actions, through the removal of soil sealing, as a measure to be taken to achieve a balance of soil consumption (Article 5.5) but also as an incentive measure for urban regeneration practices (Article 7).

2.1 De-sealing interventions as compensatory measures: the German cases

As early as the 1990s in Germany, the concepts of soil sealing and de-sealing were already being questioned (Mohs & Meiners, 1994). Other more recent authors remind us how significant the degree of imperviousness of this State is and the consequent considerable experience in implementing these principles of protection and conversion of sealed soil (Meyer, 2011; Adobati & Garda, 2018). For these reasons, it has been decided to discuss a few examples of German cities, taking them as a reference in the context of increasing urban soil permeability through planning tools.

Therefore, Germany left it up to the various Länder to supplement adaptation processes with specific technical and economic instruments, fiscal incentive policies and environmental compensatory measures (such as the promotion of de-sealing actions).

Following a chronological order, the city of Dresden, the capital of Saxony which was flooded in 2002 by a devastating overflow of the Elba river, has defined a long-term planning strategy that envisages a land take target limited to 40% of the total urban area; a target to be met also through a 'soil compensation account (Bodenausgleichskonto)' (Directorate General for Environment (European Commission), 2012). Any soil sealing, therefore, requires compensatory measures on an equivalent area within the urban perimeter, through de-sealing actions, renaturation, or greening. Areas for de-sealing are filed in the city's Climate Change Adaptation Plan and are chosen according to the size and value of the new area to be developed (Righini, 2016; Bundesministerium für Bildung und Forschung, n.d.).

Since 2003, the Bavarian Länder have also had suitable regulations to compensate consumption of new soil. The aim is to evaluate each future intervention through ecological account and compensation factors (Ökokonto), varying according to the soil quality and planned soil sealing. To achieve ecological compensation, each new intervention needs to be preceded by the renaturalisation of an area already listed in the 'Ökoflächenkataster' stock (Bayerisches Landesamt für Umwelt, n.d.).

The city of Stuttgart, since 2006, has implemented regulatory measures to reduce soil sealing and promote a more responsible use of soil. Two tools were used: the soil quality map and a soil index, the 'Bodenindikation', evaluating the quality and quantity of consumed soil. The compensatory measures also include de-sealing actions (beneficial for not very large sealed areas) and redevelopment of brownfield sites for which a constantly updated database has been set up (SOS4LIFE, 2017; Osservatorio del Paesaggio trentino, 2022).

No less careful about these issues is the city of Berlin, the German capital. The 'Potentials for Impervious Coverage Reduction' project is one of the proposals to remove the impermeable land cover: the aim is to obtain a dedicated database, after carrying out a specific assessment of the functions of all the land in the city that could potentially be renaturalised, by removing their impermeable topsoil. The project, therefore, provides for the creation of a cataloguing system throughout the city. In addition, it allows for a constant updating of the areas in the database, enabling even private landowners to access the platform both to obtain information on possible areas suitable for de-sealing and to enter their properties into the system (Senatsverwaltung für & Umwelt, Mobilität, Verbraucher und Klimaschutz, 2022).

2.2 Assess the performance of building interventions based on soil permeability: scores and indices

In addition to spatial regulations, many recent urban practices are based on assessing the quality of urban soils to preserve high ecological values, and eventually subject lower-quality soils to urban transformation. Different indicators have been used to define levels of soil quality, quantify the ecological performance of soils, and interact with urban transformation regulations. Environmental quality indices are considered valuable tools both for monitoring the phenomenon of soil sealing and for strategic urban-building planning aimed at proposing effective de-sealing/re-greening actions to contrast the effects of climate change (De Lotto et al., 2015, 2022).

Since 1994, Berlin's Landscape Program has included a regulation requiring a proportion of the area to be left as green space, creating an index/standard to be respected in case of new construction or redevelopment: the Biotope Area Factor (BAF) or BFF (Biotop Flächenfaktor) (Climate-ADAPT, n.d.). The BAF index is the result of a ratio between ecologically effective areas and the total surface area of the urban plot considered. The value of the ecological index varies according to the level of sealing of the open space and the characteristics of the built environment (e.g. the presence of green roofs or green walls). The city of Berlin has provided an abacus of urban surface types by associating weighting factors[3] from 0 to 1. A value of '0' corresponds to completely sealed surfaces with no green areas and therefore negative effects on water runoff and urban microclimate. A value of '1' corresponds to plots with vegetation connected to the underlying soil, providing maximum performance in terms of water absorption, biodiversity, and improvement of the urban microclimate. Intermediate values correspond to semi-permeable surfaces or materials with intermediate ecological values. Berlin's urban transformation regulations also set a target parameter for redevelopment and new construction. Urban and architectural planners are allowed to develop their projects freely, as long as the target is met, and soil permeability and the presence of greenery are guaranteed. An inner-city area of Seoul has also experienced this methodical and systematic approach applied to its territory, to assess and manage urban ecosystem services by implementation in local planning instruments (Lakes & Kim, 2012).

At the international level, other cities adopted different indices, such as Malmö in Sweden with the Green Space Factor (Malmö stad, 2021), Oslo in Norway with the Green-Blue Factor (Cortinovis & Geneletti, 2020) and Seattle in the U.S.A. with the Seattle Green Factor (Seattle Department of Construction & Inspections, n.d.).

Another example of an environmental soil quality index is the Reduced Building Impact (RIE), adopted by the city of Bolzano, in Italy. This parameter supports land use planning in case of new buildings or renovations and is used to limit soil sealing in favour of more permeable areas (Città di Bolzano, 2021). In 2004 the city approved the new numerical index (with a range from '0' to '10') to certify the environmental quality of any future urban-building intervention. Importance is given to the benefit that permeable soil gives to the environment and to the well-being of the inhabitants, improving the urban microclimate and the capturing of rainwater runoff.

Other Italian municipalities in recent years have adopted these indices of environmental quality within their urban planning tools (Di Paolo et al., 2020): e.g. the city of Segrate adopted the BAF (Città di Segrate, 2017) while the city of Bologna adopted the RIE (Comune di Bologna, n.d.). In addition, an automatic methodology called M4BAF (maps for BAF) has been tested in Pavia to assess the quality of urban transformation interventions by comparing environmental quality indicators ex-ante and ex-post. The methodology refers in particular to the BAF index and is capable of automatically associating the value of the BAF coefficient (following the abacus proposed by the city of Berlin) with each urban area based on the existing vector cartography of the city of Pavia and GIS technology (Casella et al., 2015). With the detailed digital mapping of soil permeability, M4BAF can be considered an accurate methodology, that is replicable elsewhere.

Another study carried out in the medium-sized Italian city of Padua (Peroni et al., 2018) uses the BAF index to assess the current soil quality and to simulate future transformation scenarios for a pilot neighbourhood in the city. The analysis led to the hypothesis of improved interventions in urban areas characterised by a high degree of soil sealing, e.g. by providing green roofs and quantifying their positive effects, through the BAF index calculation. Indeed, the more the index reaches a high value, through the replacements of paving materials with more permeable ones or the addition of green walls/rooftops, the more the area can absorb water flows and improve local thermal comfort.

[3] See (Senate Department for & the Environment, Urban Mobility, Consumer Protection and Climate Action, 2021) for updated values of BAF weighting factors.

The cases reported above demonstrate the effort and attention of local governments and scholars to the contemporary need of adapting to climate change in the existing city using greenery and cool materials. However, the reported experiences do not specify how the areas to be de-paved are chosen, except on the basis of their permeability characteristics, equal extent for compensation purposes (Bundesministerium für Bildung und Forschung, n.d.) or feasibility of the intervention (Senatsverwaltung für & Umwelt, Mobilität, Verbraucher und Klimaschutz, 2022). Therefore, the authors intend to address the lack of a rigorous methodology to prioritise de-sealing operations. The methodology considers not only soil ecological and environmental performance but also the different levels of hydraulic and heat island hazards affecting urban areas. The hydraulic hazard identifies the probability that very heavy or abundant rainfall, combined with the area characteristics, may contribute to causing a flood. Instead, heat island hazard is due to higher daytime temperatures and reduced cooling at night resulting in higher air pollution and higher risk for vulnerable people in urban areas (Rota & Zazzi, 2018).

3. Materials and methods

This chapter will illustrate the methodological approach, developed with the support of the Municipality of Parma, adopted for the identification of priority public urban areas to be de-sealed. It is based on the measurement of the degree of permeability of public land and the assessment of areas subject to greater hydraulic and heat island hazards. Performing with ArcGIS software, a specific database was designed to locate and quantify impermeable surfaces on which the public administration can intervene directly with depaving, greening and replacing paving materials with cooler materials to mitigate possible flooding and hot temperatures. Only public open spaces were mapped as potential areas of intervention, leaving the remaining private areas for further future investigation. However, in agreement with the urban planning office of the Municipality of Parma, undeveloped private areas of considerable size and potentially subject to redevelopment were still pointed out.

The paragraphs below will illustrate the method which consists of the following steps:

- design of a GIS database aimed at mapping and quantifying permeable and impermeable surfaces of public urban spaces; the research defines in detail the procedure for collecting and storing data on ground cover and paving materials, and supports the calculation of the BAF weighting factor, i.e., the parameter chosen for evaluating the ecological-environmental performance of soils;
- data management to extrapolate, based on the BAF coefficient, urban public areas with lower levels of permeability to point out the potentially de-sealing areas;
- spatial analysis for identifying urban areas most prone to hydraulic and heat island hazards and defining priority interventions;
- identification and description of the pilot case study (a residential neighbourhood in Parma), to adapt data collection methods to the specific urban context and test the GIS database in a concrete case;
- finally, data collection and data entry for the implementation of the GIS database.

The method described aims to become a rigorous but easily replicable model of analysis applicable to other urban contexts.

3.1 Building the GIS database

The GIS database aimed at mapping in detail permeable and impermeable surfaces within public open spaces and evaluating priorities for de-sealing interventions has been designed following two data modelling steps (Laurini, 2001): conceptual and physical. These steps lead to a simplification of the problem, which is useful for the public administration to facilitate planning and management choices of urban transformations.

Table 1 shows the structure of the conceptual data model containing the list of useful feature classes for the research. For each feature class it is specified, the data typology (vector/raster), the geometry used to indicate it graphically in the GIS, and a brief description of the main categories belonging to each feature class.

Feature class	Data type	Geometry	Description
Road areas	Vector	Polygon	Categories of public spaces classified as road areas: road sections, intersections, overlaps, roundabouts, traffic dividers, slopes, squares, unmarked parking areas, pavements and other pedestrian areas.
Parking lots	Vector	Polygon	Categories of public spaces classified as parking lots: stalls, manoeuvring areas, flowerbeds or green strips.
Green areas	Vector	Polygon	Categories of public spaces classified as green areas: equipped parks or gardens, unequipped green areas, school gardens, urban gardens, dog areas and any internal paved paths.
Buildings	Vector	Polygon	Area occupied by private and public buildings

Tab.1 Conceptual data model of the GIS database

The conceptual data model establishes that all public open spaces are to be classified into three main feature classes: road areas, parking lots and (public) green areas. Each feature class maps in detail the land cover related to the object of investigation (respectively roads, car parks, and green areas) and thus contains both permeable and impermeable surfaces.

Data on land cover and paving materials are stored for each entity in the feature classes' attribute tables. This necessarily leads to the generation of separate entities (geometries) depending on the different paving materials. For instance, if the parking spaces in a car park are made of concrete-grass paver blocks and the manoeuvring space for vehicles is asphalt, two separate geometries must be drawn, both belonging to the car park's feature class.

All the main attributes (type, material, BAF coefficient[4]…) of the drawn entities have been defined in detail in the physical data modelling stage. This step defines the list of attributes to be filled in and describes their meaning and possible inputs. Where possible, a domain is set per attribute, i.e., the set of possible input values within the attribute. Tabb.2, 3, and 4, show the physical data modelling of each feature class.

Attribute	Description	Domains
Type	Road area typology	Road section, intersection, overlap, roundabout, traffic dividers, subway, slope, square, unmarked parking areas, pedestrian areas
Shape area	Geometry area	Numeric value
Road type	Road category	Highway, road, avenue, street, alley, corner, other
Material	Paving material	Asphalt, cobblestones, concrete, soil, granite, grass, gravel, grass paving blocks, self-locking blocks, limestone, masonry, porphyry, stone tiles, other
BAF coefficient		0.0, 0.3, 0.5, 1.0
Status	Current status of the area	Existing, planned, under construction
Green status	Status of the greenery	Empty, free, cured
Green type	Green category	Cemetery, large urban park >8,000 sqm, equipped green area 5,000>8,000 sqm, equipped green area <5,000 sqm, listed green area, school gardens, slope, sports areas, uncultivated green areas, urban landscaping, urban gardens, wooded areas, other.
Transformable		Yes, no

Tab.2 Attribute table of the feature class 'Road areas'

[4] See Chapter 3.2 for the calculation of the BAF coefficient

Attribute	Description	Domains
Type	Area typology	Stalls, manoeuvring areas, flowerbeds or green strips
Shape area	Geometry area	Numeric value
Material	Paving material	Asphalt, cobblestones, concrete, soil, granite, grass, gravel, grass paving blocks, self-locking blocks, limestone, masonry, porphyry, stone tiles, other
BAF coefficient		0.0, 0.3, 0.5, 1.0
Green type	Green category	Cemetery, large urban park >8,000 sqm, equipped green area 5,000>8,000 sqm, equipped green area <5,000 sqm, listed green area, school gardens, slope, sports areas, uncultivated green areas, urban landscaping, urban gardens, wooded areas, other.
Green status	Status of the greenery	Empty, free, cured
Status	Current status of the area	Existing, planned, under construction
Transformable		Yes, no

Tab.3 Attribute table of the feature class 'Parking lots'

Attribute	Description	Domains
Type	Area typology	Green area, paved area
Shape area	Geometry area	Numeric value
Material	Paving material	Asphalt, cobblestones, concrete, soil, granite, grass, gravel, grass paving blocks, self-locking blocks, limestone, masonry, porphyry, stone tiles, other
BAF coefficient		0.0, 0.3, 0.5, 1.0
Green type	Green category	Cemetery, large urban park >8,000 sqm, equipped green area 5,000>8,000 sqm, equipped green area <5,000 sqm, listed green area, school gardens, slope, sports areas, uncultivated green areas, urban landscaping, urban gardens, wooded areas, other.
Green status	Status of the greenery	Empty, free, cured
Status	Current status of the area	Existing, planned, under construction
Transformable		Yes, no

Tab.4 Attribute table of the feature class 'Green areas'

An additional feature class of the GIS database stores information concerning buildings, their shape, public or private ownership and main uses. Filling in the descriptive attributes of this feature class is particularly useful for obtaining references on the functional aspects of the built environment.

In addition to the geometries mapping the entities, further information completes the GIS database:

- hydraulic hazard zones;
- urban heat island temperature.

The inclusion in the GIS database of these data is intended to guide the choices of future new territorial transformation interventions. The following section illustrates the spatial analysis process adopted to derive from the overlaying of these new data with permeable or impermeable public areas possible de-sealing actions aimed at improving environmental effects. By overlapping each of these feature classes with public areas, whether they are permeable or impermeable, mapped in the area of interest, it is possible to plan the actions to be taken, maximizing the environmental effects and economic costs.

In order to constantly update the GIS database, useful information can be derived from various sources.

Geographical data can be drawn from the official databases of local/regional geographic information systems; other information, on the other hand, can be gathered through direct and photo-interpretative surveys[5] or through collaboration with the urban planning office of city administrations.

3.2 Permeability Indices and Spatial Analysis

Once the GIS database has been set up and data have been collected and organized, information components (attribute tables) of the three feature classes that map public open space in detail (road area, green areas, and parking lots) are enriched with quantitative information about permeability and ecological effectiveness.
Each entity is then assigned a particular ecological-environmental performance parameter named 'BAF coefficient', related to the land cover material. This weighting factor of the BAF system, as explained in Chapter 2.2, is an ecological-environmental performance parameter that defines the ecological effectiveness of different land covers in terms of soil permeability and ecosystem functions (biodiversity, water absorption, urban microclimate control).
Table 5 lists the different paving materials of public open spaces in the pilot areaassociated with the corresponding BAF coefficient (according to the BAF system used by the city of Segrate) and the relative level of ecological performance.

Material	BAF coefficient	Level of ecological performance
Asphalt	0.0	Fully sealed surface: it is impermeable to water and has no plant growth. Zero evapotranspiration efficiency.
Cobblestones		
Concrete		
Granite		
Masonry		
Porphyry		
Stone tiles		
Gravel	0.3	Partially permeable surface: it is permeable to water and air but no plant growth.
Self-locking blocks		
Limestone		
Grass paving blocks	0.5	Semi-permeable surface: it is permeable to water and air. The possible vegetation is unconnected to soil below. Medium evapotranspiration efficiency.
Soil	1.0	Fully permeable and highly environmentally effective surface: vegetation is connected to the surrounding land and it is available for the development of flora and fauna.
Grass		

Tab.5 Abacus of materials and their ecological performance levels (Città di Segrate, 2017)

Once the BAF coefficients have been assigned to each geometry belonging to the main data classes of street area, green areas and parking lots, the GIS database is ready for data analysis. In this phase, the most impermeable or less efficient areas have been selected as potential areas for de-sealing and greening interventions.
Finally, a spatial analysis is conducted to identify urban areas most prone to hydraulic and heat island hazards, with the aim of defining different levels of priority for de-sealing and greening interventions. This last operational phase, supported by GIS geoprocessing tools, consists of studying the vulnerability of the urban

[5] The photo-interpretation process, in the research under review, was carried out in the systematic collection of information using the orthophoto 'Ortofoto CGR 2018 RGB (WMS). Ortofoto 30 cm' retrieved from the geoportal of the Emilia-Romagna region (https://geoportale.regione.emilia-romagna.it/servizi/servizi-ogc/elenco-capabilities-dei-servizi-wms/cartografia-di-base/service-29). *In situ* surveys and remote inspection from Google Earth and Google Street View applications were carried out for further detailed verifications.

system to flooding and rising temperatures in relation to the permeability of public open spaces. A higher priority for possible urban regeneration and de-sealing interventions can be assigned to public impermeable surfaces located in the surrounding areas of the main public facilities, since in case of extreme weather events, there would be a possible higher concentration of people affected. The public facilities considered in this methodology include mainly administrative and institutional facilities, school facilities and libraries, sports areas and major transport nodes such as the railway station. The most exposed area around each public facility is estimated to be around 300 m, a distance considered acceptable for pedestrian accessibility. Then, these buffer areas combined with hydraulic and heat island hazard zones, bring out urban areas with different potential levels of priority for intervention. Hydraulic and heat island hazards were chosen because they represent significant challenges in the urban environment, especially with the increasing effects of climate change. The latter phenomenon is particularly dangerous for citizens living in high-density urban areas, especially the most vulnerable ones, due to excessive temperature rises.

Regarding the planning of priority future soil de-sealing interventions, two possible planning solutions are evaluated:

- the first solution (A) combines the previously extrapolated selection of more impermeable surfaces with the high, medium, and low priority areas due to hydraulic hazard;
- the second solution (B) considers the same combination but based on the assessment of heat island hazard only.

Table 6 describes in detail the parameters used to assign the three intervention priority levels for the first solution examined, considering the BAF coefficients, the hydraulic hazard zones, and the most exposed areas. The criteria used to assign priority levels according to the heat island hazard (solution B) are expressed in Table 7, which takes up the approach of the previous one.

The results of the data analysis, performed on a pilot case study are described in detail in the following chapters.

BAF coeff.	**Hydraulic hazard**					
	Rare floods		Infrequent floods		Frequent floods	
	less exposed areas	most exposed areas	less exposed areas	most exposed areas	less exposed areas	most exposed areas
0.0						
0.3						
0.5						
1.0						

Priority: Low Medium High

Tab.6 Criteria for assigning priority soil de-sealing interventions according to the hydraulic hazard

BAF coeff.	**Heat island hazard**					
	27-29°C		29-31°C and 31-33°C		33+ °C	
	less exposed areas	most exposed areas	less exposed areas	most exposed areas	less exposed areas	most exposed areas
0.0						
0.3						
0.5						
1.0						

Priority: Low Medium High

Tab.7 Criteria for assigning priority soil de-sealing interventions according to the heat island hazard

3.3 Pilot case study: San Leonardo neighbourhood in Parma

The method has been applied to a significant pilot case study, the San Leonardo neighbourhood in Parma, to test its applicability and adjust data collection procedures, considering the specific urban context. The city of Parma, in accordance with regional regulations, is committed to equipping its urban plan with strategies and measures for urban compensation and adaptation to climate change, thus promoting interventions to increase the permeability of urban soils, with reference to public land which has a high degree of operability. Considering the complexity of drafting a suitable proposal, the municipal administration not only collaborated in the implementation of the methodology of this research activity but also suggested the S. Leonardo neighbourhood as a possible case study.

The neighbourhood is located in the northern, north-eastern part of the city (Fig.1). It has an extension of 444 ha and is bordered to the west by the Parma stream, to the east by the provincial road axis SP62R (Via Mantova), to the south by the Milano-Bologna railway axis and to the north partly by the northern ring road and partly by provincial road SP7. The neighbourhood is characterised by a high population density and multiethnicity, as reported by a recent document of the Statistics Office of the City of Parma (Comune di Parma, 2021). In addition, it hosts public facilities and infrastructure such as schools, sports facilities, a railway station, and a wide variety of shops.

The decision to test the methodology on this neighbourhood was guided by a few criteria. First, it is a peripheral area, therefore with fewer urban planning constraints than the historic centre. Moreover, it has a high degree of urbanisation and is located near a watercourse of the primary hydrographic network. Finally, the neighbourhood is not particularly extended, ensuring more rapid testing of the methodology proposed over here.

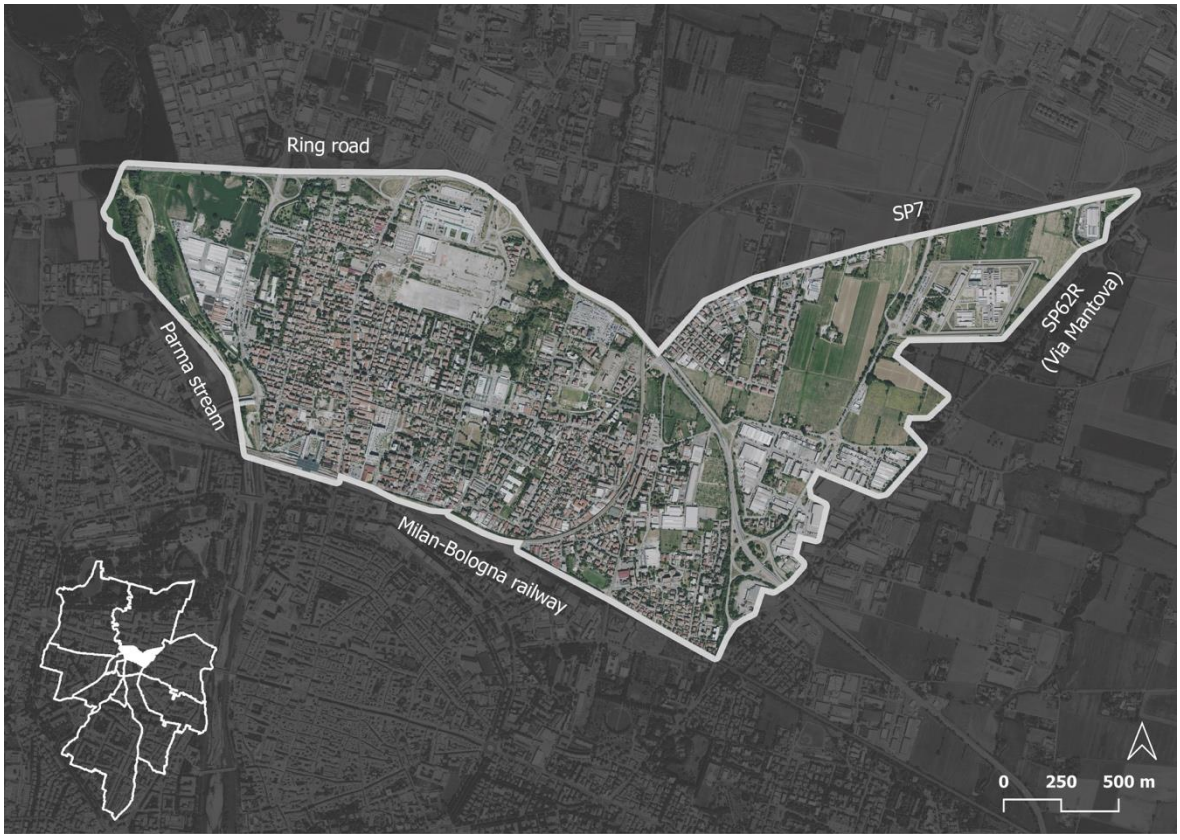


Fig.1 San Leonardo neighbourhood in Parma

3.4 Data

This phase covers all data search activities to enable the implementation and populating of the GIS database according to the data modelling described in Chapter 3.1.

In this pilot case, the data collection activity involved the consultation of existing official databases in local/regional spatial information systems, the construction of vector data through photo-interpretation and digitalisation of satellite images[6], and the collection of vector and raster maps directly from the urban planning office of the Municipality of Parma or research centres such as the Institute of Biometeorology of the National Research Council (CNR-IBIMET).

As highlighted in Tab.8, most of the cartographic data in vector format were retrieved from the Regional topographic database layers available in the geoportal of the Emilia-Romagna region. Data on the different hydraulic hazard levels were provided by the Urban Planning office, while the surface air temperature map (2015) was provided by the CNR-IBIMET (Rota, 2017). Finally, the municipal spatial information system mainly provided the necessary spatial and non-spatial information to implement the feature classes of the GIS database.

	Type	**Source**				**Editing /Updating**
	Vector (V) Raster (R)	*Municipal geoportal*	*Regional geoportal*	*Urban planning office - Municipality of Parma*	*CNR-IBIMET*	*Photo-interpretation and digitalisation of satellite images*
Base map data						
Regional topographic database	V		√			no
Pre-processed data						
Hydraulic-hazard_ER_high	V			√		no
Hydraulic-hazard_ER_medium	V			√		no
Hydraulic-hazard_ER_low	V			√		no
Surface_air_temperature _map (2015)	R				√	no
Pre-processed data						
Buildings	V	√				yes
Road_area	V	√				yes
Roundabout_material	V			√		no
Cycle_paths	V			√		yes
Green_areas	V			√		yes
Green_Work_Gen (2015)	V			√		no
Library	V			√		no
School	V			√		no
New feature classes						
Pavements	V					yes
Parking_lots	V					yes

Tab.8 Summary of data sources

[6] See note 5 for more details.

The 'Road_area' feature class served as the spatial reference for editing other feature classes of the GIS database, considering that the street area is a substantial part of the public space under investigation. Other collected data only served to retrieve qualitative attributes about the physical characteristics of public urban spaces (e.g. paving materials) to be transferred into the feature classes' attribute table.
Since the spatial and non-spatial information stored in the existing geographic data was not sufficient to provide a detailed mapping of the urban public space, several new geometries, with associated attributes, were created through photointerpretation and digitisation of satellite images. To ensure the consistency of the final GIS database, geometry validity and geometric congruence checks were performed in all feature classes, obtaining a homogeneous work base, without mistakes or data overlaps.
ArcGIS software was chosen to manage the pre-processing and data entry to ensure the compatibility and interoperability of the data provided by the Urban Planning office, which is accustomed to using this operational tool.

4. Results

The carried-out research has resulted in a cognitive framework concerning the permeable and impermeable public space of the urban fabric in the S. Leonardo neighbourhood in Parma. From the maps produced with the methodology and data described above, it is possible to highlight areas with different degrees of permeability according to the use of different surface materials within the three main open space typologies: road area, parking lots and green areas.
Fig.2 shows a detailed mapping of the different paving materials found in public space. Each colour corresponds to a different surface material. On a total of almost 134 ha of public land analysed, the quantitative analysis carried out revealed most surfaces covered by the following materials:

- asphalt (approx. 70 hectares) covers 51.96% of the total extent of public space;
- grass (approx. 55 hectares) covers 41.17% of the total extent of public space;
- grass paving blocks (approx. 3 hectares), cover 2.29% of the total extent of public space.

Asphalt mainly covers the principal road system that branches off into the urban fabric, while the greatest presence of permeable soil (grass) can be seen in the areas of the Parma stream bed, in the large green roadside areas to the north and east of the neighbourhood, and in the clearly recognisable urban parks and gardens in the middle of the neighbourhood.
Then, Fig.3 shows the BAF coefficient (i.e., the weighting factor referring to soil permeability) assigned to each surface material type according to the abacus presented in Tab.5. The graphical representation, with different colours for each coefficient value, helps to have a quick overview of the soil permeability condition.
Impermeable soil is widespread, especially in street areas and numerous public car parks, while it is only limited to some pedestrian and bicycle paths within public parks and gardens.
Partially permeable areas with intermediate ecological performance are mainly concentrated in parking lots in the northern part of the neighbourhood (since the relatively recent construction of public car parks in Parma has a considerable extension of semi-permeable paving materials and many more planted areas), and in the south, near the train station in an urban sector that has undergone recent redevelopment. However, they constitute the lowest percentage, covering only 8.22 ha out of a total of about 134 ha (Fig.4).
Through the GIS database used it was possible to find, in the study area and with reference to the three main feature classes of analysis, the presence of permeable soil equal to about 41% of the mapped surface. The remaining 59% corresponds to impermeable soil, 88% of which is classified as an asphalt area. Fig.5 shows this percentage on a graph, also adding the corresponding land extension in hectares.

Fig.2 Classification of surface materials in the public space of S. Leonardo neighbourhood

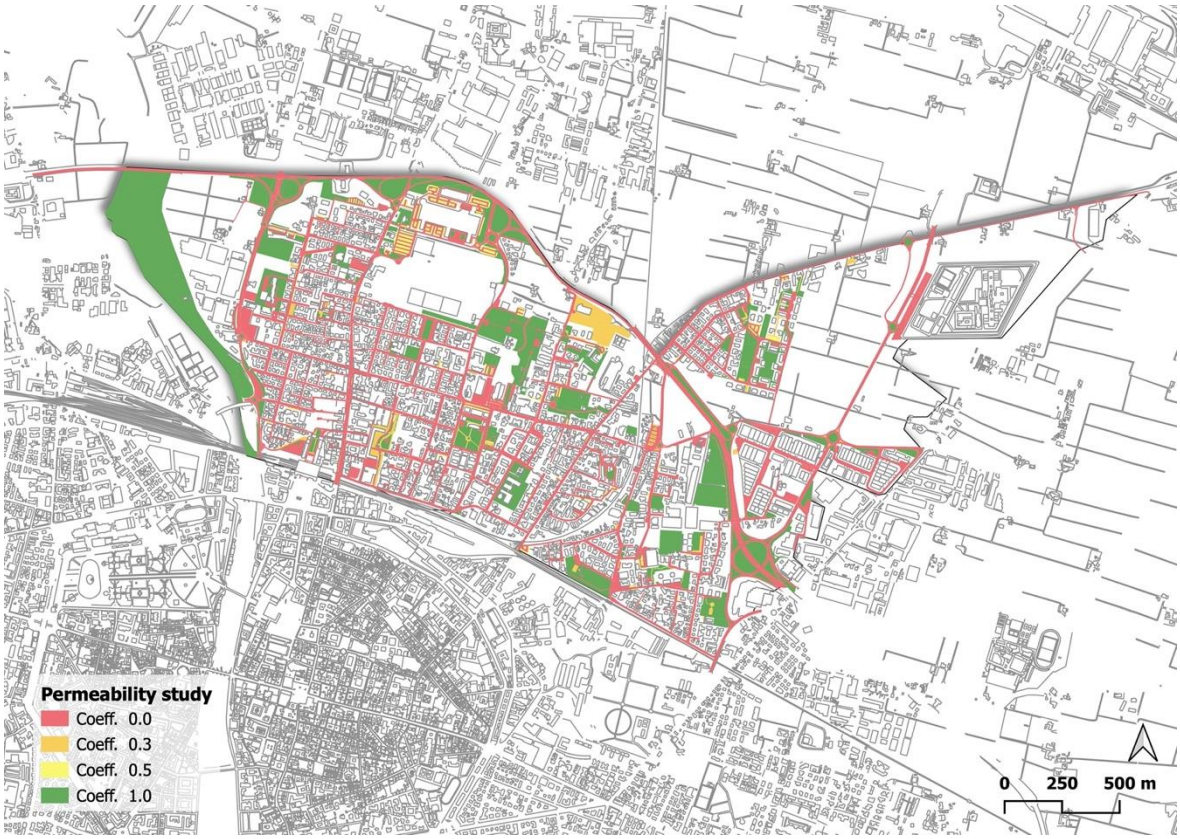


Fig.3 BAF coefficients map (permeability map) of the public space in S. Leonardo neighbourhood

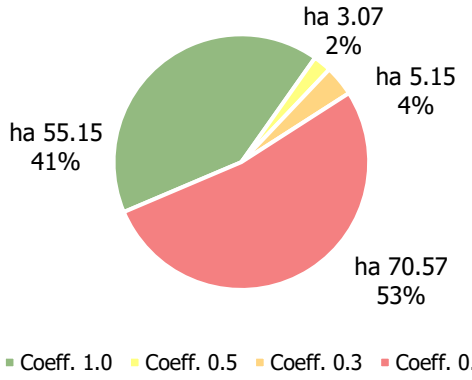


Fig.4 Quantitative analysis of soil permeability, based on the BAF coefficients, in S. Leonardo neighbourhood

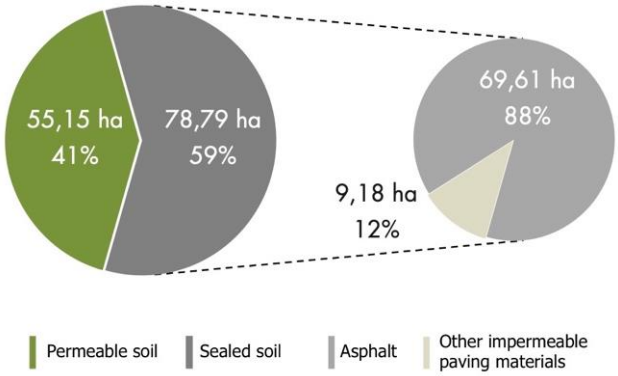


Fig.5 Quantitative analysis of impermeable public areas in S. Leonardo neighbourhood

Then, focusing on the impermeable areas only, which are in clear majority compared to the completely permeable ones, the result is a map like the one in Fig.6.

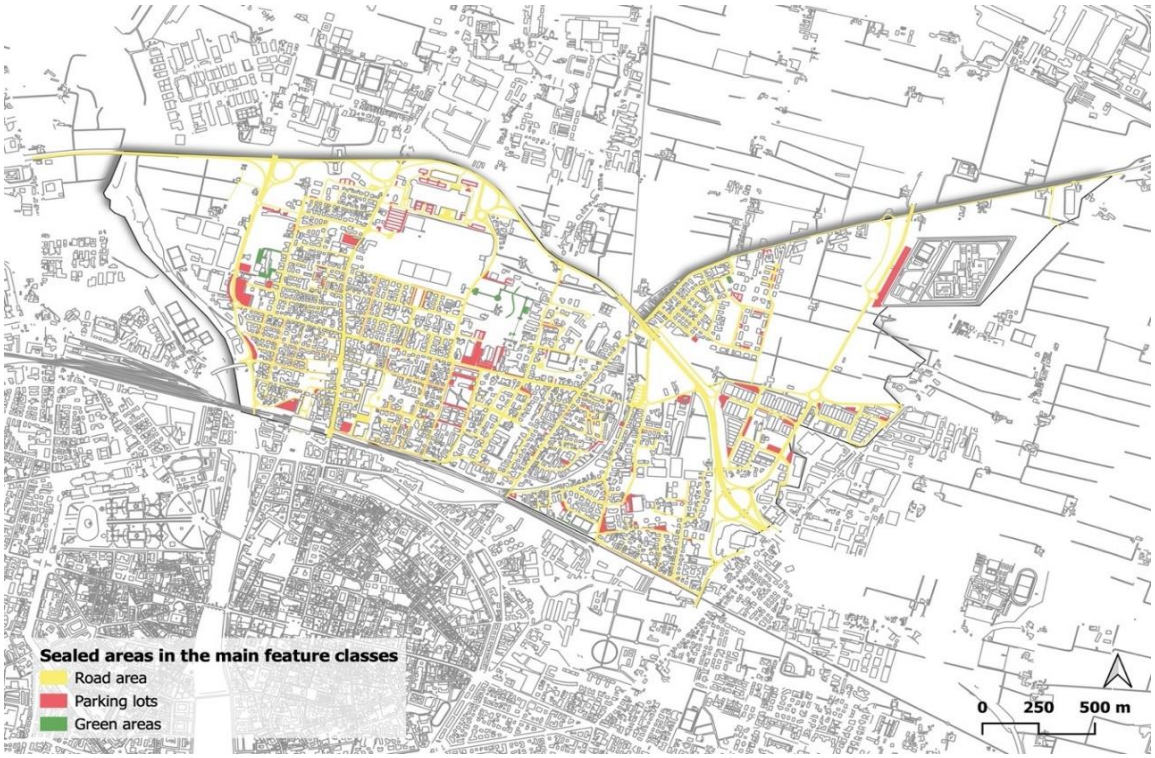


Fig.6 Location of the main feature classes' sealed areas

The areas represented have been subdivided according to the main feature classes under study and, in order of largest area occupied, we obtain:

- road areas with 57.48 ha impermeable, mostly occupied by the road network grid, equal to 73%;
- parking lots with 19.14 ha impermeable, consisting of manoeuvring areas and mainly asphalted parking spaces, equal to 24%;
- green areas with 2.17 ha considered impermeable, due to the presence within these areas of footpaths with a not fully draining surface coverage equal to 3%.

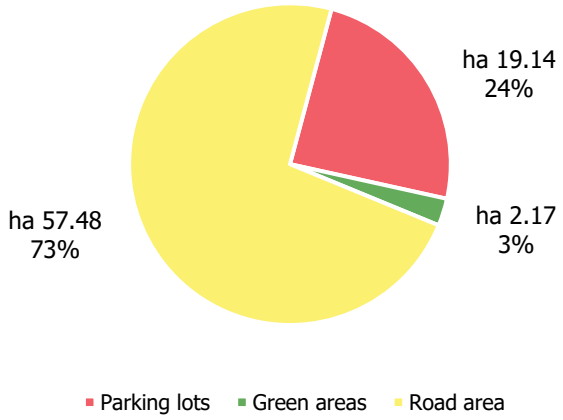


Fig.7 Graph of the sealed areas registered in the GIS database

The second phase of the analysis is aimed at identifying priority criteria for de-sealing interventions of sealed public areas in relation to areas most exposed to hydraulic and heat island hazards. Following the methodological steps described in Chapter 3.2, firstly, the main public facilities in the S. Leonardo neighbourhood have been selected (within the buildings layer of the GIS database): 1 library, 8 schools, 11 sports areas, and 1 railway station.

Then, for each public facility, a 300-meter buffer area has been generated.

In Fig.8 buffer areas have been overlaid with the hydraulic hazard map (Comune di Parma, n.d.), in which the area of flooding potential propagation is classified into three categories related to the probability of the event occurring: frequent floods, infrequent floods, and rare floods. Frequent floods mainly occur along the course of the Parma stream (with a higher probability - H); infrequent floods affect a larger area in the eastern part of the neighbourhood (medium probability - M); finally, rare floods affect urban areas in the western side of the stream (low probability - L). Public facilities buffer areas are mainly located in the medium and low hydraulic hazard zones. While the area denoted by 'H' is limited to the Parma stream bed.

Then, in Fig.9, public facilities' buffer areas have been overlaid with the surface air temperature map[7]. In this map surface air temperatures were grouped into four bands: 27-29°C, 29-31°C, 31-33°C, and over 33°C in order to have a clearer reading of the data and, consequently, easier identification of areas with different levels of criticality. A low criticality level was assigned to the 27-29°C band, medium to the 29-31°C and 31-33°C bands, and finally high to temperatures exceeding 33°C. The higher is the temperature, the higher the level of attention.

[7] CNR-IBIMET, Diurnal Land Surface Temperature (LST) detected on 23/6/2015 by ASTER (Advanced Spaceborne Thermal Emission and Reflection Radiometer), a NASA satellite remote sensing sensor.

Fig.8 Hydraulic hazard and most exposed urban areas

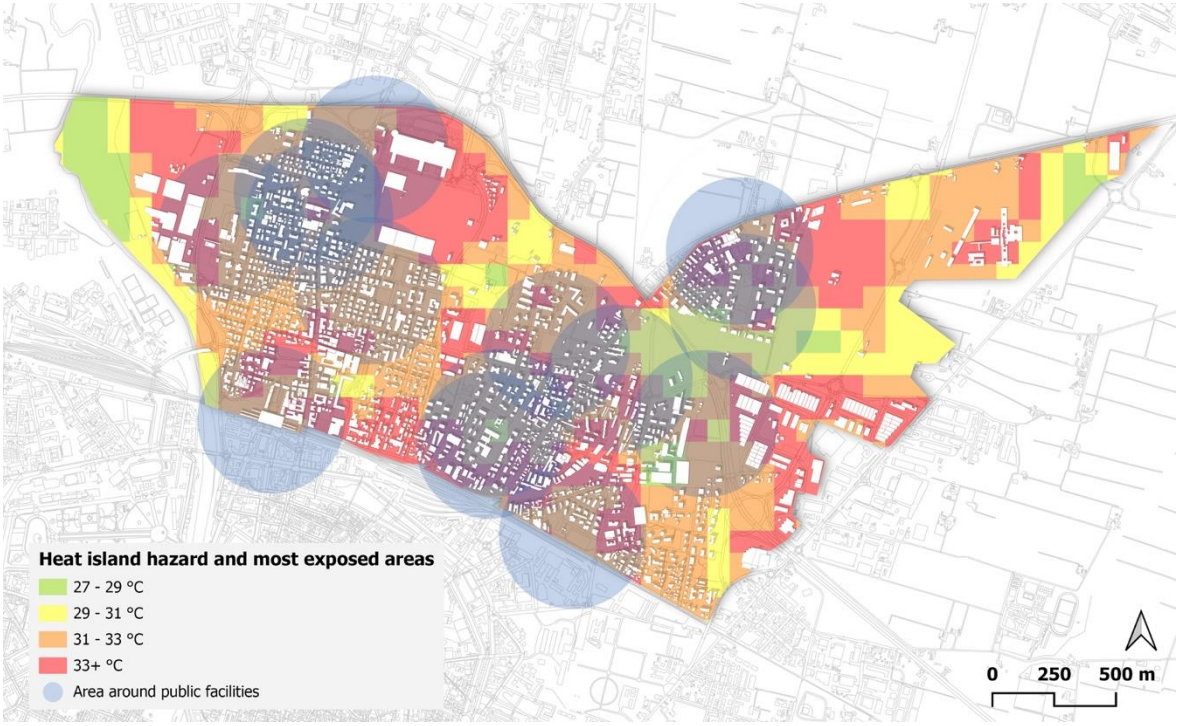


Fig.9 Heat island hazard and most exposed urban areas

The next two maps show two possible planning solutions of de-sealing intervention priorities, to adapt respectively to hydraulic hazards effects (Fig.10), by increasing the water absorption capacity of the soil, or heat island hazard effects (Fig.12), by decreasing heat absorption and release of urban space surfaces. In both maps, three priority levels have been identified: high, medium, and low. For those low-priority areas that are completely permeable, and for which there is therefore no need for de-sealing actions, greening interventions are envisaged.

It should be noted that at this stage, the data processing was carried out considering only the entities of the feature class 'Parking lots', which means that the next figures identify priority de-sealing interventions for

public car parks only. The intersection between the different permeability of the parking areas and their location near one or more public facilities, as well as areas of more or less high hydraulic danger (left in greyscale in the background), led to the elaboration of solution A (Fig.10). According to these criteria, only a few high priority areas result: 2 hectares for a total area of just less than 20 hectares. The graph below (Fig.11) completes the quantitative analysis of impervious areas by priority levels of intervention. The greater concentration of public facilities in the western part of the study area, causes a higher concentration of high-priority areas within a particularly small radius. Similarly, the presence of high hydraulic hazard on the east side of the district, although distributed over a larger area.

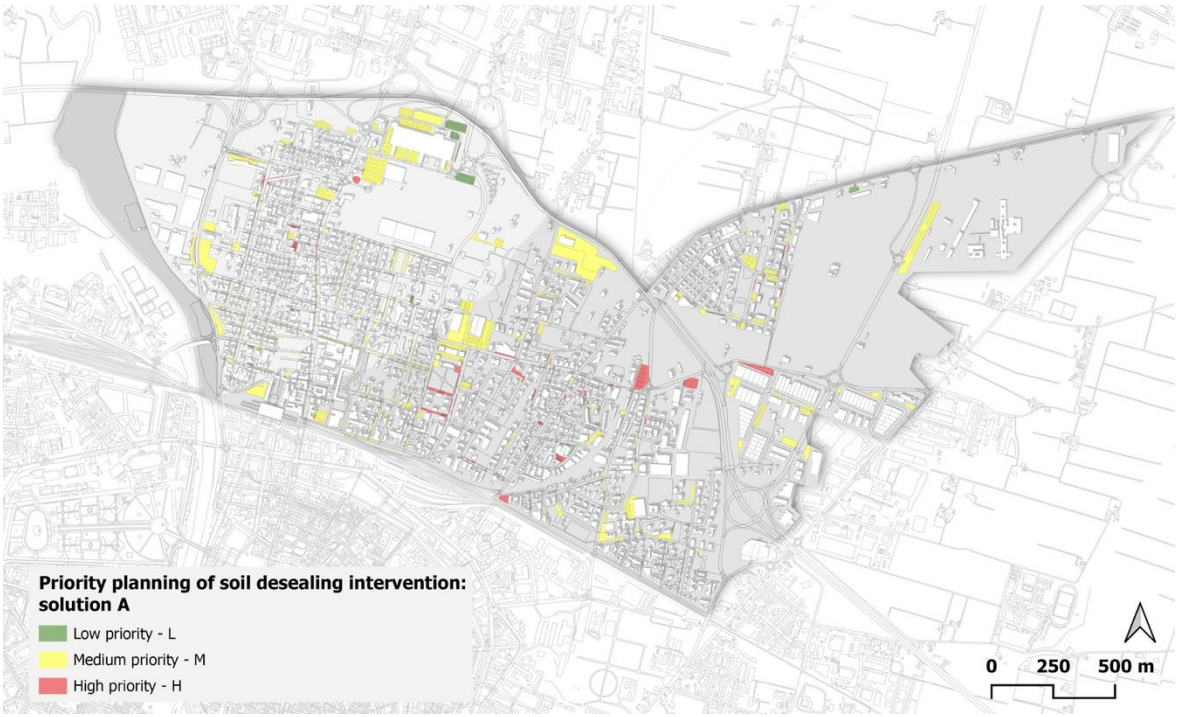


Fig.10 Planning of priority soil de-sealing interventions: solution A

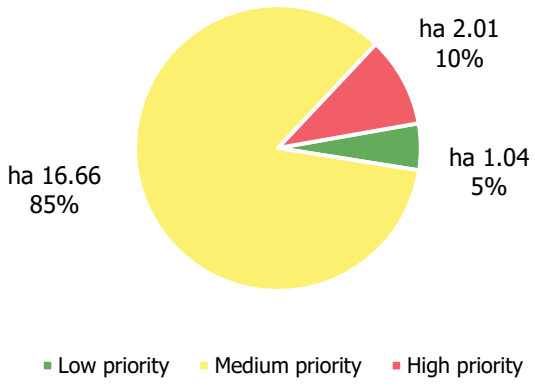


Fig.11 Quantitative analysis of the priority soil de-sealing intervention in solution A

The combination of the data on the permeability of the intervention areas and the data on the danger of the heat island (shown on a chromatic scale from black to white) led to the creation of a second scale of intervention priorities, solution B, represented in Fig.12.

The map shows how, in contrast to the previous one, the areas of high priority (H) have increased: from 2 hectares before to almost 9 hectares, following this second order of priority (Fig.13). The higher density of

buildings and the lower presence of green areas, especially in the western part of the district, have led to an intensification of the heat island phenomenon, with a more uniform temperature but, at the same time, on average higher than in other areas.

Fig.12 Planning of priority soil de-sealing interventions: solution B

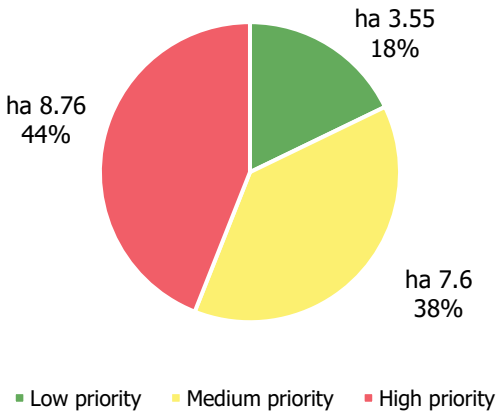


Fig.13 Quantitative analysis of the priority soil de-sealing intervention in solution B

5. Discussion and conclusion

This contribution aimed to illustrate a methodological approach, supported by GIS technology, involving detailed mapping of land cover in public space and an assessment of the location of areas to be de-sealed in relation to the identification of the most exposed urban areas. To achieve this goal, a GIS database was designed to map soil permeability in public open spaces (i.e., surface materials of road areas, parking lots,

and green areas) and specific ecological-environmental coefficients were associated to the different ground cover and paving materials. Then to draw up a priority list of public urban areas that can be subjected to future de-sealing interventions, data on hydraulic and heat island hazards were added to the analysis, as well as the perimeter of potentially more exposed/vulnerable urban areas. The systematic approach was then applied to a pilot case study, the San Leonardo neighbourhood in Parma, to test its applicability. The combination of the above data with the impermeable areas belonging to the parking lots feature class led to two different intervention priority scales: solution A with reference to the hydraulic hazard, and solution B with reference to the heat island hazard. Our identification of areas for de-sealing interventions fits and builds on the experiences cited in the literature review but adds an innovative aspect to the analysis, namely the prioritisation of intervention levels based on the assessment of hazards and vulnerability of urban systems. The areas with the lowest permeability coefficient were compared with maps representing critical climatic and environmental issues affecting the city. Working with overlapping levels, it was possible to note the coexistence of various levels of criticality, thus delineating a scale of intervention priorities. Furthermore, the analysis focuses only on public space, a system that is in the immediate availability of the public administration and thus it does not require land acquisition processes. An extension of the analysis to private areas could be also considered in future applications, including privately owned areas, especially unused and/or abandoned ones. The methodology presented lends itself to the practical application in planning tools such as the strategic component of urban plans or SEAPs. Although it starts from the design of a rigorous and original database, it does not present excessive levels of complexity and furthermore is based on the use of GIS for geographical data collection and management, a well-known tool widely used in the field of town planning and in the municipal planning offices to facilitate urban transformations choices (Harris & Elmes, 1993; Yeh, 1999; Rezvani et al., 2023; Legambiente, n.d.). A database built using such an expeditious methodology is a helpful tool that can be easily updated over time by the technicians in charge according to the needs.

However, the study has limitations, such as the use of the BAF coefficient itself: it does not contemplate differences in performance between green soil and vegetated soil, so the presence of, for example, trees that help with shading, and which would therefore play a greater role in mitigation, are not considered. Thus, extending to a larger scale, a characterization refinement of morphology and permeability of virgin soils could be a prospect of improvements in this research.Some interpretation mistakes may also arise from mapping surface materials in public open space by photo-interpretation, as proposed by the methodology, as well as less precision in digitalising and quantifying areas. In addition, the onerousness of constructing and updating data by photo-interpretation (in terms of time and people in charge) can be considered the main limitation of the application to extended urban areas, which, however, can be overcome considering the possibility of introducing faster and more automated data collection that relies on aerial surveying using sensors and machine learning methods (e.g. precision aerial surveying, using remotely piloted aircraft systems – RPAS) (Naughton & McDonald, 2019; Yigitcanlar et al., 2020). These technologies, however, while very effective in collecting data in a rather autonomous manner over large expanses of land, require specific technical skills and expensive equipment. Another observation on the validity of the method concerns the choice of criteria and factors for selecting de-sealing priority areas. In the case of Parma, for example, evaluations on which areas are to be preferred for de-sealing interventions can also be based on a comparison with the city's Public Works Programme: the overlap between de-sealing priority areas and the intervention areas identified in this Programme leads to a better optimisation and management of the necessary workforce. Finally, the economic factor also influences the choice of priorities, so it is necessary to carry out appropriate checks on the costs for redevelopment and disposal of excavation soil and other materials.

About future developments, a next step would be to apply scenarios of de-sealing, to check how effective the interventions really are in the surrounding context, depending also on other factors such as topography and morphology of each studied area.

This paper could also be a starting point for local administrations that desire to implement their urban planning tools in terms of improving urban resilience, developing integration of this methodology with devices and mechanisms for calculating hydraulic invariance of urban transformation interventions.
The work done, in addition to building a GIS methodology that can potentially be replicated in other urban contexts, lays the groundwork for research development aimed at better-defining criteria and directions for the inclusion of de-sealing objectives in the strategic and regulatory component of urban regeneration planning tools. Within this development, urban planning indices and parameters will be defined for the pursuit of de-sealing objectives related to the response of urban soils to water runoff and the heat island effect. In conclusion, the contribution aims to fill that methodological gap with regard to the choice of priority areas to be de-sealed, considering both their degree of permeability and their role in adapting to strong climatic events.

Authors' contribution

The authors jointly designed and contributed to the paper. Conceptualization, M.Z., B.C. and M.C.; Data curation, M.C.; Investigation, M.C.; Validation: M.Z. and B.C.; Methodology, M.C., M.Z., and B.C.; Supervision, M.Z.; Writing—original draft, M.C. and B.C.; Writing—review and editing, B.C. and M.Z. All authors have read and agreed to the published version of the manuscript.

Acknowledgement

The authors would like to thank the office 'Pianificazione e Sviluppo del Territorio' of the Municipality of Parma with whom the research group have actively collaborated. In addition, it is considered appropriate to thank Patrizia Rota and Luca Storchi for their contribution to the preliminary studies, the creation of the GIS database and the evaluation phase of the research.

References

Adobati, F., & Garda, E. (2018). Recuperare terra: Cinque contesti applicativi di politiche di de-sealing. *Urbanistica Informazioni 278 s.i.*, 160–164.

Agenzia Europea dell'Ambiente. (2019). *Suolo e territorio in Europa: Perché dobbiamo usare in modo sostenibile queste risorse vitali e limitate.* Ufficio delle pubblicazioni dell'Unione europea. Retrieved from: https://data.europa.eu/doi/10.2800/621824

Apreda, C. (2016). Climate change, urban vulnerability and adaptation strategies to pluvial flooding. *UPLanD - Journal of Urban Planning, Landscape & Environmental Design*, *1*(1), Articolo 1. https://doi.org/10.6092/2531-9906/5040

Bayerisches Landesamt für Umwelt. (n.d.). *Ökokonto*. Retrieved from: https://www.lfu.bayern.de/natur/oefka_oeko/oekokonto/index.htm (accessed 10 September 2022)

Bencardino, M. (2015). Consumo di suolo e sprawl urbano. Drivers e politiche di constrasto. *Bollettino della Società geografica italiana*, *VII*, 217–237.

Bundesministerium für Bildung und Forschung. (n.d.). *Risiken beherrschen, Chancen nutzen—Die Region Dresden stellt sich dem Klimawandel. Strategiekonzept zum Integrierten Regionalen Klimaanpassungsprogramm für die Region Dresden.*

Casella, V., Franzini, M., Girone, G., & Marchese, P. (2015). *Quantificazione del Biotope Area Factor (BAF) con procedure automatiche di analisi della cartografia esistente*. 10.

Città di Bolzano. (2021, dicembre 6). *Richiedere la certificazione preventiva R.I.E. (Riduzione dell'Impatto Edilizio)*. Città di Bolzano. Retrieved from: https://opencity.comune.bolzano.it/Servizi/Richiedere-la-certificazione-preventiva-R.I.E.-Riduzione-dell-Impatto-Edilizio

Città di Segrate. (2017). *Istruzioni operative per il calcolo del BAF*.

Climate-ADAPT. (n.d.). *Berlin Biotope Area Factor – Implementation of guidelines helping to control temperature and runoff*. Retrieved from: https://climate-adapt.eea.europa.eu/metadata/case-studies/berlin-biotope-area-factor-2013-implementation-of-guidelines-helping-to-control-temperature-and-runoff (accessed 5 April, 2022)

Comune di Bologna. (n.d.). *Riduzione impatto edilizio—RIE*. retrieved from: http://dru.iperbole.bologna.it/riduzione-impatto-edilizio-rie (accessed 3 September, 2022)

Comune di Parma. (n.d.). *Rischio idrogeologico*. Retrieved from: https://www.comune.parma.it/protezionecivile/Rischio-idrogeologico.aspx (accessed 16 March, 2022)

Comune di Parma. (2021). *La realtà socio-demografica dei quartieri di Parma al 31.12.2020*. Retrieved from: https://www.comune.parma.it/comune/Statistica/quartieri-1_m1067.aspx

Copernicus Land Monitoring Service. (n.d.). *Sealed surface per country and NUT3 region in 2018* [DashboardItem]. Retrieved from: https://land.copernicus.eu/dashboards/imp_country_nut3_2018 (accessed 6 september, 2022)

Cortinovis, C., & Geneletti, D. (2020). A performance-based planning approach integrating supply and demand of urban ecosystem services. *Landscape and Urban Planning*, *201*, 103842. https://doi.org/10.1016/j.landurbplan.2020.103842

Cortinovis, C., Olsson, P., Boke-Olén, N., & Hedlund, K. (2022). Scaling up nature-based solutions for climate-change adaptation: Potential and benefits in three European cities. *Urban Forestry & Urban Greening*, *67*, 127450. https://doi.org/10.1016/j.ufug.2021.127450

De Lotto, R., Casella, V., Franzini, M., Gazzola, V., di Popolo, C. M., Sturla, S., & Venco, E. M. (2015). Estimating the Biotope Area Factor (BAF) by Means of Existing Digital Maps and GIS Technology. In O. Gervasi, B. Murgante, S. Misra, M. L. Gavrilova, A. M. A. C. Rocha, C. Torre, D. Taniar, & B. O. Apduhan (A c. Di), *Computational Science and Its Applications—ICCSA 2015* (pp. 617–632). Springer International Publishing. https://doi.org/10.1007/978-3-319-21470-2_45

De Lotto, R., Sessi, M., & Venco, E. (2022). Semi-Automatic Method to Evaluate Ecological Value of Urban Settlements with the Biotope Area Factor Index: Sources and Logical Framework. *Sustainability*, *14*, 1993. https://doi.org/10.3390/su14041993

De Noia, I., Favargiotti, S., & Marzadri, A. (2022). *Renaturalising lands as an adaptation strategy. Towards an integrated water-based design approach. TeMA - Journal of Land Use, Mobility and Environment*. *15 (2)*. https://doi.org/10.6093/1970-9870/9074

Depave. (n.d.). *Depave | From Parking Lots to Paradise*. Recuperato 6 settembre 2022, da https://depave.org/

Dessì, V., Politecnico di Milano, : DAStU, & Emilia-Romagna (regione). (2016). *Rigenerare la città con la natura: Strumenti per la progettazione degli spazi pubblici tra mitigazione e adattamento ai cambiamenti climatici*. Maggioli.

Di Paolo, A., Nardino, M., & Georgiadis, T. (2020). *Rigenerazione urbana: Un indice ambientale capace di aumentare l'adattamento ai cambiamenti climatici*. *23*, 13.

Directorate General for Environment (European Commission). (2012). *Guidelines on best practice to limit, mitigate or compensate soil sealing.* Publications Office. https://data.europa.eu/doi/10.2779/75498

European Commission. (2011). *COM(2011) 571 final, Roadmap to a Resource Efficient Europe*.

European Commission. (2012). *Soil sealing*. Retrieved from: https://ec.europa.eu/environment/archives/soil/pdf/sealing/Soil%20Sealing%20In-depth%20Report%20March%20version_final.pdf

European Environment Agency. (2021). *Land take and land degradation in functional urban areas* (Publication Fasc. 17). Retrieved from: https://www.eea.europa.eu/publications/land-take-and-land-degradation

Garda, E. (2020). Le azioni di depaving dei suoli urbani per una nuova multifunzionalità degli spazi sottoutilizzati. *La città contemporanea: un gigante dai piedi d'argilla. Atti della conferenza internazionale | Torino, 15 novembre 2019*, *LA CITTÀ CONTEMPORANEA: UN GIGANTE DAI PIEDI D'ARGILLA*, 225–231. https://aisberg.unibg.it/handle/10446/160720

Garda, E. (2022). *Reasons, Concepts, and Methods for Soil De-sealing in the Regulatory Framework of the Italian Regions*. *1*.

Gerundo, C. (2018). *L'adattamento delle città ai cambiamenti climatici*. FedOA Press (Federico II University Press). https://doi.org/10.6093/978-88-6887-031-7

Harris, T. M., & Elmes, G. A. (1993). The application of GIS in urban and regional planning: A review of the North American experience. *Applied Geography*, *13*(1), 9–27. https://doi.org/10.1016/0143-6228(93)90077-E

Istat. (2022). *I cambiamenti climatici: Misure statistiche | anno 2020*.

Juhola, S. (2018). Planning for a green city: The Green Factor tool. *Urban Forestry & Urban Greening*, *34*, 254–258. https://doi.org/10.1016/j.ufug.2018.07.019

Lakes, T., & Kim, H.-O. (2012). The urban environmental indicator "Biotope Area Ratio"—An enhanced approach to assess and manage the urban ecosystem services using high resolution remote-sensing. *Ecological Indicators*, *13*(1), 93–103. https://doi.org/10.1016/j.ecolind.2011.05.016

Laurini, R. (2001). *Information Systems for Urban Planning. A Hypermedia Cooperative Approach* (1 st). CRC Press. Retrieved from: https://www.taylorfrancis.com/books/mono/10.1201/9781315274713/information-systems-urban-planning-robert-laurini

Legambiente. (n.d.). L'utilizzo dei GIS per adattare i territori ai cambiamenti climatici. *Città Clima*. Retrieved from: https://cittaclima.it/portfolio-items/lutilizzo-dei-gis-per-adattare-i-territori-ai-cambiamenti-climatici/ (accessed 7 December,

2022)

Lehmann, S. (2019). *Reconnecting with nature: Developing urban spaces in the age of climate change* (1:2). Emerald Open Research. https://doi.org/10.12688/emeraldopenres.12960.1

Maienza, A., Ungaro, F., Baronti, S., Colzi, I., Giagnoni, L., Gonnelli, C., Renella, G., Ugolini, F., & Calzolari, C. (2021). Biological Restoration of Urban Soils after De-Sealing Interventions. *Agriculture*, *11*(3), Articolo 3. https://doi.org/10.3390/agriculture11030190

Malmö stad. (2021, April 21). *The Green City* [Text]. Retrieved from: https://malmo.se/Welcome-to-Malmo/Sustainable-Malmo/Sustainable-Urban-Development/Western-Harbour/Green-City.html

Meyer, M. (2011). *Reduction of surface sealing in urban areas*. Retrieved from: https://www.grin.com/document/183038

Mohs, B., & Meiners, H.-G. (1994). *Kriterien des Bodenschutzes bei der Ver- und Entsiegelung von Böden: Untersuchungsprogramm Bodenver-/-entsiegelung, Forschungsbericht 107 03 007 16*. Umweltbundesamt.

Munafò, M. (2021). *Consumo di suolo, dinamiche territoriali e servizi ecosistemici.* (Report SNPA 22/21).

Munafò, M. (2022). *Consumo di suolo, dinamiche territoriali e servizi ecosistemici.* (Report SNPA Fasc. 32/22).

Musco, F., & Fregolent, L. (2014). *Pianificazione urbanistica e clima urbano: Manuale per la riduzione dei fenomeni di isola di calore urbano*. Il Poligrafo.

Naughton, J., & McDonald, W. (2019). Evaluating the Variability of Urban Land Surface Temperatures Using Drone Observations. *Remote Sensing*, *11*(14), 1722. https://doi.org/10.3390/rs11141722

Oliveira, E., Tobias, S., & Hersperger, A. M. (2018). Can Strategic Spatial Planning Contribute to Land Degradation Reduction in Urban Regions? State of the Art and Future Research. *Sustainability*, *10*(4), Articolo 4. https://doi.org/10.3390/su10040949

Osservatorio del Paesaggio trentino. (2022). *Rapporto di ricognizione sul tema della gestione del fenomeno del consumo di suolo*.

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

Peroni, F., Brugnaro, S., Sozzi, M., Crescini, E., Pappalardo, S., Codato, D., Gianoli, F., Lanzavecchia, A., & De Marchi, M. (2018, febbraio 27). *BAF Index e mappatura del consumo di suolo a Padova: Quantificazione e simulazione di scenari alternativi*. XXI Conferenza Nazionale ASITA, 21-23 novembre 2017, Salerno.

Pietrapertosa, F., Salvia, M., de Gregorio Hurtado, S., d'Alonzo, V., Church, J. M., Geneletti, D., Musco, F., & Reckien, D. (2018). Urban climate change mitigation and adaptation planning: Are Italian cities ready? *Cities*. https://doi.org/10.1016/j.cities.2018.11.009

Rezvani, S. M., Falcão, M. J., Komljenovic, D., & de Almeida, N. M. (2023). A Systematic Literature Review on Urban Resilience Enabled with Asset and Disaster Risk Management Approaches and GIS-Based Decision Support Tools. *Applied Sciences*, *13*(4), Articolo 4. https://doi.org/10.3390/app13042223

Righini, S. (2016). *Consumo di suolo e strategie di adattamento climatico. Lombardia e Sassonia a confronto*. Retrieved from: https://www.arcipelagomilano.org/archives/44955

Rota, P. (2017). *Una fragilità adattabile. Mappe climatiche e indirizzi urbanistici per la resilienza dei quartieri residenziali della città media emiliana. An adaptable fragility. Urban climatic maps and guidelines to the resiliency of the residential neighbourghoods of the middle Emilian city.* [Tesi di dottorato, Università di Parma]. Retrieved from: https://www.repository.unipr.it/handle/1889/3455

Rota, P., Gravante, A., & Zazzi, M. (2019). Urban Heat Island (UHI) risk maps as innovative tool for urban regeneration strategies. The case of Parma. *IOP Conference Series: Earth and Environmental Science*, *296*. https://doi.org/10.1088/1755-1315/296/1/012034

Rota, P., & Zazzi, M. (2018). *The contrast to the Urban Heat Island phenomenon to increase the urban comfort as an incentive to slow mobility. A study on the city of Parma* (pp. 233–240). https://doi.org/10.1201/9781351173360-31

Science for Environment Policy. (2016). *No net land take by 2050? Science for Environment Policy Future Brief 14*. Retrieved from: http://ec.europa.eu/environment/integration/research/newsalert/pdf/no_net_land_take_by_2050_FB14_en.pdf

Seattle Department of Construction & Inspections. (n.d.). *Seattle Green Factor*. Retrieved from: https://www.seattle.gov/sdci/codes/codes-we-enforce-(a-z)/seattle-green-factor (accessed 3 September, 2022)

Senate Department for & the Environment, Urban Mobility, Consumer Protection and Climate Action. (2021, febbraio 25). *Calculating the BAF*. Retrieved from: https://www.berlin.de/sen/uvk/en/nature-and-green/landscape-planning/baf-biotope-area-factor/calculating-the-baf/

Senatsverwaltung für & Umwelt, Mobilität, Verbraucher und Klimaschutz. (2022, agosto 17). *Entsiegelungspotenziale in Berlin*. Retrieved from: https://www.berlin.de/

Simmons, A. J., Berrisford, P., Dee, D. P., Hersbach, H., Hirahara, S., & Thépaut, J.-N. (2017). A reassessment of temperature variations and trends from global reanalyses and monthly surface climatological datasets: Reassessment of Analysed Variations and Trends in Global Temperature. *Quarterly Journal of the Royal Meteorological Society*, *143*(702), 101–119. https://doi.org/10.1002/qj.2949

SOS4LIFE. (2017). *Sintesi di norme, linee guida, buone pratiche, casi studio in materia di limitazione di consumo di suolo e resilienza urbana al cambiamento climatico* (A.1.3; p. 113).

SOS4LIFE. (2018). *Consumo di suolo, superfici impermeabilizzate, stato di attuazione aree edificabili e aree dismesse recuperabili a Forlì, Carpi e San Lazzaro di Savena* (B.1.1).

Stobbelaar, D. J., van der Knaap, W., & Spijker, J. (2021). Greening the City: How to Get Rid of Garden Pavement! The 'Steenbreek' Program as a Dutch Example. *Sustainability*, *13*(6), Articolo 6. https://doi.org/10.3390/su13063117

Urban GreenUP. (n.d.). *Urban GreenUP*. Recuperato 11 settembre 2022, da https://www.urbangreenup.eu/

Ventura, P., Zazzi, M., Caselli, B., Rossetti, S., & Ceci, M. (2021). Pianificazione sostenibile: Pianificazione sostenibile: Laboratorio di rigenerazione urbanistica per il recupero del suolo e l'adattamento al cambiamento climatico. *AND Rivista di architetture, città e architetti*, *40*, Articolo 40. https://and-architettura.it/index.php/and/article/view/392

World Health Organization. (2002). *World health report. 2002: Reducing risks, promoting healthy life*.

Yeh, A. G. (1999). *Urban planning and GIS*. 877–888.

Yigitcanlar, T., Kankanamge, N., Regona, M., Ruiz Maldonado, A., Rowan, B., Ryu, A., Desouza, K. C., Corchado, J. M., Mehmood, R., & Li, R. Y. M. (2020). Artificial Intelligence Technologies and Related Urban Planning and Development Concepts: How Are They Perceived and Utilized in Australia? *Journal of Open Innovation: Technology, Market, and Complexity*, *6*(4), 187. https://doi.org/10.3390/joitmc6040187

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

Image sources

Fig.1: Authors' elaboration with data retrieved from: Geoportale Emilia-Romagna region https://geoportale.regione.emilia-romagna.it/servizi/servizi-ogc/elenco-capabilities-dei-servizi-wms/cartografia-di-base/service-29;

Fig.2: Authors' elaboration with data retrieved from: Municipal geoportal https://opendata.comune.parma.it;

Fig.3: Authors' elaboration with data retrieved from: Municipal geoportal https://opendata.comune.parma.it;

Fig.4: Authors' elaboration;

Fig.5: Authors' elaboration;

Fig.6: Authors' elaboration with data retrieved from: Municipal geoportal https://opendata.comune.parma.it;

Fig.7: Authors' elaboration;

Fig.8: Authors' elaboration with data retrieved from: Municipal geoportal https://opendata.comune.parma.it and Comune di Parma, *Rischio idrogeologico*. https://www.comune.parma.it/protezionecivile/Rischio-idrogeologico.aspx;

Fig.9: Authors' elaboration with data retrieved from: Municipal geoportal https://opendata.comune.parma.it and CNR-IBIMET, Diurnal Land Surface Temperature (LST) detected on 23/6/2015 by ASTER (Advanced Spaceborne Thermal Emission and Reflection Radiometer), a NASA satellite remote sensing sensor;

Fig.10: Authors' elaboration with data retrieved from: Municipal geoportal https://opendata.comune.parma.it and Comune di Parma, *Rischio idrogeologico*. https://www.comune.parma.it/protezionecivile/Rischio-idrogeologico.aspx;

Fig.11: Authors' elaboration;

Fig.12: Authors' elaboration with data retrieved from: Municipal geoportal https://opendata.comune.parma.it and CNR-IBIMET, Diurnal Land Surface Temperature (LST) detected on 23/6/2015 by ASTER (Advanced Spaceborne Thermal Emission and Reflection Radiometer), a NASA satellite remote sensing sensor;

Fig.13: Authors' elaboration.

Author's profile

Marianna Ceci

Architect, since 2022 PhD student in Civil Engineering and Architecture at the University of Parma. In her research, she studies soil de-sealing as one of the climate change adaptation strategies in urban regeneration practices, mainly focusing on medium-sized cities.

Barbara Caselli

Architect, Assistant Professor (non-tenure track) in Urban and Regional Planning at the University of Parma, PhD in Urban and Regional Planning at the University of Parma. Her current research interests concern the integration of urban planning and active mobility systems with a focus on urban accessibility and open space planning. She also deals with GIS applied to spatial planning and city management.

Michele Zazzi

Civil Engineer, Professor in Urban and Regional Planning at the University of Parma, PhD in Urban and Regional Planning at the University of Bologna. Programme Coordinator of the Second Cycle Degree in Architecture and City Sustainability and of the Professional Master in Urban Regeneration at the University of Parma. His research mainly focuses on urban regeneration; adaptation to climate change and quality of public space in urban settlements; bike and pedestrian planning.

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 (2023) 147-163
print ISSN 1970-9889, e-ISSN 1970-9870
DOI: 10.6093/1970-9870/9591
Received 14th December 2022, Accepted 24th February 2023, Available online 30th April 2023

www.tema.unina.it

Usability and accessibility of urban service areas with increasing epidemics: the case of Bursa/Turkey

The effect of urban service areas on the quality of life in the post-pandemic period

Elvan Ender Altay [a], Diba Şenay [b]*

[a] Department of Landscape Architecture
Bursa Uludag University, Bursa, Turkey
e-mail: elvanender@uludag.edu.tr
ORCID: https://orcid.org/0000-0001-5933-1611

[b] Department of Landscape Architecture
Ege University, Izmir, Turkey
e-mail: diba.senay@ege.edu.tr
ORCID: https://orcid.org/0000-0003-3008-9408
* Corresponding author

Abstract
The concept of urban life quality, which comes to the fore with urbanization and evaluates the effects of environmental variables on the well-being of the citizens in every respect, is directly related to the quality, quantity, and sufficiency of the urban service areas of the cities. In this study, cultural spaces, open spaces, and green areas in the central district of Bursa are classified as 12 types of urban service areas were examined. Within the framework of the method setup, the existence and distribution of urban services were evaluated within the scope of pre- and post-pandemic conditions, and solution suggestions were developed to increase the quality of life. In this context, it was determined that 47 out of 136 neighborhoods did not have urban service areas, and per capita values were found to be sufficient in only 10 neighborhoods. It is seen that these 10 neighborhoods have more recreational activity opportunities compared to other neighborhoods. The systematic method in the study was created in order to evaluate it as a plan base for physical planning studies in the study area and to shed light on the development of suggestions for increasing the quality of life for each city in general.

Keywords
Quality of life; Urban service areas; Accessibility; Sufficiency.

How to cite item in APA format
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

1. Introduction

Today, rapid population growth and the expansion of urbanized areas have increased people's access to urban infrastructures, but at the same time reducing the quality of life due to the deterioration of the homogeneity of the components that characterize the city (Rezvani, 2013; Gavrilidis et al., 2016; Zali et al., 2016; Mittal et al., 2020; Weckroth et al., 2022).

The concept of urban quality of life (QOL), which came to the fore with urbanization, is a complex term that can be defined from different perspectives (El Din et al., 2013; Hayek et al., 2015; Marans, 2015; Gavrilidis et al., 2016; Altunkasa et al., 2017). Various studies evaluate the concept of urban QOL with environmental quality, associate it with the social and economic indicators of cities (Buttel et al., 1977; Guida & Carpentieri, 2021), and examine it in the context of the physical possibilities of the city (Massam, 2002; Gaglione et al., 2019; Xie et al., 2020; Mouratidis, 2021), and therefore various definitions of the concept (Abd El Karim & Awawdeh, 2020). The common point of these definitions is the impact and sustainability of the QOL, the objective and subjective variables related to the life and environment of the individual, on social well-being as an integrated. The multi-purpose, safe, accessible, sufficient, and qualified indoor/outdoor spaces and functions that reflect the environmental, physical, psychological, and socio-cultural characteristics of cities are the determining factors in the quality of life of the city (Krasilnikova & Goncharik, 2022).

Urbans are collective living spaces where the population in the cultural land area is concentrated spatially, and the values, traditions and customs, attitudes, and behaviors of this population are formed together and identity is formed (Salama, 2020). Therefore, the QOL is closely related to the potential of meeting the cultural and socio-economic development needs of the citizens, as well as providing contemporary urban and environmental standards in a city (Canfora & Corbisiero, 2014). When it comes to this concept, the most important tools that enable the sustainability of the city and the communication and activities of the citizens are the urban service areas. Urban service areas, which are a key factor of urban areas in terms of urban culture, urban ecosystem, urban landscape, and recreational activities of urban people, also constitute components of QOL.

Therefore, factors such as how people spend their time in a city, which recreation areas they focus on, how they reach these areas, whether these areas can meet the per capita area need of the population around them, and whether efficiency zone create an accessible city by covering the whole city, show the livability of the city (Hayek et al., 2015; Okumuş & Eyüboğlu, 2015; Salihoğlu & Türkoğlu, 2016; Zali et al., 2016; Altunkasa et al., 2017). With the increase in epidemics day by day, there is a need for a change in the planning perspective to increase livability in cities. Transforming urban recreation areas, where individuals will spend their free time in their daily lives, to a more qualified and accessible situation is one of the main priorities of recreation area planning in cities.

According to the study of Gold (1980), Simonds (1983), Marcus and Francis (1998), Dunnett et al. (2002), Watson (2003), urban service areas are divided into three main groups as structural spaces (closed/semi-open structures), open spaces and green spaces. Squares are important open space elements of the urban landscape, apart from the reserve open spaces devoted to the transportation network and the development of urban land uses. Green spaces are: "Parks (urban, district and neighborhood parks) and playgrounds" and are defined with the concept of active green space in the Regulation on the Principles of Planning, which was published in the Official Gazette dated 2.11.1985 and numbered 18,916. In this case, picnic areas, botanical and zoo gardens, which are considered within the scope of green spaces and can be used for recreation, constitute other green spaces other than active green spaces.

Apart from housing, administration, education, health, and commercial areas, cultural space gain importance within the scope of public structural spaces related to urban landscape and cultural recreation. Cultural campuses or cultural centers form the basis of these structures. Spaces such as libraries, museums, theaters, and cinemas are subgroups of these structures.

According to these definitions, cultural spaces, open and green spaces are the areas that the citizens can use at any time of the day to meet their daily recreational needs. For each of these areas, the criteria for total and per capita area size, efficiency zone, and transportation distance vary from country to country. In the physical and mental health development of urban people, the diversity and richness of open and green spaces, as well as cultural spaces, are of vital importance due to their functions in the establishment and maintenance of social relations, in the development of the urban and urbanity, identity and culture, in the context of a wide variety of actions and activities (Boyacıgil & Altunkasa, 2010; Jennings et al., 2017).

The restrictions brought to prevent epidemics in recent years have affected people in every sense, especially physically, psychologically, socially, and economically (Gehl, 2020; Salama, 2020). In particular, measures to reduce the contagiousness of the epidemic, where various restrictions were applied, introduced the concepts of a mask, hygiene, and social distance into daily life, causing people to avoid especially public transportation, sports, and indoor activities (Olivier et al., 2020; Sadiq et al., 2020; Sarla, 2020). With the technical guide published by the World Health Organization (WHO) on moving around during the Covid-19 epidemic, people have turned to individual activities in open green areas instead of indoor and collective recreation activities (Fenu, 2021). Therefore, cities with more open green spaces created areas where people interact less with each other, providing the citizens with the opportunity to move (Özdede et al., 2021). From the beginning of the Covid-19 epidemic, researchers have been investigating the dynamics of epidemic outcomes. The research results highlight environmental quality, transportation, and urban design factors among the four main themes focused on during the pandemic (Fenu, 2021). For this reason, the insufficient amount of open and green spaces has become one of the main problems that emerged in this process, the importance of these areas has been better understood and it has become necessary to consider them in planning and management studies (Eşbah & Eşbah, 2020; Karlı & Çelikyay, 2020; Camerin, 2021). During the pandemic period, it has been observed that people avoid public transportation and prefer individual transportation routes (Mouratidis, 2021). This situation has once again revealed the need for accessible urban service areas in cities (Barbarossa, 2020; Özdede et al., 2021).

When cultural space, open and green spaces are considered in terms of recreational activities of the society, the sufficiency of these urban service areas should be evaluated based on abundance or insufficiency at the neighborhood level and their distance from the user. Even if the total amount per capita reaches the values predicted by the countries in planning or practice, if the balanced distribution and accessibility (pedestrian walking distance/accessibility standards) according to urban units (especially neighborhoods) are not evaluated, the effectiveness of the areas in meeting the needs of the city decrease (Altunkasa et al., 2017). In addition to the fact that any urban service area is large in number or area, its holistic distribution within the city, in other words, its accessibility for every unit (such as a neighborhood) that makes up the city comes to the fore. This feature is the main determinant of the effectiveness of urban service areas (Van Herzele & Wiedemann, 2003; Esopi, 2018).

To ensure the homogeneous distribution of the recreational areas in the cities and to evaluate their accessibility and quality, the connections of these areas should be handled with a holistic approach, and the amount of usage, per capita area and efficiency zone (effective service radius) standards should be taken into consideration (Ender, 2015; Öztürk et al., 2019; Abd El Karim & Awawdeh, 2020). In this context, a theoretical approach has been developed in this study to determine the effectiveness of cultural space, open space, and green space components, which are interrelated concepts that affect the QOL. In the study, the changes in the QOL in the face of the physical and population growth of the city of Bursa were tried to be examined based on cultural space, open space, and green space; With the epidemics affecting the whole world, solution proposals have been developed within the framework of the constantly changing opportunities and preferences of people.

2. Material and Method

The city of Bursa was chosen as a sample area in the study because it is the fourth largest city in Turkey, it is located at the junction of other big cities, and it is also one of the big cities that receive the most immigration. Within the scope of the study, the urban service areas in the settlement pattern of Osmangazi district, which is the largest and most crowded (according to 2022 data) central district among the metropolitan districts of Bursa city, were examined. Osmangazi district, with its surface of 71,400 ha and 136 neighborhoods, is also the center of social and cultural life (Urban Development, 2020). The location of the study area is given in Fig.1.

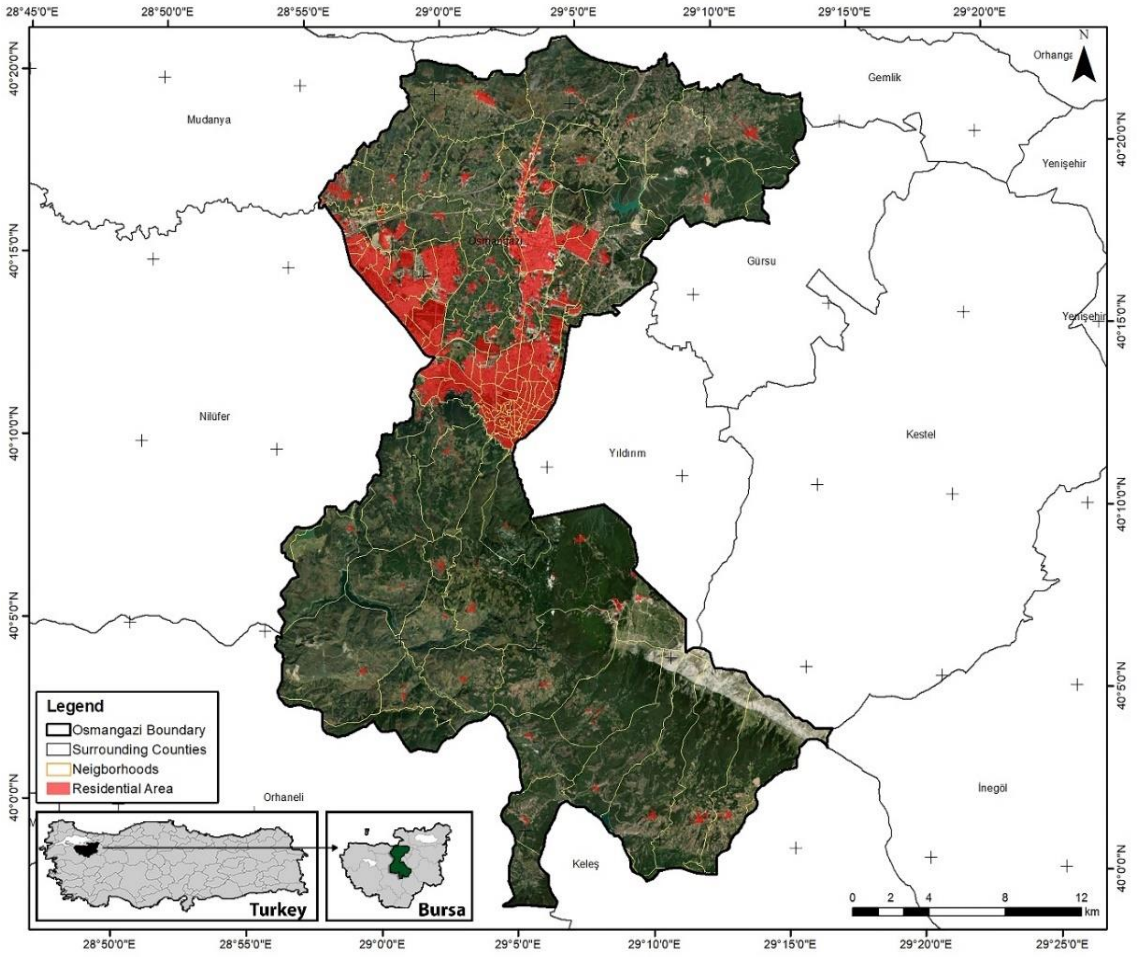


Fig.1 Location of the study area

In this context, the main material of the study is the Osmangazi district and the urban service areas in the settlement pattern of the district. In addition to the main material of the study, satellite images and digital elevation model (DEM) data of the study area constitute supplementary materials. In the study, a total of 12 types of urban service areas, including cultural spaces (museum, theatre, library, cinema, mall), open space (square), and green spaces (zoo, picnic area, urban park, district park, neighborhood park, playground), were examined.

In line with the purpose of the study, a five-stage method setup has been developed to determine the quality, quantity and sufficiency of urban service areas in the study area. The scheme summarizing the method of the study is given in Fig.2 and explained below.

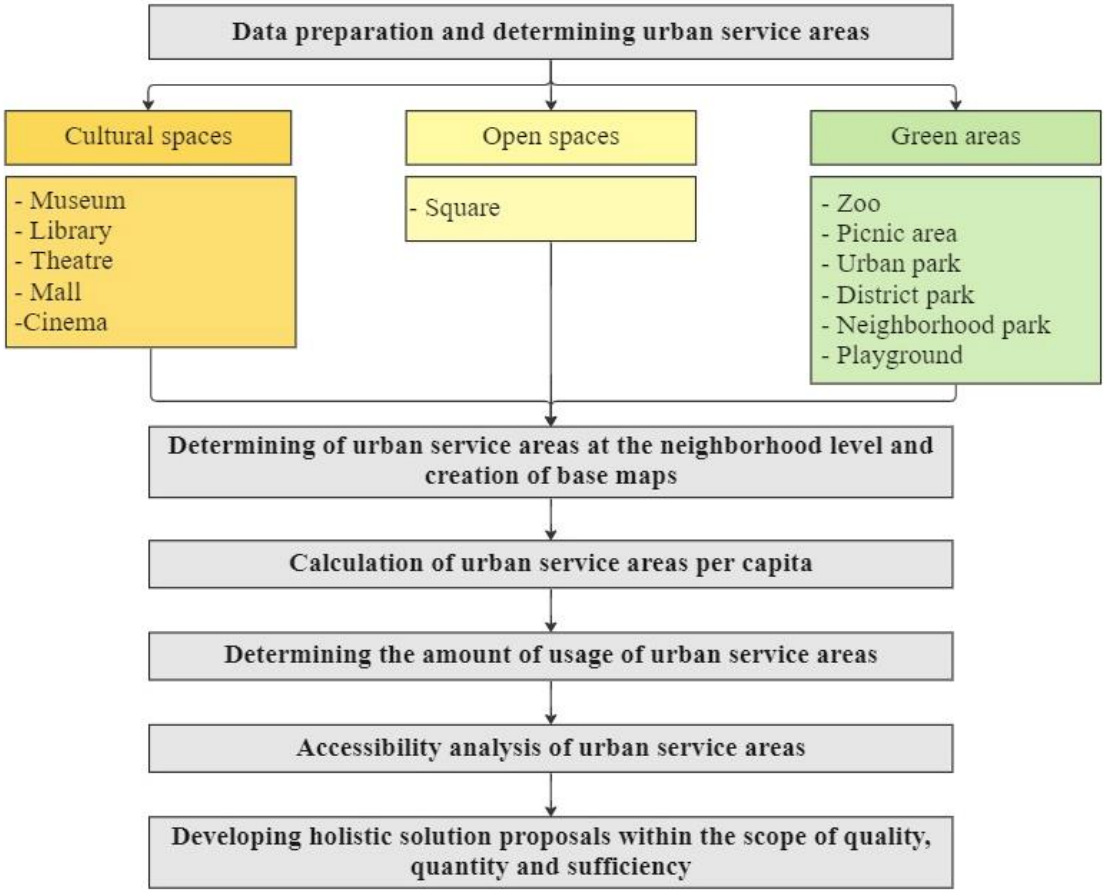


Fig.2 Scheme summarizing the method of the study

- *Determination of urban service areas at the neighborhood level and creation of base maps*
  Within the scope of the study, a field study was carried out, and the data from Google Maps, Cultural Inventory, and Bursa Metropolitan Municipality were used to determine the locations of the urban service areas. (Bursa Shopping Malls, 2021; Immovable Cultural Heritage, 2021; Libraries, 2021; Squares, 2021). ArcMap program, which is an Esri software in geographic information systems (GIS), was used for mapping urban service areas.
- *Calculation of urban service areas (cultural space, open and green spaces) per capita and creation of maps*
  In the calculations, the population data of 136 neighborhoods in the Osmangazi district and the surface areas of the urban service areas were evaluated together. The calculation of per capita areas for cultural spaces and green spaces is based on the criteria given in the "Regulation on the Principles of Plan Making" published in the Official Gazette dated 2.9.1999 and numbered 23804, regarding Urban, Social and Technical Infrastructure. These criteria are summarized within the scope of the study and given in Tab.1.

	Population			
Urban Services	*0-15,000*	*15,000-45,000*	*45,000-100,000*	*100,000<*
Cultural Spaces	0.5 m^2/per	1 m^2/per	2 m^2/per	2.5 m^2/per
Active Green Spaces	14 m^2/per	14 m^2/per	14 m^2/per	14 m^2/per

Tab.1 Urban, social and technical infrastructure criteria summarized within the scope of the study

It is stated that squares considered as open spaces should have two m^2 per capita in their location (Baud-Bovy & Lawson, 1998; Williams, 1995).

- *Determining the amount of usage of urban service areas*

  At this stage of the method, a new formula was constructed based on the total recreational activity formula used by Venter et al. (Venter et al., 2020) and the amount of usage of urban service areas was calculated.

$$A = \frac{\sum_a^n (X_a \times Y_a)}{f} \quad (1)$$

  In this formula, the amount of urban service area usage for each urban service area can be calculated separately and when a is a single urban service area type, X is the number of calibrated users, Y is the area size of the segment (km^2) and f is the activity constant (the number of each urban service area and the effective service area standard for diameter). f is defined as the product of the number of services per recreational activity and the effective service area (accessibility) distance for each type of equipment. The average number of users was obtained from the weekday and weekend counts in the domains. Counts were made in September and October 2019 before Covid-19, and in September and October 2021 after Covid-19. The number of users is indexed between 1-10. The total number of population/users in the district was calculated as 10 and the data obtained from the censuses made in each urban service area were indexed to this number and the value of X was reached. Y represents the total area size of each urban service area in the research area. Values of activity constant f are: 41.6 km for museums, 19.2 km for theatre, cinema and picnic areas, 16 km for libraries, 25.6 km for shopping centers, 3.2 km for zoos, 57.6 km for squares, 19.2 km for picnic areas, 12.8 km for city parks, 7.2 km for the district parks, 59.2 km for the neighborhood parks and 49.6 km for the playground. As a result of this formula, the change in the amount of usage before and after the pandemic will be understood with the effect of the area sizes and service diameters of the urban service area.

- *Accessibility analysis of urban service areas and creation of maps*

  Accessibility distances of urban service areas determined by relevant scientific studies were processed using the Euclidean Distance analysis, one of the Spatial Analysis Tools and accessible buffer zones were created for each urban service area.

  The concept of urban QOL mentions the need for citizens to benefit equally from all public services and urban service areas, thus revealing the importance of the principle of accessibility. Accordingly, in determining the effective efficiency zone of the urban service areas, accessibility standards to these areas were taken into consideration. As a result of the literature review, according to Williams (1995) and Baud-Bovy and Lawson (1998), museum, theatre, cinema, library, mall, square, and zoo urban service areas serve at the urban scale and have an efficiency zone (effective service radius) of 3,200 m; Williams (1995) and (Altunkasa, 2004) stated that the district park serves at the district scale and its effective service radius is 1,200 m. According to Williams (1995), Baud-Bovy & Lawson (1998), Önder & Polat (2012), Gökyer ve Bilgili (2014), Ender (2015), Ender ve Cengiz (2016), the efficiency zone (effective service radius) of the neighborhood park is 800 m; Altunkasa (2004), Khan (2006), Bilgili et. Al. (2011), Gökyer & Bilgili (2014), Aşık & Kara (2021) determined that playgrounds have an effective service radius of 600 m. These standards were used in the study.

- *Developing holistic solution proposals within the scope of quality, quantity and sufficiency*

  Solution proposals have been developed for all urban service areas by considering the efficiency zone (effective service radius) that changes at the urban scale, as well as the amount per capita, accessibility standards, and amount of usage.

3. Results

After the research and analysis, the locations of the urban service areas in the study area are mapped as cultural space (museum, theatre, cinema, mall, library), open space (square), and green space (zoo, picnic area, urban park, district park, neighborhood park, and playground), and given in Fig.3.

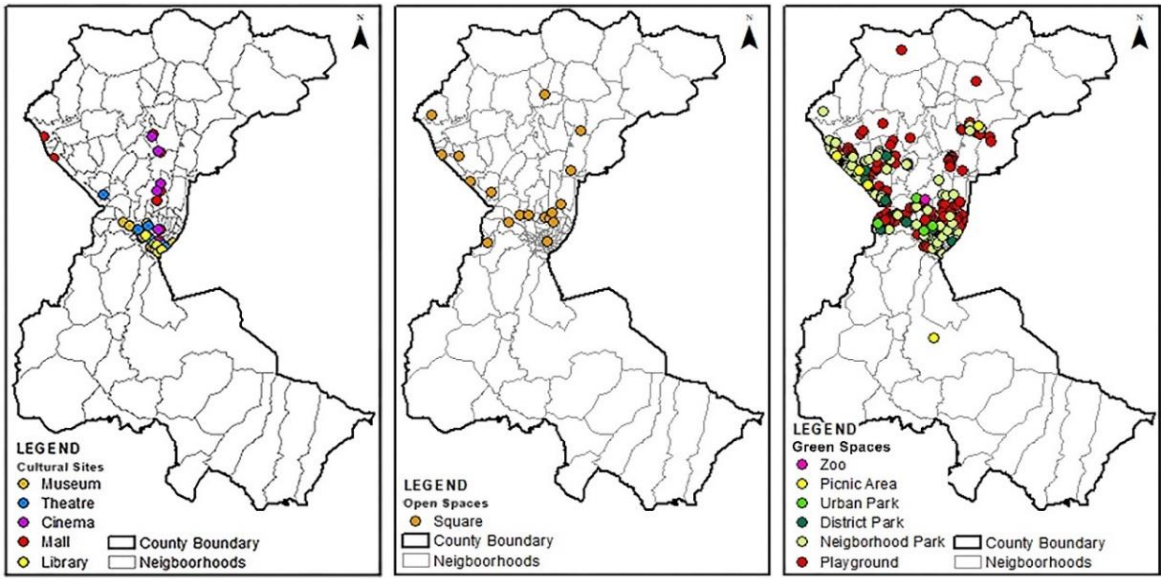


Fig.3 Locations of urban service areas in the district

Osmangazi district is the most populous district of Bursa province with a population of 884,451 compared to 2022 (TUIK, 2022). The population map of the district based on the neighborhood is given in Fig.4.

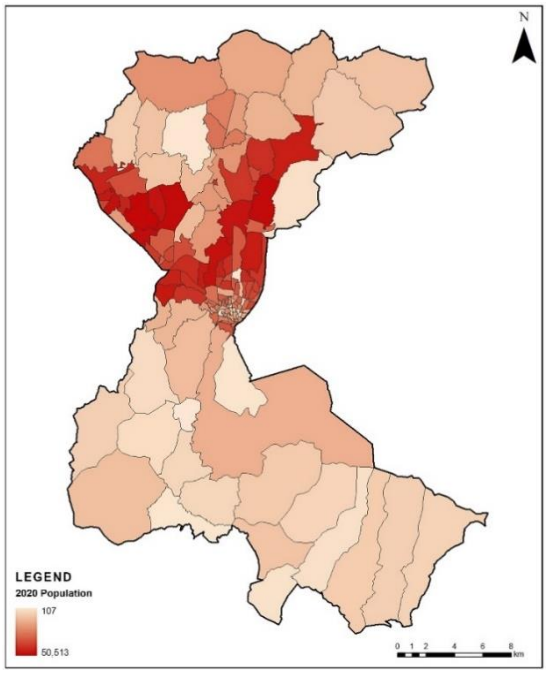


Fig.4 Population map of Osmangazi district on the basis of neighborhoods

The area values per capita are calculated and mapped within the scope of the population data of the neighborhoods and the area of urban service areas and are given in Fig.5. Based on the criteria given for Urban, Social and Technical Infrastructure in the Regulation on the Principles of Planning, published in the Official Gazette numbered 23804, the amount of cultural spaces required per capita varies according to the population of the neighborhood. In this context, according to Fig.4, it has been determined that only 10 of the 136 neighborhoods in the Osmangazi district provide sufficient space for their population.

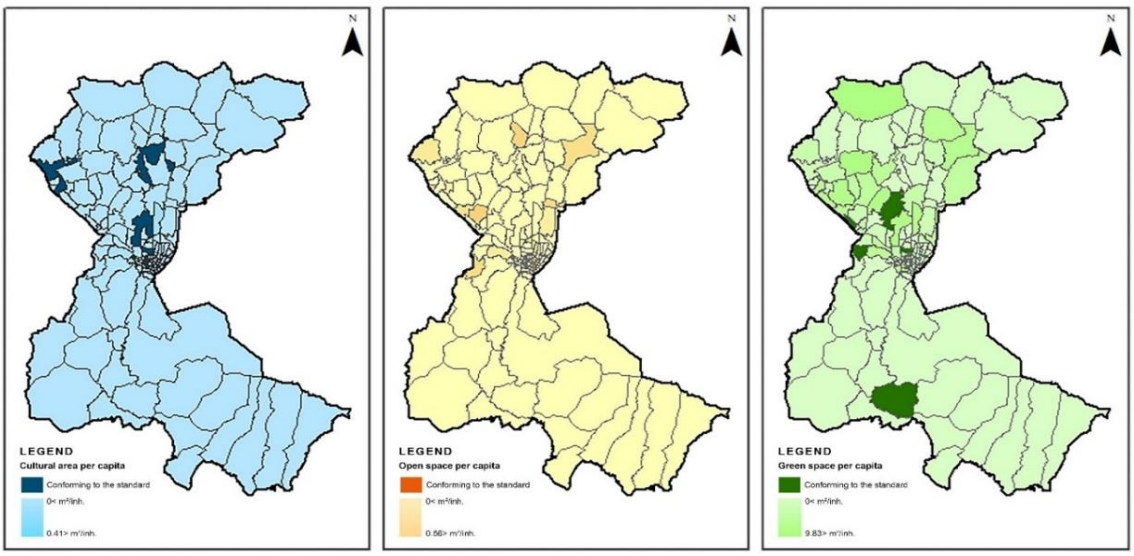


Fig.5 Cultural space, green and open space per capita

Considering the two m^2/person criterion stated by Williams (1995) and Baud-Bovy and Lawson (1998) for squares within the scope of open spaces, it is seen that two neighborhoods in the Osmangazi district of Bursa meet this criterion.

Within the scope of active green spaces, the area per capita does not vary up to 0-100,000 people. According to the regulation, areas with populations between these values must provide at least 14 m^2 of active green space per capita. As a result of the study, seven neighborhoods in the district meet this criterion. When the calculations are evaluated, it has been determined that the cultural space per capita is 1.09 m^2, the open space is 0.05 m^2 and the green space is 2.68 m^2 throughout the district.

The fact that people tend to individual activities rather than community recreational activities during the epidemic has also affected the urban service area preferences. With the formula developed within the scope of the study, the estimated usage amounts of these areas before and after epidemics affect people's lives were calculated. The graph created as a result of the calculation is given in Figure 6. These values represent X in the formula.

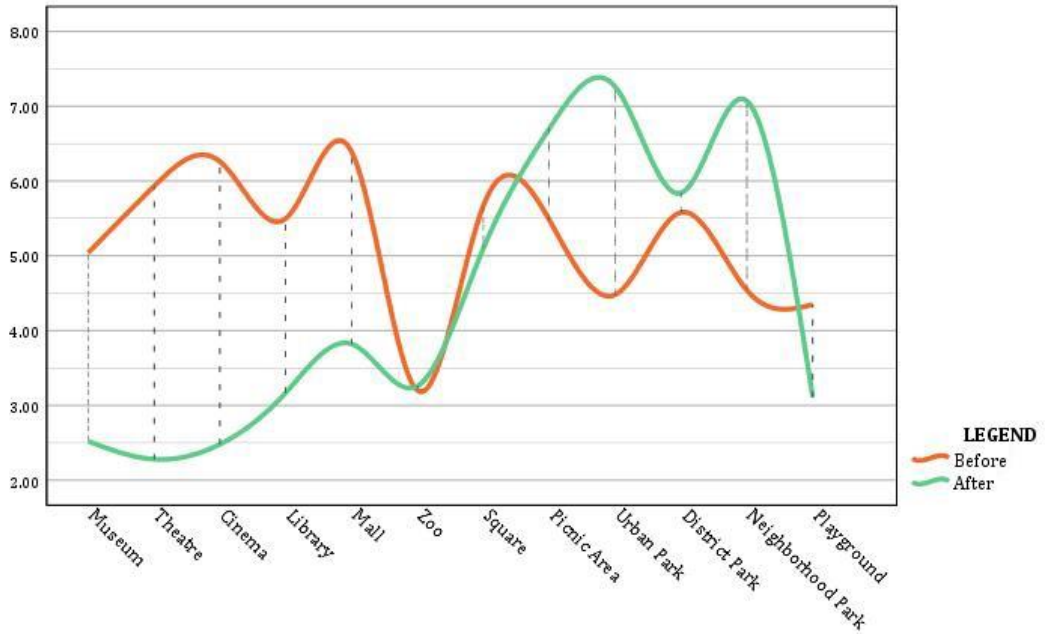


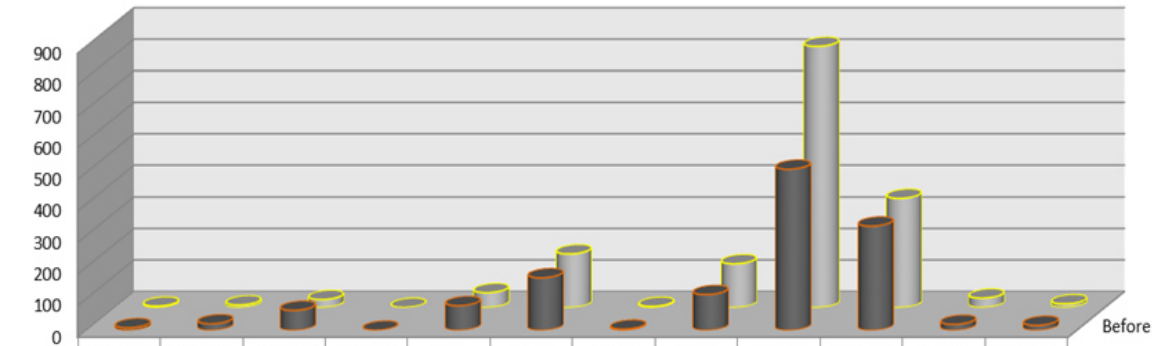
Fig.6 Users numbers of urban service area before and after pandemic (*X*)

The sample calculation for the usage amounts and changes of the urban service area according to the formula determined in the method is as follows:

$$\textbf{Museum usage amount(A)} = \frac{The\ indexed\ value\ of\ the\ number\ of\ museum\ users\ (X)\ \mathbf{x}\ The\ total\ area\ of\ the\ museum\ (Y)}{Number\ of\ museums\ \mathbf{x}\ Effective\ service\ area\ diameter\ standard\ (f)} = \quad (2)$$

$$= \frac{5.04(\mathrm{x}\ 1000)\ \mathbf{x}\ 68.7}{13\ \mathbf{x}\ 3.2} = \frac{346.248}{41.6} = 8.32$$

The same formula was used for all reinforcement areas and the usage amount values were obtained (Fig.7).



	Museum	Theatre	Cinema	Library	Mall	Zoo	Square	Picnic Area	Urban Park	District Park	Neigh. Park	P.ground
Before	8,32	20,66	63,32	0,45	78,28	166,60	3,67	113,28	510,86	330,62	18,95	15,86
After	4,16	7,94	25,08	0,26	46,80	169,72	3,30	138,50	827,87	346,02	29,51	11,34

Fig.7 Usage amounts of urban service area before and after pandemic (A)

According to Fig.6, people's preference for museums, theaters, cinemas, libraries, and squares as cultural spaces post-pandemic decreased compared to pre-pandemic; In addition, it is seen that the preference for green spaces such as picnic areas, urban, district, and neighborhood parks has increased. The preference rates of malls, cinemas, theaters, and squares, which had a higher than average usage rate pre-pandemic, decreased by almost half post-pandemics. The reason is that the restrictions brought during the pandemic process and the concept of social distance are adapted to daily lives and direct people to open spaces rather than indoor spaces.

The concept of accessibility plays a role in the QOL, which is defined with the help of various parameters and supports the creation of livable, sustainable, and healthy cities as a result of ensuring urban and environmental standards. Accordingly, within the scope of the study, the urban service areas were mapped under 3-degree classes by determining the effective service radius standards.

According to Fig.8, it is seen that the distribution of urban service areas is concentrated in the urban settlement areas of the district.

According to the maps, one zone in which uninterrupted access to urban service areas is provided in museums, theaters, cinemas, libraries, zoos, squares, urban parks, and district parks; it is observed that there are three zones in the neighborhood parks and eight zones in the playgrounds.

First, second, and third-degree accessible areas of urban service areas are given in Tab.2.

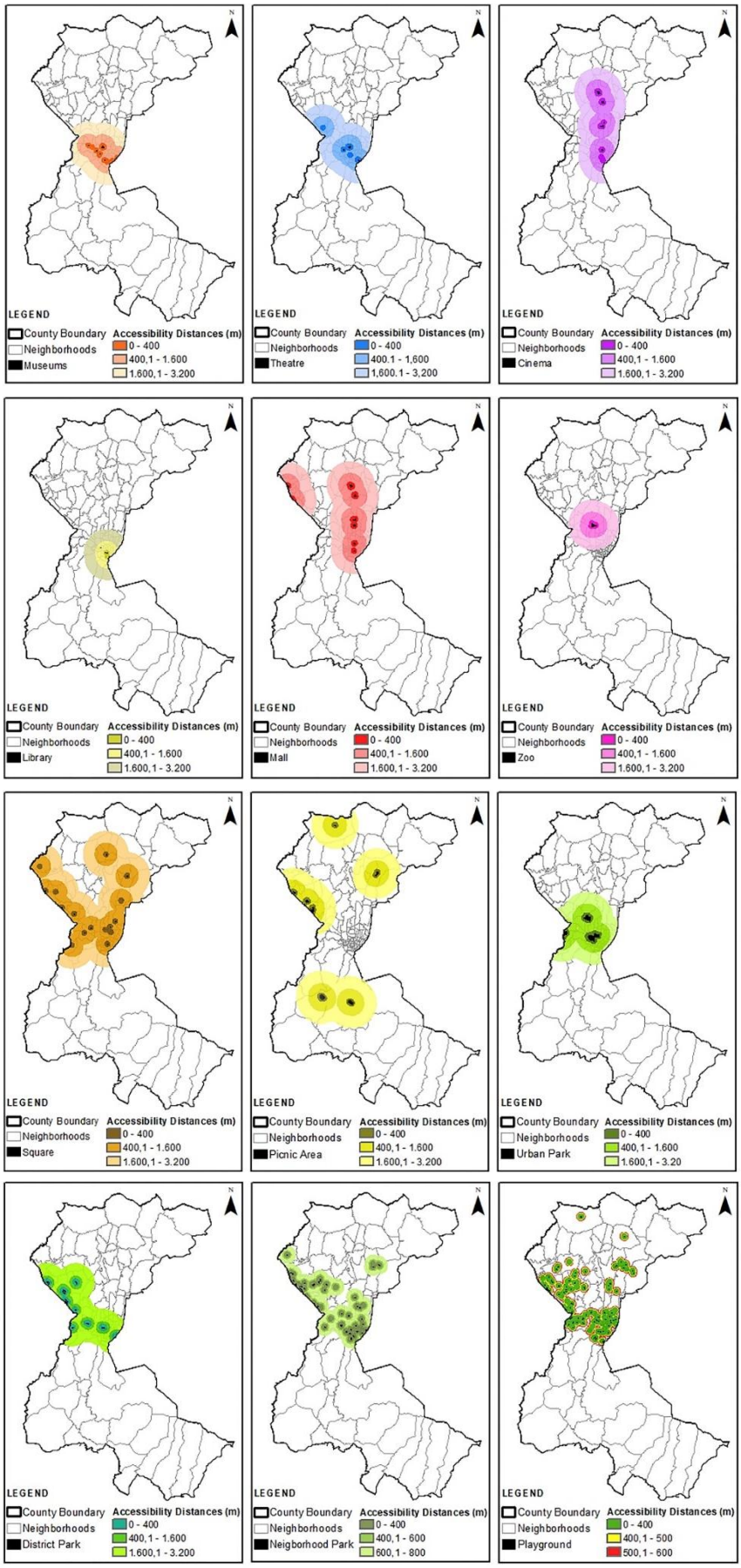


Fig.8 Accessibility analysis of urban service areas

Urban services	Accessibility (ha)		
	1st degree accessible area	*2nd degree accessible area*	*3rd degree accessible area*
Museum	510.58	2,719.4	6,748.06
Theatre	330.07	2,706.95	7,737.72
Cinema	492.39	3,825.54	9,607.95
Library	91.98	982.11	3,579.55
Mall	664.59	5,289.55	10,863.09
Zoo	136.25	1,089.19	3,786.98
Square	935.66	9,713.2	22,408.18
Picnic Area	857.82	7,211.75	21,402.47
Urban Park	700.1	3,785.93	8,641.31
District Park	824.72	2,407.78	4,419.55
Neighborhood Park	2,469.13	4,131.85	5,841.76
Playground	3,891.4	5,093.11	6,184.17

Tab.2 1st, 2nd and 3rd degree accessible areas of urban service areas

The number of neighborhoods in the district where the urban service areas are located, their number, maximum and minimum area sizes, and the neighborhoods where they are located are given in Tab.3.

Urban services	Distribution of service sreas in neighborhoods					
	Number	*Number of neighbordhood*	*Max. area (ha)*	*Neighborhood*	*Min. area (ha)*	*Neighborhood*
Museum	14	10	5.11	Santral garaj	0.02	Muradiye
Theatre	7	6	0.28	Alacamescit	0.03	İstiklal
Cinema	8	8				
Library	5	5	0.16	Şehreküstü	0.01	Osmangazi
Mall	8	8	15.2	Demirtaş Dumlupınar	0.59	Şehreküstü
Zoo	1	1	20.6	Soğanlı		
Square	19	19	1.295	Nalbantoğlu	0.324	Kemerçeşme
Picnic Area	8	9	18.722	Çağlayan	1.354	Gündoğdu
Urban Park	4	4	51	Hüdavendigar	25.25	Santral garaj
District Park	10	9	11.29	Soğukkuyu	1.04	Doburca
Neighborhood Park	75	40	1.868	Pınarbaşı	0.237	Gülbahçe
Playground	131	52	0.681	Zafer	0.008	Kırcaali

Tab.3 Neighborhood, number, maximum and minimum areas of urban service areas

In line with the data obtained, in Fig.8, the location of the urban service areas created by evaluating the QOL in all aspects, both qualitative and quantitative, was determined and mapped.

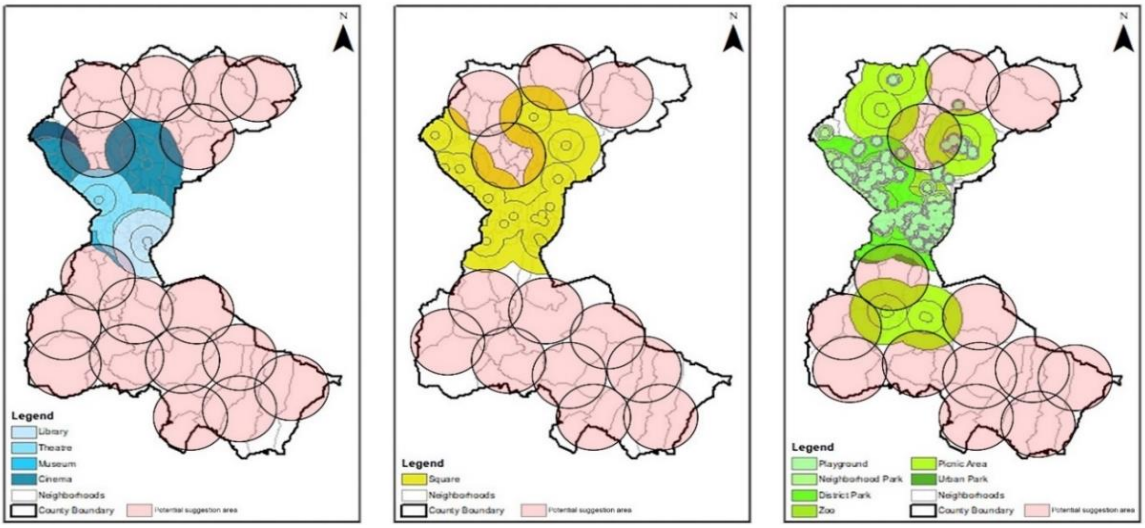


Fig.9 Potential proposal areas to increase accessibility and usability

4. Discussion and conclusion

Today, it is known that more than half (55%) of the 7.8 billion world population live in cities. When the projections for the future are examined in the studies, it is seen that the population is expected to reach 8.9 billion by 2050 (Mazzeo, 2016; Jennings et al., 2017; Ritchie & Roser, 2018) As a result of the rapid population growth in cities, urbanization has caused a deterioration in the distribution of the components that characterize the city, reducing the QOL, which is a measure of people's life satisfaction and social well-being in the city (Bhattarai & Budd, 2019; Bhatti et al., 2017).

Within the scope of the study, urban service areas, which play an important role in the concept of QOL, were evaluated at the neighborhood scale within the framework of the method setup consisting of five-stages.

In studies conducted by different researchers with different methods, various factors that play an important role in the QOL have been determined. Ülengin et al. (2001) conducted a survey-based study to determine the priorities, expectations, and needs of the citizens living in Istanbul and to improve the QOL and examined recreational areas, cultural services, and green spaces. Zlender & Thompson (2017) compared the green spaces preferred by the citizens in two different cities which have similar sizes but opposite green space strategies, and as a result, they determined that the most important effect on the QOL is accessibility. Li (2020), on the other hand, studied urban parks in three different cities and emphasized that QOL is directly related to population and behavioral variables. Van Herzele & De Vries (2012), tried to examine the sufficiency of green spaces and their effects on the health and well-being of the residents, based on a survey, in two neighborhoods with similar social and environmental characteristics such as population, socioeconomic factors, and housing conditions. In their studies, the presence of green space and especially its sufficiency is the most important factor in the QOL of the citizens. In this study, 12 different urban service areas, classified as cultural space, open space, and green spaces, aimed at improving the QOL, were evaluated within the scope of their quality, quantity and sufficiency. In this evaluation, it was emphasized that the amount of usage of each urban service area is important as well as the per capita areas.

Within the scope of the study, the per capita areas of the urban service areas were calculated at the neighborhood scale and their sufficiency was determined by analyzing their accessibility. Güngor & Polat (2017), in their study, surveyed to determine the current qualifications and sufficiency of urban parks in Konya. In the study of Çetin (2015), the presence and amount of green spaces in Kütahya and the distribution of green spaces at the neighborhood scale were evaluated within the framework of accessibility and per capita area. Altunkasa et al. (2017) determined the areas per capita at the neighborhood scale to determine the effectiveness of green spaces and socio-cultural facilities, used the distance-based method to estimate the

effectiveness of these areas, and as a result, a base map was obtained for the development of the areas that were found to have a non-homogeneous distribution. In this study, cultural space, open and green spaces per capita were calculated in each of the 136 neighborhoods in the Osmangazi district, which were determined as the study area within the scope of the sufficiency of the urban service areas, and effective service radius and accessibility analyzes were made by considering the walking distance of these areas. In this context, the aim is to evaluate the m^2/person values of the urban service areas together with accessibility.

Mouratidis (2021) examined how the COVID-19 pandemic, which has affected the whole world since 2019 and caused various environmental, psychological, social, and economic changes as well as people's habits and preferences, affects the urban QOL. For this purpose, seven different factors were evaluated: travel, entertainment, work, social relations, housing well-being, emotional reactions, and health. In this context, improvement studies on these seven factors aimed at improving the QOL under pandemic conditions today and under normal conditions in the future have been shed light on. Gehl (2020) revealed surprising results on the use of public urban service areas with an online study of 2023 people from different countries over a 10 days in April 2020, during the COVID-19 pandemic. According to the research, which is defined as preliminary research, 35% of the participants stated that they never used the urban service areas except for compulsory work during the pandemic. In this study, people's preferences for urban service areas were calculated with a mathematical formula before and after the pandemic. In addition to these calculations, urban service areas with decreasing and increasing usage amounts have been determined, and the effects of these areas on the QOL have been determined within the framework of the method setup, and potential proposal areas have been developed to increase their quality, quantity, and sufficiency.

The importance of green spaces has been understood with the awareness of people that they can spend time safely in open green spaces. Today, there has been a tendency towards green spaces, especially in cities that have been built with the increase in population, and sometimes these areas have been insufficient to meet the needs of the population. In the before and after epidemics comparisons, it was determined that these orientations were mostly toward urban and neighborhood parks. In addition to these, the zoo, picnic area, and district park green spaces have become the areas that people prefer more for their recreational activities. However, playgrounds faced a decrease in the amount of usage compared to the pre-pandemic. The reason is the assumption that parks especially for children have common ground, which is thought by parents to result in increased contagiousness (Ahmad & Istighfari, 2021; Alizadehtazi et al., 2020; Noël et al., 2021; Volenec et al., 2021). But beyond this thought, the importance of parks in terms of the physical and mental health of children, as well as their play and learning development, especially during the pandemic period, cannot be denied (Ender Altay et al., 2021; Goldfeld & Sewell, 2021; King, 2021).

The amount of usage of the urban service areas is directly related to the interaction with the immediate surroundings and the easy accessibility. If an urban service area can meet the needs of the population within the boundaries of the neighborhood where it is located and easy access to this area is provided, the amount of usage in the urban service area will increase in direct proportion to these features.

The least complicated and standard way to understand whether an urban service area is sufficient for its environment is to calculate the amount of urban service area per capita, defined as m^2/person (Gerçek & Güven, 2017). However, besides the concept of quantitative sufficiency, accessibility has an important role in determining the qualitative sufficiency of the urban service area.

Euclidean distance analysis was used in mapping the accessibility in the method setup of the study. This analysis approximates the standard-based effective service radius of the urban service area based on bird flight. But in reality, it is known that users cannot travel in straight lines, their movement distance will always be greater than the bird's flight distance. In addition, this analysis assumes that the urban service areas are accessible along their borders. In further studies, the accessibility analysis should be mapped by calculating the movement distances of the users over the walking routes.

In the study, it is necessary for physical planning studies to create cultural space, open and green space maps, to determine the effective presence in the neighborhoods, to examine and compare their distribution at the neighborhood level, to consider the amount of usage this area in today's pandemic conditions in the urban service area proposals. In this respect, the study is considered important with the potential of systematic data obtained to form a basis for planning studies.

References

Abd El Karim, A., & Awawdeh, M.M. (2020). Integrating GIS accessibility and location-allocation models with multicriteria decision analysis for evaluating quality of life in Buraidah city, KSA. *Sustainability, 12*(4), 1412. https://doi.org/10.3390/su12041412.

Ahmad, S., & Istighfari, A. (2021). Adapting with Global Pandemic: Challenges and Recommendations for Playground Facilities. *5th International Conference on Early Childhood Education (ICECE 2020)*. 240-245. Atlantis Press. https://doi.org/10.2991/assehr.k.210322.051.

Alizadehtazi, B., Tangtrakul, K., Woerdeman, S., Gussenhoven, A., Mostafavi, N., & Montalto, F.A. (2020). Urban park usage during the COVID-19 pandemic. *Journal of Extreme Events, 7*(4), 2150008. https://doi.org/10.1142/S2345737621500081.

Altunkasa, M.F., Berberoglu, S., Uslu, C., & Duymus, H., (2017). The effectiveness of urban green spaces and socio-cultural facilities. *TeMA - Journal of Land Use, Mobility and Environment, 10*(1), 41-56. https://doi.org/10.6092/1970-9870/4087.

Altunkasa, M.F. (2004). *Adana'nın kentsel gelişim süreci ve yeşil alanlar. Adana Kent Konseyi Çevre Çalışma Grubu Bireysel Raporu, Adana*. Adana City Council Environment Working Group Individual Report, Adana. https://doi.org/10.13140/2.1.3996.8967.

Aşık, Y., & Kara, B. (2021). To Investigate the Service Radius of Children's Playgrounds in the Case Study of Aydın City, Turkey. *The Journal of Graduate School of Natural and Applied Sciences of Mehmet Akif Ersoy University, 11*(Ek (Suppl.) 1), 301-312. https://doi.org/https://doi.org/10.29048/makufebed.795157.

Barbarossa, L. (2020). The post pandemic city: Challenges and opportunities for a non-motorized urban environment. An overview of Italian cases*. Sustainability, 12*(17), 7172. https://doi.org/https://doi.org/10.3390/su12177172.

Baud-Bovy, M., & Lawson, L. (1998). *Tourism and recreation: handbook of planning and design*. Oxford: Butterworth-Heinemann Ltd.

Bhattarai, K., & Budd, D. (2019). Effects of rapid urbanization on the quality of life. In B.R. Kumar Sinha (Ed.), *Multidimensional Approach to Quality-of-Life Issues* (pp. 327-341). Singapore: Springer. https://doi.org/10.1007/978-981-13-6958-2_21.

Bhatti, S.S., Tripathi, N.K., Nagai, M., & Nitivattananon, V. (2017). Spatial interrelationships of quality of life with land use/land cover, demography and urbanization. *Social indicators research, 132*(3), 1193-1216. https://doi.org/10.1007/s11205-016-1336-z.

Bilgili, B.C., Çığ, A., & Şahin, K. (2011). Evaluation of Public Green Areas Adequacy in the City of Van for Accessibility. *Yüzüncü Yıl Üniversitesi Tarım Bilimleri Dergisi, 21*(2), 98-103.

Boyacıgil, O., & Altunkasa, M. F. (2010). Kamusal rekreasyon olanaklarının etkinliğinin belirlenmesi: İskenderun (Hatay) örneği. *Ekoloji*, 19(74), 110-121.

Buttel, F.H., Wilkening, E.A., & Martinson, O.B. (1977). Ideology and social indicators of the quality of life. *Social Indicators Research, 4*, 353-369. https://doi.org/10.1007/BF00353138.

Camerin, F. (2021). Former military sites and post-Covid-19 city in Italy. May their reuse mitigate the pandemic impacts? *TeMA - Journal of Land Use, Mobility and Environment, 14*(2), 227-243. https://doi.org/10.3390/su12041412.

Canfora, F., & Corbisiero, F. (2014). Centro Direzionale of Naples. A "Smart" Concept. *Tema - Journal of Land Use, Mobility and Environment, 7* (3), 315-332. http://dx.doi.org/10.6092/1970-9870/2792.

Çetin, M. (2015). Using GIS analysis to assess urban green space in terms of accessibility: case study in Kutahya. *International Journal of Sustainable Development & World Ecology, 22*(5), 420-424. https://doi.org/10.1080/13504509.2015.1061066.

Dunnett, N., Swanwick, C., & Woolley, H. (2002). Improving urban parks, play areas and green spaces. Department for transport, local government and the regions London. *Ekoloji, 19*(74), 110-121. https://doi.org/10.5053/ekoloji.2010.7414.

El Din, H.S., Shalaby, A. Farouh, H.E., & Elariane, S.A. (2013). Principles of urban quality of life for a neighborhood. *Hbrc Journal, 9*(1), 86-92. https://doi.org/https://doi.org/10.1016/j.hbrcj.2013.02.007.

Ender Altay, E., Şenay, D., & Eyüpoğlu, Z. (2021). Outdoor Indicators for the Healthy Development of Children. *Child Indicators Research, 14* (6), 2517-2545. https://doi.org/10.1007/s12187-021-09855-8.

Ender, E. (2015). *A Model Proposal in Terms of Open Space and Green Space Planning for the City of Bursa*. Çukurova University. Adana. https://tez.yok.gov.tr/UlusalTezMerkezi/tezDetay.jsp?id=EXgrDaVBOtu4_VzNJGOCYg&no=46E2JWjN1TCwFZk7wblocw.

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

Fenu, N. (2021). Bicycle and urban design. A lesson from Covid-19. *TeMA - Journal of Land Use, Mobility and Environment, 14* (1), 69-92. https://doi.org/10.6092/1970-9870/7716.

Gaglione, F., Gargiulo, C., & Zucaro, F. (2019). Elders' quality of life. A method to optimize pedestrian accessibility to urban services. *TeMA - Journal of Land Use, Mobility and Environment, 12*(3), 295-312. https://doi.org/10.6092/1970-9870/6272.

Gavrilidis, A.A., Ciocănea, C.M. Niţă, M.R. Onose, D.A., & Năstase, I.I. (2016). Urban landscape quality index – planning tool for evaluating urban landscapes and improving the quality of life. *Procedia Environmental Sciences, 32*, 155-167. https://doi.org/10.1016/j.proenv.2016.03.020.

Gehl, J. (2020). *Public space and public life during Covid 19*. Copenhagen: Gehl Institute. https://covid19.gehlpeople.com/.

Gold, S.M. (1980). *Recreation planning and design*. New York: Mc Graw-Hill Book Company.

Goldfeld, S., & Sewell, J. (2021). Children need playgrounds now, more than ever. We can reduce COVID risk and keep them open. Retrieved from: https://theconversation.com/children-need-playgrounds-now-more-than-ever-we-can-reduce-covid-risk-and-keep-them-open-166562. February, 2022.

Gökyer, E., & Bilgili, B. (2014). Bartın İli örneğinde yeşil alanların ulaşılabilirliğinin değerlendirilmesi üzerine bir araştırma. *SDU Faculty Forestry Journal, 15*(2), 140-147. https://doi.org/10.18182/tjf.25011.

Guida, C., & Carpentieri, G. (2021). Quality of life in the urban environment and primary health services for the elderly during the Covid-19 pandemic: An application to the city of Milan (Italy). *Cities, 110*, 103038. https://doi.org/10.1016/j.jclepro.2019.119926.

Güngör, S., & Polat, A.T. (2017). The evaluation of the urban parks in Konya province in terms of quality, sufficiency, maintenance, and growth rate. *Environmental monitoring and assessment, 189*(4), 1-11. https://doi.org/10.1007/s10661-017-5875-9.

Hayek, U.W., Efthymiou, D., Farooq, B., von Wirth, T., Teich, M., Neuenschwander, N., & Grêt-Regamey, A. (2015). Quality of urban patterns: Spatially explicit evidence for multiple scales. *Landscape and urban planning, 142*, 47-62. https://doi.org/10.1016/j.landurbplan.2015.05.010.

Jennings, V., Floyd, M.F., Shanahan, D, Coutts, C., & Sinykin, A. (2017). Emerging issues in urban ecology: Implications for research, social justice, human health, and well-being. *Population and Environment, 39*(1), 69-86. https://doi.org/10.1007/s11111-017-0276-0.

Karlı, R.G.Ö., & Çelikyay, S. (2020). Akıllı Kentlerin Gelişiminde Covid-19 Etkisi. *Yüzüncü Yıl Üniversitesi Sosyal Bilimler Enstitüsü Dergisi.* (Outbreak Diseases Special Issue), 321-338.

King, P. (2021). The impact of COVID-19 on playwork practice. *Child Care in Practice*, 1-17. https://doi.org/10.1080/13575279.2020.1860904.

Li, C.-L. (2020). Quality of life: The perspective of urban park recreation in three Asian cities. Journal of Outdoor *Recreation and Tourism, 29*, 100260. https://doi.org/10.1016/j.jort.2019.100260.

Marans, R.W. (2015). Quality of urban life & environmental sustainability studies: Future linkage opportunities. *Habitat International, 45*, 47-52. https://doi.org/10.1016/j.habitatint.2014.06.019.

Marcus, C.C., & Francis, C. (1997). *People Places: Design Guidlines for Urban Open Space*. Haboken: John Wiley & Sons.

Massam, B.H. (2002). Quality of life: public planning and private living. *Progress in planning, 58*(3), 141-227. https://doi.org/10.1016/S0305-9006(02)00023-5.

Mazzeo, G. (2016). *La città leggera: Smart City e urbanistica attuativa*. Napoli: FedOA-Federico II University Press. https://doi.org/10.6093/978-88-6887-008-9.

Mittal, S., Chadchan, J., & Mishra, S.K. (2020). Review of Concepts, Tools and Indices for the Assessment of Urban Quality of Life. *Social Indicators Research, 149*, 187-214. https://doi.org/10.1007/s11205-019-02232-7.

Mouratidis, K. (2021). How COVID-19 reshaped quality of life in cities: A synthesis and implications for urban planning. *Land Use Policy, 111*, 105772. https://doi.org/10.1016/j.landusepol.2021.105772.

Noël, C., Rodriguez-Loureiro, L, Vanroelen, C., & Gadeyne, S. (2021). Perceived health impact and usage of public green spaces in brussels' metropolitan area during the COVID-19 epidemic. *Frontiers in Sustainable Cities, 3*, 30. https://doi.org/10.3389/frsc.2021.668443.

Okumuş, D.E., & Eyüboğlu, E.E. (2015). Kentsel Dönüşüm Öncesi Kentsel Yaşam Kalitesi Araştırmasına Yönelik Yöntem Önerisi ve Ataşehir Barbaros Mahallesi Örneklemi. *Planlama. 25*(2), 93-106. https://doi.org/10.5505/planlama.2015.09709.

Olivier, L.E., Botha, S., & Craig, I.K. (2020). Optimized lockdown strategies for curbing the spread of COVID-19: A South African case study. *Ieee Access, 8*, 205755-205765. https://doi.org/10.1109/ACCESS.2020.3037415.

Önder, S., & Polat, A.T. (2012). Kentsel açık-yeşil alanların kent yaşamındaki yeri ve önemi. *Formation and Maintenance Principles of Urban Landscape Areas Seminar, 19*, 73-96.

Özdede, S., Kalonya, D.H., & Aygün, A. (2021). Pandemi Sonrası Dönemde Kişi Başına Düşen Kentsel Yeşil Alan İhtiyacını Yeniden Düşünmek. *İDEALKENT (Transformation of Urban Public Spaces After COVID-19)*, 362-388. https://doi.org/10.31198/idealkent.843386.

Öztürk, S., Işınkaralar, Ö., & M. Kalaycı Kadak, (2019). Evaluation of Urban Open-Green Areas in terms of Sufficiency in Beylikdüzü District. *Journal of Current Research on Social Sciences, 9*(4), 59-66. https://doi.org/10.26579/jocress-9.4.5.

Krasilnikova, E., & Goncharik, A. (2022). Landscape and urban planning approach within regional spatial planning system. Case study of Moscow oblastʹ. *TeMA - Journal of Land Use, Mobility and Environment, 15*(3), 471-486. https://doi.org/10.6093/1970-9870/9151.

Rezvani, M.R., Mansourian, H., & Sattari, M.H. (2013). Evaluating Quality of Life in Urban Areas (Case Study: Noorabad City, Iran). *Soc Indic Res, 112*, 203–220. https://doi.org/10.1007/s11205-012-0048-2.

Ritchie, H., & Roser, M. (2018). Urbanization. *Published online at OurWorldInData.org*. https://ourworldindata.org/urbanization.

Sadiq, A., Saleem, M.S. Malik, M. Malik, M.I., Akhtar, F.K., & Waheed, K. (2020). How COVID-19 is changing behaviors of population: A study from Punjab. *Biomedica, 36*(3), 253-259.

Salama, A.M. (2020). Coronavirus questions that will not go away: interrogating urban and socio-spatial implications of COVID-19 measures. *Emerald Open Research, 2*. https://doi.org/10.35241/emeraldopenres.13561.1.

Salihoğlu, T., & Türkoğlu, H. (2016). A Geographic Approach to Leisure Spaces in İstanbul. *Planlama, 26*(3), 204–218. https://doi.org/10.14744/planlama.2016.39306.

Sarla, G.S. (2020). COVID 19: myths and facts. *Research & Review: Management of Emergency and Trauma Nursing, 2*(2), 5-8. https://doi.org/10.5281/zenodo.3742655.

Simonds, J.O. (1983). *Landscape Architecture*. New York: McGraw-Hill.

TUIK (2022). *Address Based Population Registration System Results*. Turkish Statistical Institute. https://data.tuik.gov.tr/Bulten/Index?p=Adrese-Dayali-Nufus-Kayit-Sistemi-Sonuclari-2021-45500.

Tunçay, H., & Eşbah, H.O. (2020). Sağlıklı Kentler ve Pandemi: COVID-19 Pandemisinin Düşündürdükleri. *Peyzaj, 2* (2), 57-64.

Ülengin, B., Ülengin, F., & Güvenç, Ü. (2001). A multidimensional approach to urban quality of life: The case of Istanbul. *European Journal of Operational Research, 130*(2), 361-374. https://doi.org/10.1016/S0377-2217(00)00047-3.

Van Herzele, A., & Wiedemann, T. (2003). A monitoring tool for the provision of accessible and attractive urban green spaces. *Landscape and urban planning, 63*(2), 109-126. https://doi.org/10.1016/S0169-2046(02)00192-5.

Venter, Z.S., Barton, D.N., Gundersen, V., Figari, H., & Nowell, M. (2020). Urban nature in a time of crisis: recreational use of green space increases during the COVID-19 outbreak in Oslo, Norway. *Environmental research letters, 15*(10), 104075. https://doi.org/10.1088/1748-9326/abb396.

Volenec, Z.M., Abraham, J.O., Becker, A.D., & Dobson, A.P. (2021). Public parks and the pandemic: How park usage has been affected by COVID-19 policies. *PloS one, 16*(5), e0251799. https://doi.org/10.1371/journal.pone.0251799.

Watson, V. (2003). *Change and continuity in spatial planning: metropolitan planning in Cape Town under political transition*. London: Routledge.

Weckroth, M., Ala-Mantila, S. Ballas, D. Ziogas, T,. & Ikonen, J (2022). Urbanity, Neighbourhood Characteristics and Perceived Quality of Life (QoL): Analysis of Individual and Contextual Determinants for Perceived QoL in 3300 Postal Code Areas in Finland. *Social Indicators Research, 164*, 139-164. https://doi.org/10.1007/s11205-021-02835-z.

Williams, S. (1995). *Outdoor recreation and the urban environment*. London: Routledge.

Xie, J., Luo, S., Furuya, K., & Sun, D. (2020). Urban parks as green buffers during the COVID-19 pandemic. *Sustainability, 12*(17), 6751. https://doi.org/10.3390/su12176751.

Zali, N., Rahimpoor, M., Benab, S.S. Molavi, M., & Mohammadpour, S. (2016). The distribution of public services from the perspective of sustainable spatial equality in the Tabriz Metropolitan in Iran. *TeMA - Journal of Land Use, Mobility and Environment, 9*(3), 287-304. https://doi.org/10.6092/1970-9870/3976.

Žlender, V., & Thompson, C.W. (2017). Accessibility and use of peri-urban green space for inner-city dwellers: A comparative study. *Landscape and urban planning, 165*, 193-205. https://doi.org/10.1016/j.landurbplan.2016.06.011.

Internet sources

Bursa Shopping Malls (2021a). *Bursa Shopping Malls*. Retrieved from: https://www.avmgezgini.com/avmler/bursa-alisveris-merkezleri/. May, 2021.

Immovable Cultural Heritage (2021b). *Immovable Cultural Heritage in Osmangazi District of Bursa*. Retrieved from: https://kulturenvanteri.com/bolge/turkiye/marmara-bolgesi/bursa/osmangazi/. July, 2021.

Libraries (2021c). *Libraries*. Retrieved from: http://kutuphaneler.bursa.bel.tr/kutuphanelerimiz. May, 2021.

Squares (2021d). *Squares*. Retrieved from: http://www.osmangazi.bel.tr/tr/projeler/kategori/meydanlar. July, 2021.

Urban Development (2020). *Urban Development*. Retrieved from: https://www.worldbank.org/en/topic/urbandevelopment/overview#1. February, 2022.

Image Sources

All figures are original, produced by the authors for this paper.

Author's profile

Elvan Ender Altay

She was born in Bursa in 1985. She graduated from Cukurova University, Department of Landscape Architecture in 2008. She completes his master's and doctorate degrees at Cukurova University on open and green spaces. She has received different awards in urban design competitions. She has been working as an associate at Bursa Uludag University Department of Landscape Architecture since 2014. She conducts landscape design courses and also takes part in landscape projects of different scales.

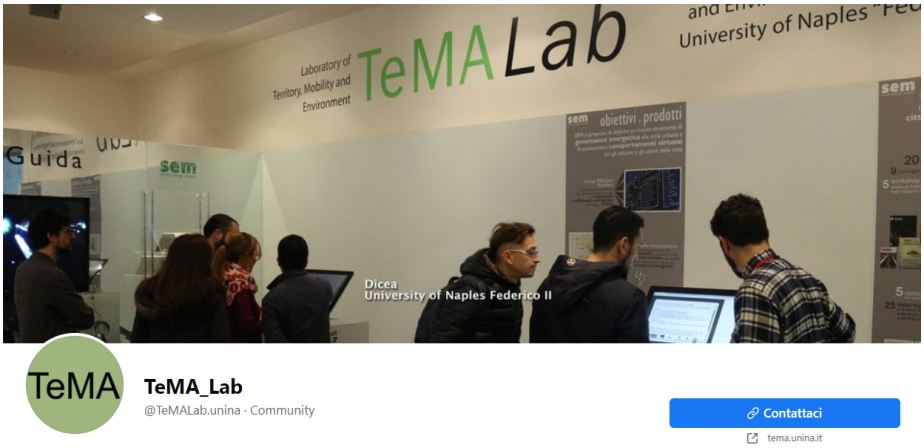
Diba Şenay

She was born in Izmir in 1998. She graduated from Istanbul University Department of Landscape Architecture in 2020. In the same year, she started master's degree at Bursa Uludag University. In 2022, she was assigned to Ege University as a research assistant. She is currently continuing master's degree at Ege University. She is also a student in the department of GIS at Anadolu University. She works on landscape planning and design, remote sensing, and GIS. In addition, she conducts research on the concepts of urban design and urban quality of life.

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 (2023) 165-182
print ISSN 1970-9889, e-ISSN 1970-9870
DOI: 10.6093/1970-9870/9813
Received 30th January 2023, Accepted 16th April 2023, Available online 30th April 2023

www.tema.unina.it

Applying Delphi method to develop sustainable city indicators. A case study of Chiang Mai, Thailand

Wiwat Pongruengkiat [a], Korrakot Y. Tippayawong [b], Pruk Aggarangsi [c], Preda Pichayapan [d], Tossapon Katongtung [e], Nakorn Tippayawong[f] *

[a] Graduate Program in Energy Engineering, Faculty of Engineering, Chiang Mai University, Chiang Mai, Thailand
e-mail: wiwat_p@cmu.ac.th
ORCID: https://orcid.org/0000-0003-0630-7399

[b] Department of Industrial Engineering, Faculty of Engineering, Chiang Mai University, Chiang Mai, Thailand
e-mail: korrakot@eng.cmu.ac.th
ORCID: https://orcid.org/0000-0003-4892-0079

[c] Department of Mechanical Engineering, Faculty of Engineering, Chiang Mai University, Chiang Mai, Thailand
e-mail: pruk.a@cmu.ac.th
ORCID: https://orcid.org/0000-0001-9832-1467

[d] Department of Civil Engineering, Faculty of Engineering, Chiang Mai University, Chiang Mai, Thailand
e-mail: preda@eng.cmu.ac.th
ORCID: https://orcid.org/0000-0002-1476-4867

[e] Department of Mechanical Engineering, Faculty of Engineering, Chiang Mai University, Chiang Mai, Thailand
e-mail: tossapon.katongtung@gmail.com
ORCID: https://orcid.org/0000-0001-9612-1883

[f] Department of Mechanical Engineering, Faculty of Engineering, Chiang Mai University, Chiang Mai, Thailand
e-mail: n.tippayawong@yahoo.com
ORCID: https://orcid.org/0000-0002-6104-7676
* Corresponding author

Abstract
Cities around the world have expanded and consumed many resources. The expansion of these cities has had a huge impact on our planet. There are many ideas about sustainable urban development around the world to slow down or stop the destruction of the environment. Sustainable urban development is a concept that allows the economy, society, and environment to grow together in a balanced and sustainable manner. Chiang Mai in Thailand is considered a city with much potential. It currently has good city planning. However, indicators to evaluate the potential of sustainable cities are still lacking. Hence, this work aims to develop appropriate indicators for assessing the sustainability of Chiang Mai city using the Delphi method of panel surveys. At least 20 experts in various fields were selected to take the Delphi surveys conducted in three rounds. The results of the Delphi processes showed that there were 35 indicators suitable for assessing Chiang Mai's potential as a sustainable city and helping with the development planning of Chiang Mai in the future.

Keywords
Clean energy; Sustainability; Sustainable city; Delphi; Chiang Mai.

How to cite item in APA format
Pongruengkiat, W., Tippayawong, K. Y., Aggarangsi, P., Pichayapan, P., Katongtung, T. & Tippayawong, N. (2023). Applying Delphi method to develop sustainable city indicators. A case study of Chiang Mai, Thailand. *Tema. Journal of Land Use, Mobility and Environment*, *16* (1), 165-182. http://dx.doi.org/10.6093/1970-9870/9813

1. Introduction

Expansion of urban society is one of the major trends and challenges that the world will face (Shaobo & Xiaolong, 2022; Wei et al., 2022; Do et al., 2022; Zeng et al., 2023). In the 21st century, the United Nations estimated that by 2050, the world will have an urban population of about 2.4 billion people, or 66% of the world's population (Amoushahi et al., 2022; Sun et al., 2021). Especially, Asia and Africa are showing rapid urbanization (Duan et al., 2022; Luo et al., 2022). For Thailand, there has been a continuous expansion of urbanization since the 1957s. Currently, Thailand has an urban population of about 55%, and it is estimated that by 2050, Thailand will account for 73% of the urban population. The growth of medium and small regional city centers and medium-sized cities will see a marked increase in population density. The economy of many regional cities will grow at a higher rate than Bangkok and above the national average (Chunark et al., 2021). Urbanization is both an opportunity and a challenge. Urban communities generate more than 80% of the world's gross domestic product while consuming more than 70% of their energy and carbon emissions (Hashmi et al., 2021; Margiotta et al., 2021; Rahman & Alam, 2021; Wang et al., 2022). Urbanization can drive an economy that benefits businesses from population density. Efficient use of land means low cost of transportation of goods, and it is also a source of innovation and technology. At the same time, recent urbanization has caused many problems (Pellicelli et al., 2022; Li et al., 2023), including directionless urbanization, environmental degradation, social inequality, inconsistent basic service, and housing shortages due to mass immigration. In addition, the changing situations in the world and Thailand have created a context that affects current and future urban development, including climate change and increased risk of disasters, rise of the middle class, an aging society, and technological advances and the transition to the digital economy (Spadaro et al., 2022; Szabó et al., 2022; Zhong & Chen, 2022). Therefore, it is imperative that the future development and management of cities rely on knowledge to create opportunities from urbanization and deal with problems that may arise from urbanization under the changing context (Boglietti & Tiboni, 2022). It can be said that the long-term sustainable development of a country will depend on the ability to develop cities and the indicators that will guide the cities of the future to be sustainable (Adshead et al., 2019; Franco, 2021; Henderson & Loreau, 2023).

Chiang Mai is currently undergoing continuous development. The development has been determined to align with the National Economic and Social Development Plan, and the northern region plan has been developed as a master plan for axial development. North-South Economic Corridor has a policy that emphasizes the importance of Chiang Mai as the center of the country and the sectors of business, trade, investment, administration, air transport, travel services, food, and health with international standards (Zhang et al., 2021), (Pongruengkiat et al., 2022). Due to its potential and role, Chiang Mai has many development projects from both the public and private sectors. However, no project has yet been able to measure the sustainability of Chiang Mai city development. Chiang Mai has much potential: it is the economic center of the North and the cultural capital of a country with a continuous influx of tourists as it is included in the preliminary list of UNESCO World Heritage Sites. In addition, Chiang Mai is also designated as a pilot area for developing smart cities, thus being a development base in digital technology. Moreover, Chiang Mai has the potential to be the center of education, medicine, and travel in the North; also, it has a beautiful natural environment. This makes Chiang Mai a livable city and worthy of sustainable urban development (Pongruengkiat et al., 2022).

Based on literature reviews and research papers on Chiang Mai's sustainable development, there are no indicators for assessing and monitoring sustainable urban development. Therefore, this work aims to facilitate, evaluate and choose suitable indicators to determine the potential of Chiang Mai city as a sustainable city through the Delphi method, with experts in various fields selecting and evaluating the indicators ideal for the city of Chiang Mai. To acquire relevant indicators for assessing the viability of Chiang Mai as a sustainable city, further investigation is necessary. Sustainable development consists of three main considerations: economic, social, and environmental (Zhao et al., 2019; Niemets et al., 2021; Al-Badi & Khan, 2022). Relevant

development must have the overlapping alternatives of these keywords, such as the interaction between socioeconomic dimensions and environment to social needs (Tanguay et al., 2010; Future, 2011; Winter & Knemeyer, 2013; Gosling et al., 2017). Economic development must avoid destroying ecosystems and losing nonrenewable resources (Tanguay et al., 2010). Sustainable city indicators must include not only the environmental dimension but also the social and economic dimensions (Lai, 2021). Therefore, this research studied the indicators from the Chiang Mai city development plan, Chiang Mai smart city strategy plan 2019, the master plan for the development of the Chiang Mai transportation system, bio-circular-green (BCG) economic model, transit-oriented development (TOD), and the United Nations' sustainable development goals (SDGs) (Franco, 2022) to cover all dimensions of the search for appropriate indicators to assess sustainable cities. From the aforementioned references, the researchers are interested in finding indicators used to evaluate the sustainable city potential of Chiang Mai. They intend to develop new indicators that are relevant to the specific context of Chiang Mai by integrating key indicators from various sources. The aim is to create a set of indicators that are tailored to the unique characteristics and circumstances of Chiang Mai as much as possible.

Developing sustainable city indicators for Chiang Mai would be highly relevant to the scope of TeMA Journal. This topic falls within the journal's focus on urban and regional planning, architecture, engineering, technology, and management, and addresses the challenges and opportunities related to the development, management, and sustainability of urban areas. Some potential sustainable city indicators for Chiang Mai could include green space, energy, Waste management, Transportation and Social equity. Developing sustainable city indicators for Chiang Mai could help identify areas where the city is doing well and areas where improvements are needed. This information could be used by policymakers, urban planners, and community stakeholders to guide decisions about resource allocation, infrastructure development, and sustainability initiatives.

2. Materials and methods

2.1 Delphi Method

Delphi techniques are widely accepted and popular research techniques in business, politics, health, economy, and education (Spranger et al., 2022; Chan & Lee, 2019; Drumm et al., 2022). The Delphi technique is a process or tool used to make decisions or draw conclusions on a matter systematically without the direct confrontation of a group of experts by gathering and asking for the experts' opinions. It is a technique that seeks input from experts' opinions on a particular subject by answering the questionnaire (OLADEGA et al., 2021). Henceforth, the designated experts must respond to the questionnaires presented by the researcher in a diligent and judicious manner, ensuring both precision and clarity in their responses. An expert, in this context, is an individual who possesses a wealth of knowledge and expertise in the particular subject under investigation. It is also a technique in which each expert involved in the research does not know who is and who has an opinion and does not know how each person views each item. This eliminates the influence of the group that affects their opinions. The Delphi technique was derived from questionnaires or other forms that do not require experts to meet. Experts are required to answer all the questionnaire steps to get the correct opinion. Therefore, it is necessary to use multiple rounds of questionnaires. In general, the questionnaire in Round 1 is open-ended, and in subsequent rounds, it is closed-ended (A. Y. P. Chan et al., 2013). A rating scale allows each expert to answer the questionnaire in a more carefully scrutinized and harmonious way. The experts agreed with the researchers' opinions, which were consistent with each answer to the previous questionnaire expressed in statistical terms, i.e., the median and the interquartile range. Then, they return the questionnaires to each expert to determine whether they want to keep the same answers or change them. The statistics used in the analysis are the basic statistics: the measure of the central tendency, namely, mode, median, and mean, and the measure of the distribution of the data, which is interquartile (P. Chan & Lee,

2019). The Delphi consensus method is a structured approach to reaching a consensus among experts or stakeholders on a particular topic or problem. It is a process that typically involves several rounds of data collection and analysis, aiming to refine opinions and converge toward a consensus view. The Delphi consensus method is a powerful tool for bringing together diverse perspectives and reaching a consensus on complex topics or problems. It can help ensure that all voices are heard and considered, leading to more robust and comprehensive results that inform policy decisions, research agendas, and other critical activities (Humphrey-Murto et al., 2017; Chan, 2022).

The 6-point Likert method was used to weigh the indicators chosen by the experts for further statistical analysis of the obtained values. In general, a 6-point Likert scale may provide a more nuanced response than a 5-point Likert scale, as it allows for an additional response option in the middle of the scale. This can help to reduce response bias and provide more precise measurements of attitudes and opinions. Additionally, having an odd number of response options prevents respondents from choosing the neutral option, which can encourage more thoughtful and meaningful responses (Dolnicar et al., 2011; Taherdoost, 2019). The Delphi technique used in conjunction with this 6-point Likert method collects the first round of data using an open-ended questionnaire. The next round will use a closed end. The first round of data collection using an open-ended questionnaire was intended to collect general opinions from experts for the second round of questionnaires, developed from the responses to the first round. All expert opinions are synthesized into an open-ended questionnaire of estimator type and sent to experts to prioritize or predict trends in each item. Each item obtained from the second round of questionnaires was calculated for statistical values. An issue to consider in the preparation of the questionnaire is the selection of statistical values used as feedback consisting of aggregated expert opinions. These values may be represented by mean, median, baseline, or percentage to represent the idea of most people and a statistical value showing the distribution of expert opinions. The most common statistics are standard deviation, quartile deviation, or the frequency or percentage distribution in each answer group to show the degree of consistency of the experts' thinking. The second group is a number that shows the experts' answers in the previous round to compare the consistency or differences of opinions of individual experts with the opinions of groups (Sourani & Sohail, 2015).

2.2 Relevant indicator selection, review, and classification

From previous research, the indicators are compiled as follows: Chiang Mai city development plan, Chiang Mai smart city strategy plan 2019, the master plan for the development of the Chiang Mai transportation system, BCG economic model (Otwong et al., 2021), transits city, transit-oriented development (TOD) (Sung & Oh, 2011), and SDGs (Bogers et al., 2022). All indicators were selected under the concept of sustainable development. Based on the previous research [The 12th International Conference on Logistics & Transport 2022: Identifying Suitable Indicators to Assess Chiang Mai as A Sustainable City Using Delphi Method], the indicators affecting the sustainable development of Chiang Mai can be divided into 18 groups, 64 indicators with additional groups and indicators from the experts who completed the questionnaire. The expert group is comprised of individuals with diverse backgrounds and expertise, including four city planners, seven local government officials, six representatives from the private sector, two energy experts, two social science experts, and two environmental experts. All group members were selected based on their extensive experience and held trusted positions in their respective fields. Such positions include membership in the National Planning Board, former deputy governor, and university professors with high academic standing. In the first round, these indicators were analyzed and used to prepare the questionnaire rounds 2 and 3. The details of the indicators are shown in Tab.1.

Category	Indicator	SDGs	Master plan	CNX plan 65	CNX smart	TOD	BCG
Energy	I1 Consumption of electricity per capita			✓	✓		✓
	I2 Consumption of fuel per capita		✓	✓	✓	✓	
	I3 The use of renewable energy in Chiang Mai area			✓	✓		✓
	I4 Projects and research on promoting the use of renewable energy	✓		✓	✓		✓
	I5 Energy conservation work	✓		✓	✓		✓
Environment quality	I6 Air quality	✓	✓	✓	✓	✓	✓
	I7 Emissions in transportation	✓	✓	✓	✓	✓	✓
	I8 Water	✓		✓	✓		✓
	I9 Waste	✓		✓	✓		✓
Land use	I10 Population density		✓	✓	✓	✓	✓
	I11 Integrated town plan		✓	✓	✓	✓	✓
	I12 Expansion pattern of the city	✓	✓	✓	✓	✓	✓
Transportation	I13 Type of transport (public, individual)		✓	✓	✓	✓	
	I14 Number of personal vehicles		✓				
	I15 Number of public vehicles		✓				
	I16 Vehicle usage rate	✓	✓			✓	
Health and wellbeing	I17 Number of beds in the hospital			✓	✓		
	I18 Number of hospitals and rehab centers through the Ministry of Health	✓	✓	✓			
	I19 Number of doctors			✓			
	I20 The potential of the hospital			✓	✓		
	I21 Sickness rate	✓		✓	✓		
	I22 Duration and ease of access to the public health system			✓			
	I23 Population health	✓		✓	✓		
	I24 Number of exercise locations and health promotion places			✓			
	I25 Average age of the population	✓		✓	✓		
Population	I26 Population	✓	✓	✓	✓	✓	✓
	I27 Birth rate			✓			
Labor	I28 Unemployment and Employment Rate	✓		✓	✓	✓	
	I29 Average income per capita	✓		✓	✓		
	I30 Level of knowledge and expertise of workers			✓			
Housing	I31 Number of residences		✓	✓	✓	✓	✓
	I32 The cost of buying or renting	✓	✓	✓		✓	
	I33 Distance/duration To travel for activities		✓	✓		✓	
Education	I34 Number of universities, schools, colleges	✓	✓	✓	✓	✓	
	I35 Graduation rate from bachelor's degree			✓	✓		
	I36 Number of students		✓	✓	✓		
	I37 Literacy rate	✓		✓			
	I38 The rate of employment in different areas / different areas After graduating at all levels and institutions		✓	✓			
Violence	I39 Number of crimes			✓	✓		
	I40 Number of police			✓	✓		
	I41 Number of police stations			✓	✓		
	I42 Amount of crime-risk areas (dark areas)	✓			✓		
Culture	I43 Number of ethnicities living in Chiang Mai			✓			
	I44 Number of festival management			✓	✓		
	I45 Number of recreational activities			✓			
	I46 Number of traditions			✓	✓	✓	
	I47 Income from cultural activities			✓			
Convenience	I48 Number of department stores and convenience stores	✓	✓	✓	✓	✓	✓
	I49 Number of markets		✓	✓	✓	✓	✓
	I50 Number of entertainment businesses		✓	✓	✓	✓	✓
	I51 Number of restaurants		✓	✓	✓	✓	✓
GPP	I52 Total product value in Chiang Mai	✓	✓	✓	✓	✓	✓
Creativity	I53 Number of creative courses	✓			✓		
	I54 Number of Creative Events and Exhibitions	✓		✓			
	I55 Income from Creative events and exhibitions	✓		✓			
Innovation	I56 Amount of innovation research	✓		✓	✓		
	I57 Income from research and innovation	✓		✓			

	I58 Innovation success rate	✓		✓			
Trade	I59 Amount of Trade Value	✓		✓	✓		✓
	I60 Income for each sector	✓		✓	✓		✓
Tourism	I61 Number of tourists		✓	✓	✓	✓	
	I62 Tourist spending rate			✓			
	I63 Currency exchange rate			✓			
Service	I64 Number of service businesses		✓	✓		✓	

Tab.1 Indicator review and classification

2.3 Questionnaire Development

The Delphi polling process involved three rounds of data collection. It is important to note that the questionnaire was not administered on a single occasion but was developed over multiple iterations, as illustrated in Fig.1. The details are as follows:

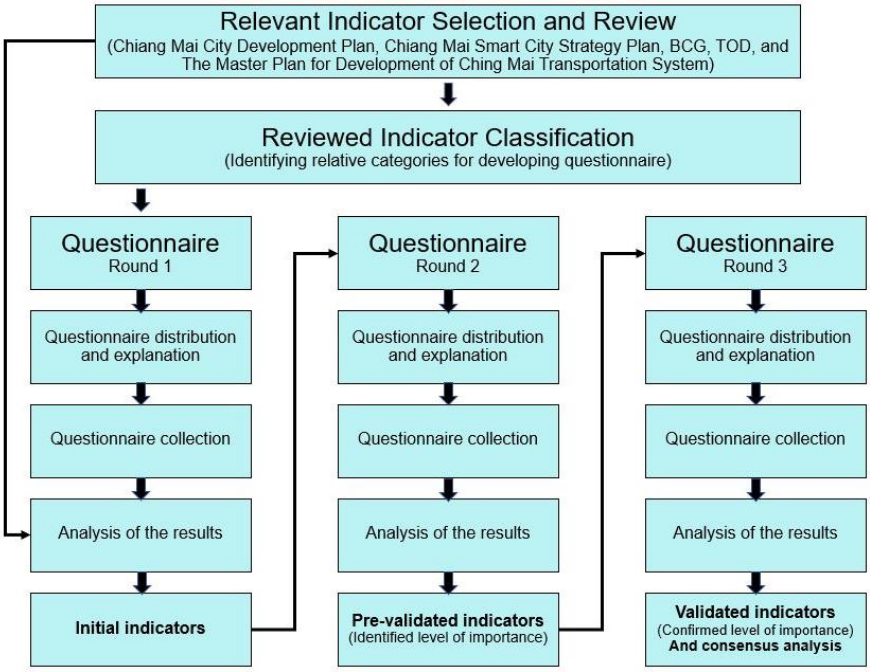


Fig.1 Research flow

Round 1: In Round 1, a validated questionnaire was used, and the indicators of sustainable urbanization were selected based on the previously mentioned data. Because sustainable city indicators are complex and numerous, the researcher has developed a questionnaire divided into 18 categories, with gaps for the participants to add information that they consider important. In order to streamline the questionnaire completion process for participants, it may be necessary to simplify and reduce the complexity of the questions. A sample questionnaire is shown in Fig.2.

Indicator Selection	
Indicator	Explanation
.....	.....

Fig.2 Delphi example Round 1

Round 2: In the second round, the indicators from the first questionnaire were used to determine the level of importance of the indicators using the 6-point Likert method, as shown in Fig.3.

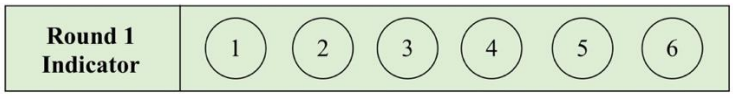


Fig.3 Delphi example Round 2

Round 3: In Round 3, a questionnaire in Round 2 was used to confirm the importance of the indicator. The mean values were added to the questionnaire, as shown in Fig.4.

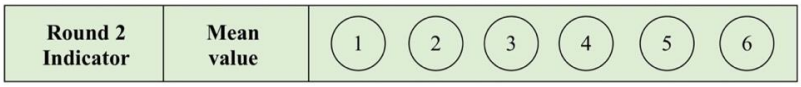


Fig.4 Delphi example Round 3

2.4 Conducting panel surveys

Panelist selection, invitation, and participation

Generally, the Delphi method defines the number of respondents differently depending on the suitability of the job (Sourani & Sohail, 2015). The number of participants involved in a study depends on the topic being considered, and in most cases, more than eight participants are included (Weidman et al., 2011). However, most studies have surveyed 8–16 participants or more, as appropriate (Hallowell & Gambatese, 2010). Based on previous literature studies, the majority of studies involved 8–16 participants (Pongruengkiat et al., 2022). Therefore, over 20 participants with expertise in each field were selected for this study. All the experts worked in fields related to the city's sustainability, city planners, local managers/governmental officers, private sectors, energy experts, transport experts, social science experts, and environmental experts, with 2-5 experts invited in each field.

Panel survey processes

Before completing the questionnaire, the participants were briefed on the objectives of this research, including the Delphi method of polling, where the lecture focuses on filling out additional questionnaires for the spaces provided in Fig.4. Participants were asked to identify at least five indicators of Chiang Mai's sustainability. There was a gap for participants to add groups of indicators they saw as relevant, with the most important being a sustainable city. This method must meet the guidelines of Chan & Lee (2019), Sourani & Sohail (2015). In the second round, the questionnaire was designed with regard to the indicators acquired from the first round. In this round, the significance level of the indicator was added by a 6-point Likert-type scale. The details are as follows: 6 means strongly agree, 5 means agree, 4 means slightly agree, 3 means slightly disagree, 2 means disagree, and 1 means strongly disagree (Dolnicar et al., 2011; Taherdoost, 2019).
In the third round, the questionnaire was similarly developed with reference to the indicators obtained from the second round of questionnaires. Here, the mean value was added to examine the level of significance of the identified indicators because each participant can change their opinion according to the mean value received from Round 2.

2.5 Consensus analysis and investigation

This work did not have a consensus analysis of Round 2, as the significance of the Round 2 indicators has not been confirmed. However, the average value of Round 2 has helped the contributors. The final decision was made in Round 3 to conclude the level of importance of the indicator. Therefore, in this study, consensus analysis was conducted in Round 3 based on data from Chiang Mai. The results of identifying the level of importance of the agreed-upon indicators were more than 83% of the responses voted on the pointer. The scales were most important, very important, and important. Sourani and Sohail (Sourani & Sohail, 2015) reported the percentage of respondents who agreed on the criterion rankings. On the 6-point Likert category, consensus can be determined based on 75% or more respondents agreeing on a mean value of 4.50. Consequently, in this work, the consensus was determined based on the importance of a voted indicator equal to or higher than 4.50 and the percentage of panelists who agreed that a given rating of 4 to 6 was equal to or higher. Over 75% of the accredited indicators that achieve this consensus will be selected as the sustainable

cities indicator for Chiang Mai. The consensus sustainable city indicator is also based on audits and agreements, which is suitable for Chiang Mai for sustainable urban development.

3. Results and discussion

3.1 Developing indicators in Delphi round 1

In previous studies in [The 12th International Conference on Logistics & Transport 2022: Identifying Suitable Indicators to Assess Chiang Mai as A Sustainable City Using Delphi Method], it was found that after Delphi Round 1 of 20participants, 29 indicators were left with a choice frequency greater than 75%, measured from all 64 initial indicators. In addition, 25 indicators have been guided by experts, and another group of indicators was "Facility." Thus, there were 54 indicators obtained from Delphi Round 1. All of these indicators will be used for weighting in Delphi Round 2. Fig.5 shows the frequency of selecting indicators. Tab.2 shows indicators selected from the initial indicators and Tab.3 shows indicators from expert recommendations.

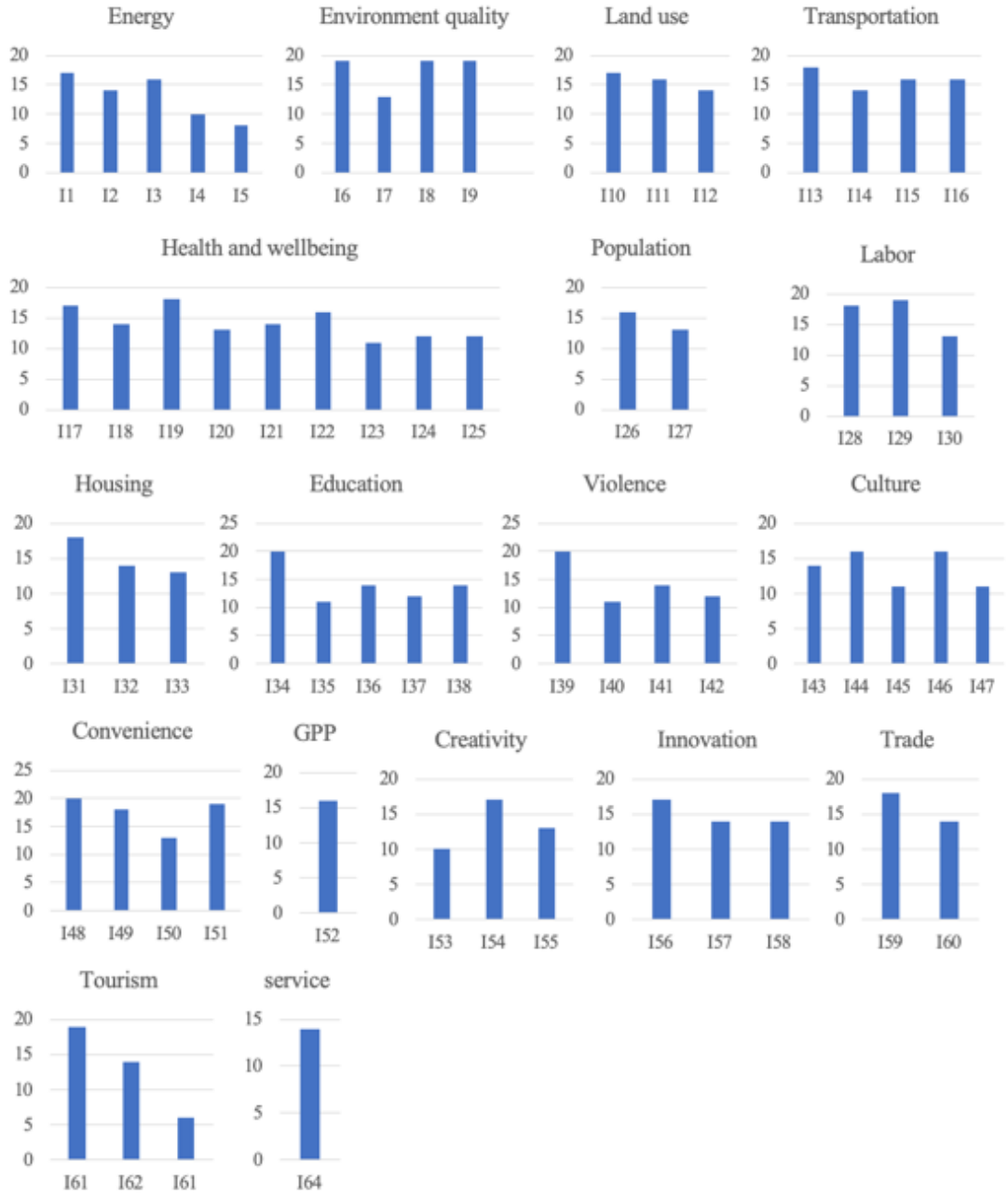


Fig.5 The frequency of selecting indicators

Category	Indicator	Category	Indicator
Energy	I1 Consumption of electricity per capita	Labor	I28 Unemployment and Employment Rate
	I3 The use of renewable energy in Chiang Mai area		I29 Average income per capita
Environment quality	I6 Air quality	Housing	I31 Number of residences
	I8 Water	Education	I34 Number of universities, schools, colleges
	I9 Waste	Violence	I39 Number of crimes
Land use	I10 Population density	Culture	I44 Number of festival management
	I11 Integrated town plan		I46 Number of traditions
Transportation	I13 Type of transport (public, individual)	Convenience	I48 Number of department and convenience stores
	I15 Number of public vehicles		I49 Number of markets
	I16 Vehicle usage rate		I51 Number of restaurants
Health and wellbeing	I17 Number of beds in the hospital	GPP	I52 Total product value in Chiang Mai
	I19 Number of doctors	Creativity	I54 Number of Creative Events and Exhibitions
	I22 Duration and ease of access to the public health system	Innovation	I56 Amount of innovation research
Population	I26 Population	Trade	I59 Amount of Trade Value
		Tourism	I61 Number of tourists

Tab.2 The indicators obtained from round 1 of Delphi by selected

Category	Indicator	Category	Indicator
Energy	Proportion of using renewable energy in the organization	Culture	Database-number of local experts/craftsmen/artists
Land use	Ratio of green area to total area		The number of museums that provide knowledge of the local culture
	Road area per total area		Statistics on the number of tourists who come during the festival
Transportation	Number of stops and distribution of public transport	Creativity	Number of local creative businesses
	Average travel per capita in different modes is connected to different fuel consumption	Innovation	Number of agencies that support innovation research
Health and wellbeing	Ratio of the elderly to the population		Number of start-ups
	Death rate	Tourism	Number of accommodations
Population	Latent population		Statistics of foreign tourists and Thai people
Housing	Residential building type		Objectives of foreign tourism
Education	Proportion of the undereducated population to the educated population		Number of days of provincial tourism for foreign and Thai tourists
Violence	Area per number of CCTV cameras		Number of tourist attractions by type
Facility	Utilities consumption rate	Service	Service business type
			Service business income per total provincial income

Tab.3 The indicators obtained from Round 1 **of Delphi by expert recommended**

3.2 Prevalidation of Indicators in Delphi Round 2

After analyzing the indicators obtained from Round 2 of Delphi, it was found that the passing indicators with a mean value greater than or equal to 75% were 35 indicators. The highest mean value is 5.6, and the lowest mean value is 4.0 as shown in Tab.4.

From Tab.4, it can be observed that the cut-out indicators are those with a mean value lower than 4.5, causing the group of Facility and Convenience indicators to be cut off, so the group of indicators will be reduced to 17 groups, and the indicators obtained the prevalidated indicators (SI), as shown in Tab.5.

3.3 Validation of Indicators in Delphi Round 3

After analyzing the results of Delphi Round 3, some metrics were renamed for greater clarity: "Water" was changed to "Water quality," "Waste" was changed to "Waste management," and "Total product value in Chiang Mai" changed to "Gross provincial products of Chiang Mai." The highest mean value is 5.55, and the lowest mean value is 4.68. The indicators with the highest mean were those in the Environment quality group (SI4, SI5, SI6), followed by the Energy group (SI2), shown in Tab.6.

3.4 Consensus Analysis

Indicators developed need to be confirmed based on a significance level equal to or above 4.5, so the percentage rating must be at levels 6, 5, or 4 equal to or above 75%. Referring to the consensus analysis, the proportion of panelists voting as 6, 5, or 4 for the 35 validated indicators is 100% for 14, 95% for 14, and 90% for 7. Hence, all of the 35 indicators reached consensus, as shown in Tab.7.

Category	Mean	Indicator	Category	Mean	Indicator
Energy	5.2	Consumption of electricity per capita	Education	4.7	Number of universities, schools, colleges
	5.2	The use of renewable energy in the Chiang Mai area		4.6	Proportion of the undereducated population to the educated population
	5.1	Proportion of using renewable energy to total energy	Violence	4.9	Number of crimes
Environment quality	5.6	Air quality		4.6	Area per number of CCTV cameras
	5.3	Water	Culture	4.6	Number of festivals and traditions
	5.4	Waste		4.4	Database-number of local experts/craftsmen/artists
Land use	4.8	Population density		4.4	The number of museums that provide knowledge of the local culture
	5	Integrated town plan		4.3	Statistics on the number of tourists who come during the festival
	5.2	Ratio of green area to total area		4.4	Number of traditions
	4.3	Road area per total area	Convenience	4.1	Number of department stores and convenience stores
Transportation	5	Type of transport (public, individual)		4.2	Number of markets
	4.4	Number of public vehicles		4.3	Number of restaurants
	4.3	Vehicle usage rate	GPP	4.8	Total product value in Chiang Mai
	4.2	Number of stops and distribution of public transport	Creativity	4.5	Number of creative events and exhibitions
	4	Average travel per capita in different modes is connected to different fuel consumption		4.7	Number of local creative businesses

Facility	4.3	Utilities consumption rate	Innovation	4.7	Amount of innovation research
Health and wellbeing	4.7	Number of beds in the hospital		4.6	Number of agencies that support innovation research
	4.6	Number of doctors		4.4	Number of start-ups
	5.0	Duration and ease of access to the public health system	Trade	4.5	Amount of trade value
	4.5	Ratio of the elderly to the population	Tourism	4.6	Number of tourists
	4.2	Death rate		4.5	Number of accommodations
Population	4.8	Population		4.3	Statistics of foreign tourists and Thai people
	4.4	Latent population		4.3	Objectives of foreign tourism
Labor	4.6	Unemployment and employment rate		4.5	Number of days of provincial tourism for foreign and Thai tourists
	4.9	Average income per capita		4.5	Number of tourist attractions by type
Housing	4.5	Number of residences	service	4.5	Service business type
	4.0	Residential building type		4.6	Service business income per total provincial income

Tab.4 The mean value of indicators obtained from Round 2 of Delphi

Category	**Indicator**	**Category**	**Indicator**
Energy	SI1 Consumption of electricity per capita	Education	SI19 Number of universities, schools, colleges
	SI2 The use of renewable energy in the Chiang Mai area		SI20 Proportion of the undereducated population to the educated population
	SI3 Proportion of using renewable energy to total energy	Violence	SI21 Number of crimes
Environment quality	SI4 Air quality		SI22 Area per number of CCTV cameras
	SI5 Water	Culture	SI23 Number of festivals and traditions
	SI6 Waste		
Land use	SI7 Population density	GPP	SI24 Total product value in Chiang Mai
	SI8 Integrated town plan	Creativity	SI25 Number of creative events and exhibitions
	SI9 Ratio of green area to total area		SI26 Number of local creative businesses
Transportation	SI10 Type of transport (public, individual)	Innovation	SI27 Amount of innovation research
Health and wellbeing	SI11 Number of beds in the hospital		SI28 Number of agencies that support innovation research
	SI12 Number of doctors	Trade	SI29 Amount of Trade Value
	SI13 Duration and ease of access to the public health system	Tourism	SI30 Number of tourists
	SI14 Ratio of the elderly to the population		SI31 Number of accommodation
Population	SI15 Population		SI32 Number of days of provincial tourism for foreign and Thai tourists
Labor	SI16 Unemployment and Employment Rate		SI33 Number of tourist attractions by type
	SI17 Average income per capita	Service	SI34 Service business type
Housing	SI18 Number of residences		SI35 Service business income per total provincial income

Tab.5 The indicators obtained the prevalidated indicators

Category	Mean	Indicator	Category	Mean	Indicator
Energy	5.09	SI1 Consumption of electricity per capita	Education	4.91	SI19 Number of universities, schools, colleges
	5.36	SI2 The use of renewable energy in the Chiang Mai area		5.14	SI20 Proportion of the undereducated population to the educated population
	5.23	SI3 Proportion of using renewable energy to total energy	Violence	5.09	SI21 Number of crimes
Environment quality	5.55	SI4 Air quality		5.05	SI22 Area per number of CCTV cameras
	5.55	SI5 Water quality	Culture	4.91	SI23 Number of festivals and traditions
	5.55	SI6 Waste management			
Land use	5.09	SI7 Population density	GPP	5.05	SI24 Gross provincial products of Chiang Mai
	5.27	SI8 Integrated town plan	Creativity	4.95	SI25 Number of creative events and exhibitions
	5.27	SI9 Ratio of green area to total area		5.14	SI26 Number of local creative businesses
Transportation	4.95	SI10 Type of transport (public, individual)	Innovation	5.27	SI27 Amount of innovation research
Health and wellbeing	4.86	SI11 Number of beds in the hospital		5.09	SI28 Number of agencies that support innovation research
	5.05	SI12 Number of doctors	Trade	5.09	SI29 Amount of trade value
	5.27	SI13 Duration and ease of access to the public health system	Tourism	5	SI30 Number of tourists
	4.68	SI14 Ratio of the elderly to the population		4.95	SI31 Number of accommodation
Population	4.91	SI15 Population		4.95	SI32 Number of days of provincial tourism for foreign and Thai tourists
Labor	4.95	SI16 Unemployment and Employment Rate		4.86	SI33 Number of tourist attractions by type
	5.09	SI17 Average income per capita	service	5	SI34 Service business type
Housing	4.82	SI18 Number of residences		5.05	SI35 Service business income per total provincial income

Tab.6 The mean value of indicators obtained from Round 3 of Delphi

Category	Indicator	Mean	Percentage of panelists voting for indicators as							
			6	5	4	3	2	1	6 or 5 or 4	3 or 2 or 1
Energy	SI1	5.09	41	27	32	0	0	0	100	0
	SI2	5.36	45	45	10	0	0	0	100	0
	SI3	5.23	32	59	9	0	0	0	100	0
Environment quality	SI4	5.55	68	22	5	5	0	0	95	5
	SI5	5.55	50	45	5	0	0	0	100	0
	SI6	5.55	50	45	5	0	0	0	100	0
Land use	SI7	5.09	32	45	23	0	0	0	100	0
	SI8	5.27	40	50	5	5	0	0	95	5
	SI9	5.27	55	22	18	5	0	0	95	5
Transportation	SI10	4.95	32	40	18	10	0	0	90	10

Health and wellbeing	SI11	4.86	23	45	27	5	0	0	95	5
	SI12	5.05	27	50	23	0	0	0	100	0
	SI13	5.27	45	36	18	0	0	0	100	0
	SI14	4.68	18	40	32	10	0	0	90	10
Population	SI15	4.91	27	41	27	5	0	0	95	10
Labor	SI16	4.95	23	50	27	0	0	0	100	0
	SI17	5.09	23	64	14	0	0	0	100	0
Housing	SI18	4.82	23	45	22	10	0	0	90	10
Education	SI19	4.91	23	50	22	5	0	0	95	10
	SI20	5.14	40	40	10	10	0	0	90	10
Violence	SI21	5.09	45	23	27	5	0	0	95	5
	SI22	5.05	36	36	32	0	0	0	100	0
Culture	SI23	4.91	32	32	31	5	0	0	100	0
GPP	SI24	5.05	32	41	27	0	0	0	100	0
Creativity	SI25	4.95	32	32	36	0	0	0	100	0
	SI26	5.14	32	55	8	5	0	0	95	5
Innovation	SI27	5.27	45	41	9	5	0	0	95	5
	SI28	5.09	45	27	23	0	5	0	95	5
Trade	SI29	5.09	36	41	18	5	0	0	95	5
Tourism	SI30	5	27	55	8	10	0	0	90	10
	SI31	4.95	27	50	13	10	0	0	90	10
	SI32	4.95	23	58	14	0	5	0	95	5
	SI33	4.86	22	50	18	10	0	0	90	0
Service	SI34	5	18	68	9	5	0	0	95	5
	SI5	5.05	32	45	18	5	0	0	95	5

Tab.7 Consensus analysis

3.5 Development, validation, and consensus

From Round 1 of Delphi analysis, it was found that 54 indicators were obtained from the selection of the initial indicators and the indicators recommended by the experts. A new group of indicators was added from the experts' recommendations, the group of "Facility" totaling 19 indicator groups. These changes are based on preliminary indicators and expert recommendations. After the second Delphi analysis, the group of indicators and indicators was reduced to 17 and 35 indicators, respectively. The group of indicators that were excluded was the Facility and Convenience group. After the third Delphi analysis, it was found that the number of indicator groups and the number of indicators were 17 groups and 35 indicators, respectively. The indicator is still the same as that from the second Delphi, but some indicators were renamed to increase clarity of that indicator. In addition, it was found that the group of indicators with the highest mean value was the group of Environment quality indicators; all three indicators in this group had a mean value of 5.55. The next high mean value was the Energy indicator group, where the SI2 indicator had a mean of 5.36.

According to consensus, the indicators developed were confirmed, taking into account significance levels equal to or greater than 4.5 and a 6, 5, or 4 score equal to or greater than 75% based on the consensus analysis. The fraction of experts voting 6, 5, or 4 for 35 verified indicators was 100% for 14 indicators, 95% for 14, and 90% for 7; hence, all 35 indicators reached a consensus.

This research follows the Delphi method to identify and validate sustainable city indicators for Chiang Mai. Through the initial study, 64 indicators were initially acquired. Through the validation process, 54 indicators were reduced to 35 after specifying the importance level. In addition, 35 verified indicators remained the same after confirming the priority (prevalidated). All 35 reviewed indicators reached a consensus. The two most important indicators are "Environment quality" and "Energy." Therefore, these indicators may be used to evaluate the potential of Chiang Mai as a sustainable city.

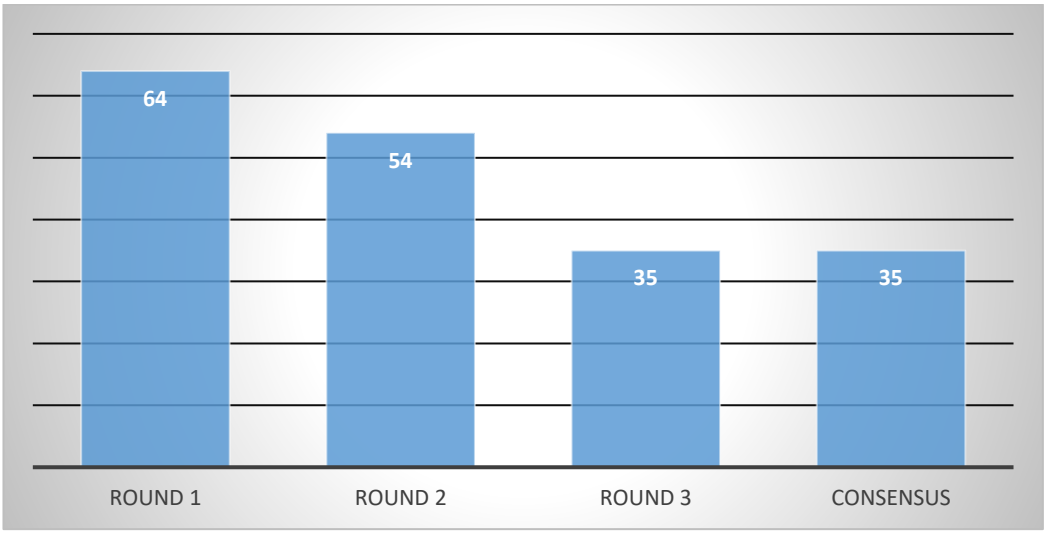


Fig.6 Number of indicators in each round

In future research, to use the indicators developed in this study to assess the sustainable city of Chiang Mai, a comprehensive assessment framework needs to be developed (Chan & Lee, 2019b; Chan & Lee, 2019a; Chan, 2020). This framework should incorporate the 35 identified indicators and other relevant indicators based on the specific needs and context of the city. Here are some steps that can be taken to use the developed indicators for assessing the sustainable city of Chiang Mai:

1. Identify the relevant sustainability dimensions - The sustainability dimensions that need to be assessed should be identified, such as environmental quality, social equity, economic growth, and governance;
2. Develop a comprehensive list of indicators - Based on the identified sustainability dimensions, a comprehensive list of indicators should be developed, including the 35 indicators identified in this study and other relevant indicators;
3. Collect data - Data should be collected for each indicator to evaluate the sustainability of the city. This data can be obtained from various sources, including government agencies, nongovernmental organizations, and academic research;
4. Analyze the data - The collected data should be analyzed to evaluate the sustainability of the city in relation to the identified sustainability dimensions and indicators;
5. Develop a sustainability report - The results of the analysis should be compiled into a sustainability report, which should include an overview of the sustainability status of the city, the identified strengths and weaknesses, and recommendations for improvement;
6. Develop a sustainability action plan: Based on the findings of the sustainability report, a sustainability action plan should be developed to guide the implementation of strategies and actions that will improve the sustainability of the city.

It is important to note that the developed indicators are specific to Chiang Mai and may not directly apply to other cities. Therefore, when using these indicators to assess the sustainability of other cities, adjustments and customization may be necessary to suit each city's specific needs and circumstances.

4. Conclusions

The study described here is an essential contribution to the field of urban development and sustainability, as it focuses specifically on identifying the indicators that impact sustainable urbanization in Chiang Mai. The use of multiple data sources and the Delphi method for data collection and analysis provide a robust framework for identifying these indicators and their applicability to the city. The study found that most indicators related to sustainable urbanization in Chiang Mai were related to environmental quality and energy. This suggests that efforts to promote sustainable urbanization in the city should focus on these areas. The indicators identified in this study can be used to evaluate the potential for sustainable urbanization in Chiang Mai. They can inform the development of a conceptual framework for planning a livable and sustainable city in the region. However, it is important to note that the indicators identified in this study may not be directly applicable to other cities. Each city's local context and specific conditions need to be considered when using these indicators to evaluate sustainable urbanization potential in other places. This requires careful adjustment and customization of the indicators to suit each city's specific needs and circumstances. Overall, this study provides a valuable contribution to the field of sustainable urban development and can be used to guide future efforts to promote sustainable urbanization in Chiang Mai.

The findings of this study can have practical implications for urban planners and policymakers in Chiang Mai, providing a roadmap for promoting sustainable urbanization and improving the overall livability of the city. The indicators identified in this study can inform the development of policies and strategies to enhance the quality of the environment, energy efficiency, and other key factors that contribute to sustainable urbanization. For future research, this study can serve as a foundation for further investigations into sustainable urbanization in Chiang Mai and other cities. Researchers can build upon the identified indicators and use them as a framework for evaluating the sustainability of other cities and identifying areas for improvement. This research can also include a more comprehensive assessment of other sustainability dimensions, such as social equity, economic growth, and governance. In summary, the findings of this study provide a valuable contribution to the field of sustainable urbanization and can inform efforts to promote livable and sustainable cities in Chiang Mai.

Acknowledgment

This work was partially supported by the National Research Council of Thailand and Chiang Mai University.

References

Adshead, D., Thacker, S., Fuldauer, L. I., & Hall, J. W. (2019). Delivering on the Sustainable Development Goals through long-term infrastructure planning. *Global Environmental Change*, *59*(November), 101975. https://doi.org/10.1016/j.gloenvcha.2019.101975

Al-Badi, A., & Khan, A. I. (2022). A Sustainable Development Neural Network Model for Big Data in Smart Cities. *Procedia Computer Science*, *202*, 408–413. https://doi.org/10.1016/j.procs.2022.04.057

Amoushahi, S., Salmanmahiny, A., Moradi, H., Tabrizi, A. R. M., & Galán, C. (2022). Localizing sustainable urban development (SUD): Application of an FDM-AHP approach for prioritizing urban sustainability indicators in Iran provinces. *Sustainable Cities and Society*, *77*(August 2021). https://doi.org/10.1016/j.scs.2021.103592

Bogers, M., Biermann, F., Kalfagianni, A., Kim, R. E., Treep, J., & de Vos, M. G. (2022). The impact of the Sustainable Development Goals on a network of 276 international organizations. *Global Environmental Change*, *76*(February), 102567. https://doi.org/10.1016/j.gloenvcha.2022.102567

Boglietti, S., & Tiboni, M. (2022). Public spaces critical issues analysis for soft mobility. A methodology for the cognitive framework definition. *Tema. Journal of Land Use, Mobility and Environment,* 131-145. http://dx.doi.org/10.6092/1970-9870/8643

Chan, A. Y. P., Ford, J. J., McMeeken, J. M., & Wilde, V. E. (2013). Preliminary evidence for the features of non-reducible discogenic low back pain: Survey of an international physiotherapy expert panel with the Delphi technique. *Physiotherapy (United Kingdom)*, *99*(3), 212–220. https://doi.org/10.1016/j.physio.2012.09.007

Chan, P. (2022). An Empirical Study on Data Validation Methods of Delphi and General Consensus. Data, 7(2), 1–16. https://doi.org/10.3390/data7020018

Chan, P. (2020). Assessing sustainability of the capital and emerging secondary cities of cambodia based on the 2018 commune database. *Data, 5*(3), 1–36. https://doi.org/10.3390/data5030079

Chan, P., & Lee, M. H. (2019). Developing sustainable city indicators for Cambodia through delphi processes of panel surveys. *Sustainability (Switzerland)*, *11*(11). https://doi.org/10.3390/su11113166

Chan, P., & Lee, M.-H. (2019). Prioritizing Sustainable City Indicators for Cambodia. Urban Science, 3(4), 104. https://doi.org/10.3390/urbansci3040104

Chunark, P., Hanaoka, T., & Limmeechokchai, B. (2021). Shared socioeconomic pathways and long-term GHG mitigation towards 2050 in Thailand cement industry. *Cleaner and Responsible Consumption*, *2*(August 2020), 100006. https://doi.org/10.1016/j.clrc.2020.100006

Do, T. A. T., Do, A. N. T., & Tran, H. D. (2022). Quantifying the spatial pattern of urban expansion trends in the period 1987–2022 and identifying areas at risk of flooding due to the impact of urbanization in Lao Cai city. *Ecological Informatics*, *72*(July), 101912. https://doi.org/10.1016/j.ecoinf.2022.101912

Dolnicar, S., Grun, B., Leisch, F., & Rossiter, J. (2011). Three good reasons NOT to use five and seven point Likert items Three good reasons NOT to use five and seven point Likert items Recommended Citation Recommended Citation. *University of Wollongong*.

Drumm, S., Bradley, C., & Moriarty, F. (2022). 'More of an art than a science'? The development, design and mechanics of the Delphi Technique. *Research in Social and Administrative Pharmacy*, *18*(1), 2230–2236. https://doi.org/10.1016/j.sapharm.2021.06.027

Duan, X., Li, X., Tan, W., & Xiao, R. (2022). Decoupling relationship analysis between urbanization and carbon emissions in 33 African countries. *Heliyon*, *8*(9). https://doi.org/10.1016/j.heliyon.2022.e10423

Franco, S. (2022). Urban sustainable development: the cost of pursuing SDGs. *Tema. Journal of Land Use, Mobility and Environment, 15* (3), 561-564. http://dx.doi.org/10.6092/1970-9870/9422

Franco, S. (2021). Sustainable development in cities: a review of frameworks and indexes. *Tema. Journal of Land Use, Mobility and Environment, 14* (3), 515-519. http://dx.doi.org/10.6092/1970-9870/8312

Future, B. (2011). *Human Development Report 2011 A Better Future for All*.

Gosling, J., Jia, F., Gong, Y., & Brown, S. (2017). The role of supply chain leadership in the learning of sustainable practice: Toward an integrated framework. *Journal of Cleaner Production*, *140*, 239–250. https://doi.org/10.1016/j.jclepro.2016.09.101

Hallowell, M. R., & Gambatese, J. A. (2010). Qualitative Research: Application of the Delphi Method to CEM Research. *Journal of Construction Engineering and Management*, *136*(1), 99–107. https://doi.org/10.1061/(asce)co.1943-7862.0000137

Hashmi, S. H., Fan, H., Habib, Y., & Riaz, A. (2021). Non-linear relationship between urbanization paths and CO2 emissions: A case of South, South-East and East Asian economies. *Urban Climate*, *37*(February), 100814. https://doi.org/10.1016/j.uclim.2021.100814

Henderson, K., & Loreau, M. (2023). A model of Sustainable Development Goals: Challenges and opportunities in promoting human well-being and environmental sustainability. *Ecological Modelling*, *475*(November 2022), 110164. https://doi.org/10.1016/j.ecolmodel.2022.110164

Humphrey-Murto, S., Varpio, L., Wood, T. J., Gonsalves, C., Ufholz, L. A., Mascioli, K., Wang, C., & Foth, T. (2017). The Use of the Delphi and Other Consensus Group Methods in Medical Education Research: A Review. *Academic Medicine*, *92*(10), 1491–1498. https://doi.org/10.1097/ACM.0000000000001812

Lai S., Isola F., Leone F. & Zoppi C. (2021). Assessing the potential of green infrastructure to mitigate hydro- geological hazard. Tema. Journal of Land Use, Mobility and Environment, 109-133. http://dx.doi.org/10.6092/1970-9870/7411

Li, S., Shao, Y., Hong, M., Zhu, C., Dong, B., Li, Y., Lin, Y., Wang, K., Gan, M., Zhu, J., Zhang, L., Lin, N., & Zhang, J. (2023). Impact mechanisms of urbanization processes on supply-demand matches of cultivated land multifunction in rapid urbanization areas. *Habitat International*, *131*(November 2022), 102726. https://doi.org/10.1016/j.habitatint.2022.102726

Luo, Q., Zhou, J., Zhang, Y., Yu, B., & Zhu, Z. (2022). What is the spatiotemporal relationship between urbanization and ecosystem services? A case from 110 cities in the Yangtze River Economic Belt, China. *Journal of Environmental Management*, *321*(July), 115709. https://doi.org/10.1016/j.jenvman.2022.115709

Margiotta, N., Palermo, A. & Viapiana, M.F. (2021). Environmental quality of emergency areas. A methodology to assess shelter areas liveability. *Tema. Journal of Land Use, Mobility and Environment,* 135- 154. http://dx.doi.org/10.6092/1970-9870/7416

Niemets, K., Kravchenko, K., Kandyba, Y., Kobylin, P., & Morar, C. (2021). World cities in terms of the sustainable development concept. *Geography and Sustainability*, *2*(4), 304–311. https://doi.org/10.1016/j.geosus.2021.12.003

Oladega, A., Mojdami, D., Hope, A., Watson, E. R. I. N., & Glogauer, M. (2021). the Process of Developing Consensus Guidelines By Dental Oncologists for Pre-Radiotherapy Dental Care in Head and Neck Cancer Patients Using the Modified Delphi Technique. *Journal of Evidence-Based Dental Practice*, *21*(4), 101620. https://doi.org/10.1016/j.jebdp.2021.101620

Otwong, A., Jongmeewasin, S., & Phenrat, T. (2021). Legal obstacles for the circular economy in Thailand: Illegal dumping of recyclable hazardous industrial waste. *Journal of Cleaner Production*, *302*, 126969. https://doi.org/10.1016/j.jclepro.2021.126969

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. http://dx.doi.org/10.6092/1970-9870/8646

Pongruengkiat, W., Pichayapan, P., Tippayawong, K. Y., & Tippayawong, N. (2022). *Applying Sustainable City Assessment Framework for Chiang Mai ' s Future Urban Development*. *AIP Conf. Proc., 2681, 020015*. https://doi.org/10.1063/5.0128712

Rahman, M. M., & Alam, K. (2021). Clean energy, population density, urbanization and environmental pollution nexus: Evidence from Bangladesh. *Renewable Energy*, *172*, 1063–1072. https://doi.org/10.1016/j.renene.2021.03.103

Shaobo, W. A. N. G., & Xiaolong, L. U. O. (2022). The evolution of government behaviors and urban expansion in Shanghai. *Land Use Policy*, *114*(222), 105973. https://doi.org/10.1016/j.landusepol.2021.105973

Sourani, A., & Sohail, M. (2015). The Delphi Method: Review and Use in Construction Management Research. *International Journal of Construction Education and Research*, *11*(1), 54–76. https://doi.org/10.1080/15578771.2014.917132

Spadaro, I., Pirlone, F. & Candia, S. (2022). Sustainability charter and sustainable mobility. *Tema. Journal of Land Use, Mobility and Environment*, 115-129. http://dx.doi.org/10.6092/1970-9870/8647

Spranger, J., Homberg, A., Sonnberger, M., & Niederberger, M. (2022). Reporting guidelines for Delphi techniques in health sciences: A methodological review. *Zeitschrift Fur Evidenz, Fortbildung Und Qualitat Im Gesundheitswesen*, *172*, 1–11. https://doi.org/10.1016/j.zefq.2022.04.025

Sun, S., Dai, T. L., Wang, Z. Y., Chou, J. M., Chao, Q. C., & Shi, P. J. (2021). Projected increases in population exposure of daily climate extremes in eastern China by 2050. *Advances in Climate Change Research*, *12*(6), 804–813. https://doi.org/10.1016/j.accre.2021.09.014

Sung, H., & Oh, J. T. (2011). Transit-oriented development in a high-density city: Identifying its association with transit ridership in Seoul, Korea. *Cities*, *28*(1), 70–82. https://doi.org/10.1016/j.cities.2010.09.004

Szabó, B., Korányi, D., Gallé, R., Lövei, G. L., Bakonyi, G., & Batáry, P. (2022). Urbanization decreases species richness, and increases abundance in dry climates whereas decreases in wet climates: A global meta-analysis. *Science of The Total Environment*, *859*(July 2022), 160145. https://doi.org/10.1016/j.scitotenv.2022.160145

Taherdoost, H. (2019). What Is the Best Response Scale for Survey and Questionnaire Design; Review of Different Lengths of Rating Scale / Attitude Scale / Likert Scale. *International Journal of Academic Research in Management (IJARM)*, *8* (1), 2296–1747.

Tanguay, G. A., Rajaonson, J., Lefebvre, J. F., & Lanoie, P. (2010). Measuring the sustainability of cities: An analysis of the use of local indicators. *Ecological Indicators*, *10*(2), 407–418. https://doi.org/10.1016/j.ecolind.2009.07.013

Wang, S., Xie, Z., Wu, R., & Feng, K. (2022). How does urbanization affect the carbon intensity of human well-being? A global assessment. *Applied Energy*, *312*(July 2021), 118798. https://doi.org/10.1016/j.apenergy.2022.118798

Wei, L., Zhou, L., Sun, D., Yuan, B., & Hu, F. (2022). Evaluating the impact of urban expansion on the habitat quality and constructing ecological security patterns: A case study of Jiziwan in the Yellow River Basin, China. *Ecological Indicators*, *145*(August), 109544. https://doi.org/10.1016/j.ecolind.2022.109544

Weidman, J. E., Miller, K. R., Christofferson, J. P., & Newitt, J. S. (2011). Best Practices for Dealing with Price Volatility in Commercial Construction. *International Journal of Construction Education and Research*, *7*(4), 276–293. https://doi.org/10.1080/15578771.2011.552936

Winter, M., & Knemeyer, A. M. (2013). Exploring the integration of sustainability and supply chain management: Current state and opportunities for future inquiry. *International Journal of Physical Distribution and Logistics Management*, *43*(1), 18–38. https://doi.org/10.1108/09600031311293237

Zeng, J., Cui, X., Chen, W., & Yao, X. (2023). Impact of urban expansion on the supply-demand balance of ecosystem services : An analysis of prefecture-level cities in China. *Environmental Impact Assessment Review*, *99*(August 2022), 107003. https://doi.org/10.1016/j.eiar.2022.107003

Zhang, Y., Peng, Y., Song, W., Zhang, Y. L., Ponsawansong, P., Prapamontol, T., & Wang, Y. (2021). Contribution of brown carbon to the light absorption and radiative effect of carbonaceous aerosols from biomass burning emissions in Chiang Mai, Thailand. *Atmospheric Environment*, *260*, 118544. https://doi.org/10.1016/j.atmosenv.2021.118544

Zhao, L., Zha, Y., Zhuang, Y., & Liang, L. (2019). Data envelopment analysis for sustainability evaluation in China: Tackling the economic, environmental, and social dimensions. *European Journal of Operational Research*, *275*(3), 1083–1095. https://doi.org/10.1016/j.ejor.2018.12.004

Zhong, Z., & Chen, Z. (2022). Urbanization, green development and residents' happiness: The moderating role of environmental regulation. *Environmental Impact Assessment Review*, *97*. https://doi.org/10.1016/j.eiar.2022.106900

Author's profile

Wiwat Pongruengkiat

Graduate Ph.D. Program in Energy Engineering, Faculty of Engineering, Chiang Mai University, Chiang Mai, Thailand. Interested in sustainable development and have engineering and management knowledge to apply to work related to sustainable urban development.

Korrakot Y. Tippayawong

Industrial Engineering, assistant professor in Faculty of Engineering, Chiang Mai University, Chiang Mai, Thailand. Her research protocol is manufacturing, engineering Industrial, engineering business, administration port, management transport, and economics.

Pruk Aggarangsi

Mechanical Engineering, assistant professor in Faculty of Engineering, Chiang Mai University, Chiang Mai, Thailand. He does research in renewable energy systems, energy management, waste to energy, mechanical system, building acoustics, and smart city.

Preda Pichayapan

Civil Engineering, assistant professor in Faculty of Engineering, Chiang Mai University, Chiang Mai, Thailand. He does research in logistics, traffic engineering, transportation planning, and tourism.

Tossapon Katongtung

Mechanical Engineering, graduate master's degree in Faculty of Engineering, Chiang Mai University, Chiang Mai, Thailand. He does research in environmental engineering, bioengineering, mechanical engineering, energy, and machine learning.

Nakorn Tippayawong

Mechanical Engineering, a full professor, working at the Department of Mechanical Engineering, Chiang Mai University, Thailand. He graduated from Imperial College London, UK. He does research in biomass thermal conversion, energy efficiency, low carbon engineering, and air pollution control. Current projects include "biomass pyrolysis," "vio-oil generation and upgrading," "viomass pretreatment," "Energy 4.0", "carbon capture & storage," and "aerosol monitoring & trapping."

TeMA Journal of Land Use, Mobility and Environment

TeMA 1 (2023) 183-199
print ISSN 1970-9889, e-ISSN 1970-9870
DOI: 10.6093/1970-9870/9850
Received 21st February 2023, Accepted 22nd March 2023, Available online 30th April 2023

www.tema.unina.it

The small smart city: renewable energy sources in little town of Italy

Romano Fistola [a], Federica Gaglione [b], Ida Zingariello [c]

[a] Department of Civil, Architectural and Environmental Engineering, University of Naples Federico II, Naples, Italy
e-mail: fistola@unina.it
https://orcid.org/0000-0001-6758-7510

[b] Department of Engineering, University of Sannio, Benevento, Italy
e-mail: fgaglione@unisannio.it
https://orcid.org/0000-0002-7067-7784
* Corresponding author

[c] Department of Engineering, University of Sannio, Benevento, Italy
e-mail: izingariello@unisannio.it

Abstract

The topic of energy has burst into the international and national scientific debate. Urban systems have taken on a fundamental role in having to support technological progress aimed at increasing renewable energy sources such as wind power. On the one hand, the scientific community has concentrated its studies on optimization models to support the energy organization of territorial contexts and on the other, on identifying optimal strategies within complex management systems. In turn, many efforts have also been made in the development of support tools for the improvement of urban energy systems to support decision-making processes. Wind energy is a valid option to improve the economic conditions in the region and reduce the environmental impact, even if the regulatory framework, especially in Italy, has shown structural deficiencies. In this direction, the work takes its cue from a scientific technical consultancy of the Department of Engineering of the University of Sannio and of the Department of Civil, Environmental, Land, Construction and Chemistry Engineering of the Polytechnic of Bari in support of the technical office of the municipality of Biccari (FG) in the definition of the guidelines for the drafting of the General Urban Plan.

Keywords

Urban Planning; Renewable energy sources; Municipal urban plan (PUC).

How to cite item in APA format

Fistola, R., Gaglione, F. & Zingariello, I. (2023). The small smart city: renewable energy sources in little town of Italy. *Tema. Journal of Land Use, Mobility and Environment*, *16* (1), 183-199.
http://dx.doi.org/10.6093/1970-9870/9850

1. Introduction

The global energy crisis is determining a decisive economic-industrial shift towards the production of energy from Renewable Energy Sources (RES). The greatest energy supply needs are manifested by the large anthropic settlements where most of the use is concentrated due to the high density of activities located in the area. However, outside these metropolitan contexts, settlements of limited size should also be considered, located in areas of high landscape value, which contribute decisively to the connotation of the national territory and in many cases preserve historical-architectural peculiarities which contribute to the cultural value, national recognition and also to the tourist polarization of the various countries. Italy has a heritage of small towns, generally located in the internal Apennine and Alpine areas, many of which are characterized as "villages" of ancient foundation (about 300), represent an invaluable territorial heritage and which, also due to recent events pandemics, has rekindled the attention of extra-metropolitan housing on itself. This relevance is demonstrated by the recent policies of the National Agency for Territorial Cohesion which has promoted a specific policy and a series of related actions for these territories. In particular, 72 areas have been selected as part of the National Strategy for inland areas, equal to 1060 Municipalities (13.4% of the national total), with an overall population of less than 2 million inhabitants (3.3% of the national total) and an area that represents 17% of the country's soil (https://www.agenziacoesione.gov.it/news_istituzionali/aree-interne/). In the face of this sensitivity, however, an inherent territorial contradiction emerges in the fact that in many of the municipal areas of these settlements, in areas such as the south of Italy which are richer in RES such as: wind, sun, geothermal, etc., plants are installed, especially wind, with a high territorial and perceptual impact. These plants significantly change the perception of the landscape both during the day, when the density and size of the wind turbines intercept the lines of the hilly profiles, and at night, when the red lights signaling obstructions to flight placed on each generator storm the darkness of rural contexts. Furthermore, in many cases, the energy produced by these plants is transferred to other anthropized contexts leaving the settlement sites only the problems of territorial entropy (Fistola, 2012) attributable to the perceptive modification of the landscape, noise pollution, of local biotopes, the subtraction of vast areas (buffer zones) that the plants require for safety, etc. This contribution reflects on the possibility of defining territorial compatibility policies capable of providing small extra-metropolitan centers with autonomous energy production systems compatible with the specificities of the places and capable of defining multifunctional uses that actively contribute to the cultural, sporting and tourist attraction of the settlement.

2. Literature review

Urban systems play a key role in supporting progress towards reducing emissions of greenhouse gases (GHG) (Sethi et al., 2020). Urban areas as complex systems have the task of exploiting the opportunities offered in the recovery and resilience plans for renewable energy in order to respond to the current urban sustainability standards (Gaglione & Etigo, 2022; Gaglione & Ayiine-Etigo, 2021). In recent years, population extension, economic development and improvement of living standards have increased the demand for energy resources. The different territorial contexts are the largest consumers of energy, accounting for approximately 60-80% and at the same time 75% of carbon emissions (Cheng et al., 2021). The creation of infrastructures based on renewables requires considerable efforts in the management of urban and territorial transformations (Soares et al., 2018). The role of planning today is in reducing environmental and health impacts, recognizing the link between the urban form and all its components (Jabareen, 2006; Mobaraki & Oktay Vehbi, 2022). The scientific debate is strongly accessed on the analysis of energy systems in a multidisciplinary vision in line with the approach adopted Energy for Sustainability (EfS) at the University of Coimbra. At the same time, the European Union has also taken on a leading role through Urban Europe which promotes research activity on the city system in a unitary key which aims to optimize the local energy system through energy efficiency, flexibility, and generation of energy from renewable sources in actions towards (urban) energy transition and climate

neutrality and the integration of these actions into urban planning processes (Gargiulo & Russo, 2017). Thus, the identification of the potential of renewable energy has become an area of interest in the policy field as well (Richards et al., 2012). However, the difficulties of administrative management as well as of economic resources indirectly lead to having to think about how to "optimize" the energy possibilities and opportunities of urban systems. Optimization can become an effective tool for identifying optimal strategies within complex management systems (Salehin et al., 2016). Surely the main element remains the need to recognize through coherent technical analyzes how renewable energy can be implemented and can have on other parts of the energy system (Lund & Mathiesen, 2009). Such analyzes require technical-scientific skills capable of giving useful answers to the defined energy systems. In particular, the scientific community has developed, in recent decades, numerous optimization models to support the energy organization of territorial contexts. Models have been widely used to define an optimal allocation of relevant energy resources, technologies and services within one or more administrative objectives (Fakhari et al., 2021; Wimmler et al., 2015). On the one hand, the studies investigate linear programming methods based on the desire to provide dynamic models relating to energy supply on a national scale (Farzaneh et al., 2016; Jebaraj & Iniyan, 2006) and others instead on non-linear programming models to identify optimal energy consumption schedules within production factories (Ostadi et al.,2007). The study by Beck, Samy and Yuan, propose a modeling approach to support optimal planning of energy networks such as regional-scale power generation by combining global optimization and agent-based modeling tools (Beck et al., 2008; Samy et al., 2022; Yuan et al., 2014). The technological support turns out to be a significant and crucial element for the development of a series of software to support the scientific research of reference. The study by Connolly of 2010 illustrates an overview of the different IT tools that can be used to analyze the integration of renewable energies. Some significant examples are EnergyPLAN (user friendly analysis of national energy systems); MESAP PlaNet (linear network models of national energy systems); LEAP (Usage Analysis for National Energy Systems); STREAM overview of national energy systems to create scenarios useful for measuring the environmental and economic effects of energy activities (Urban et al., 2007; Lund et al., 2007; Schlenzig, 1999). Numerous efforts by scientific research have also been made in the development of support tools for the management and improvement of urban energy systems in support of decision-making processes (Becchio et al., 2018). Most of the tools are based both on geographic information systems (GIS) capable of acquiring and managing spatial data related to land features combined with multi-criteria analysis to help decision makers to explore and solve problems that require trade-offs between multiple and conflicting objectives (Hettinga et al.,2018). The studies of Noorollahi, Mrówczyńska, and Elleuch, analyzed a multi-criteria decision support system to determine the potential of wind energy and to enhance the utilization of renewable energy resources and meet new international environmental requirements and provide self-sufficient domestic energy supplies (Noorollahi et al., 2016; Mrówczyńska et al., 2021; Elleuch et al., 2021). In turn, wind offers direct benefits for renewable electricity generation, but also indirect benefits for ventilation, pollution dispersion and mitigation of the urban heat island effect. In territories where urban wind is used such as New Zealand it has the potential to supply 33% of the electrical needs of residential buildings with horizontal axis wind turbines (HAWT) and 40% with counter-rotating vertical axis wind turbines (VAWT). Unfortunately, the construction of modern wind farms is still an ambitious and difficult project in the territorial planning processes although they generally produce from 2 to 3 W/m 2 with horizontal axis wind turbines (HAWT) and with vertical axis wind turbines counter-rotating (VAWT) can reach 30 W/m^2 (Kammen & Sunter, 2016). Even considering that there are advantages in the construction of wind power, it is still difficult for local communities to accept energy systems in relation to the environmental impact of the choices (Scorza et al., 2020; Tira, 2020). It is evident that we are faced with a complex process of territorial transformation that aims at the production of clean energy (Batty, 2013). Unfortunately, the territorial planning in this regard, especially in the Italian regulatory framework given that the case study of this research work is found to be in the Puglia region, has shown structural deficiencies. The legislation in this regard identifies the

articulated responsibilities of territorial bodies (mainly public) which operate in the elaboration and management of planning. The region has the task of identifying suitable areas and criteria for installations and measures for the exploitation of renewable energies. Municipalities are directly responsible for the authorization cycle of small-scale renewable energy plants. In the light of these considerations, two difficulties and criticalities emerge: on the part of the scientific community in the availability of finding effective data that serve the modeling and evaluation capacity to support decision makers in the management of territorial development and on the other in the rigidity of the prescriptive regulations, in the management of territorial transformations both in terms of resources and monitoring of territorial impacts.
In this direction, this contribution illustrates a segment of the technical-scientific consultancy work carried out by the Department of Engineering of the University of Sannio and the Department of Civil, Environmental, Land, Construction and Chemistry Engineering of the Polytechnic of Bari in support of the technical office of the municipality of Biccari (NA) in the drafting of a Municipal Urban Plan. In particular, the definition of a wind farm is examined in accordance with the provisions of the plan choices[1].

3. Smart energy for small town

As mentioned elsewhere (Fistola et al., 2021) in the governance processes of territorial transformations, technology must be "adopted" in the preparation of future structures of the urban system and not merely added or even imposed, as is widely the case with regard to large energy production systems. The energy problem is, without a doubt, one of the elements of crisis of the human settlement and, together with the systems of mitigation and adaptation to climate change, the topic on which most of the international scientific research is currently concentrated. As shown in the previous paragraph, the energy problem and the need to produce energy from RES is suggesting new territorial transformation processes oriented towards the production of clean energy (Batty, 2013).
It should also be considered that the current historical phase and the global energy crisis, also triggered by the war conflict generated at the gates of Europe, are determining the casual and dangerous overcoming of the compatibility checks of the canonical energy production plants, with the characteristics (and fragility) of settlement territories. This problem is even more felt in those territories, extra metropolitan and rural, characterized by small settlements with a high historical-environmental value and by landscapes connotative of national territorial contexts. For these anthropic settlements it could be useful to provide, within the instruments of territorial government, compatible energy production systems, with reference to the limited energy needs of the centers themselves. It should also be considered that the small centers represent, due to the high potential of Internet connection now available in almost all territorial contexts, also thanks to the fiber optic cabling policies and the diffusion of Wi-Fi systems, the elective place of settlement for new types of residence, which can carry out their work remotely within a decidedly healthier context than metropolitan settlements.
What is of interest here is the possibility, for small urban centers, of setting up autonomous, sustainable and non-invasive energy supply systems, safeguarding the territorial and vocational landscape characteristics typical of extra-metropolitan urban settlements. In other words, what appears interesting to underline is how the small towns and villages of the internal areas of many European contexts, and in particular of the Italian sub-Apennine internal areas, can escape the invasive installation of energy systems that damage their own landscape peculiarities of these areas by degrading their perceptive image (Lynch, 2006). For these areas, the possibility of integrated constructions that configure the center as an independent energy community capable of producing the energy necessary for its survival must be explored. In many cases, and particularly in the internal areas of the Italian context, the energy problem has been solved through the installation of large wind

[1] The scientific coordination of the convention is entrusted to prof. D. Camarda and R. Fistola; the members of the research group are the arch. I. Zingariello, Eng. M. R. Stufano Melone, Eng. F. Gaglione and Eng. G. Mastrodonato".

turbines which have heavily modified the panorama and the landscape of those areas. It should also be considered that, in most cases, these plants have been installed in rural areas, but often they do not return the energy produced to the existing urban settlements, which is then transferred to other areas.
Another non-trivial component of the problem is the social acceptance of large energy production plants or fossil fuel extraction plants which are perceived, by the socio-anthropogenic component of the urban system, as elements of degradation and territorial vulnerability.
Considering also that in some cases they have even been implemented in plants that used fracking for the extraction of energy fossil sources. What we want to support here is the possibility of foreseeing within the drafted urban planning instruments, processing plants for renewable energy sources that can be integrated into the territorial context, without compromising the perception of the landscape both acoustically and visually.
Furthermore, these systems can be integrated with further installations that small towns should give priority to in non-functional areas of their territory such as abandoned quarries or former landfills. These areas, which constitute deep wounds in the landscape, continue to represent an element of territorial vulnerability but can easily be reconverted into RES production areas through the installation of solar capitation systems made through photovoltaic panels capable of covering the extraction. In the same way, it is possible to set up integrated wind farms that do not require the installation of mega generators, but small collection systems that can be easily installed in the area. Reiterating a consideration set forth, the opportunity of integrated use of the settlement areas of the plants should be underlined for which it is possible to provide additional equipment, for example of a sports type at the service of citizens and which can represent an element of polarization of use also by non-municipal utilities.

4. The case study of the Municipality of Biccari

Assuming that currently, in the Italian context, the Region has the task of identifying the areas and criteria suitable for the plants and measures for the exploitation of renewable energies, it is necessary to observe that the municipalities are directly responsible for the authorization cycle of the renewable energy plants of small size.
Compared to the reference scientific framework, the research work in question falls within the territorial context of the Puglia region, precisely in the municipality of Biccari in the province of Foggia.
In order to synthetically frame the municipal territory of Biccari from a physical-environmental, socio-demographic and socio-economic point of view, it is deemed necessary to outline its attributes as well as recall the initiatives and projects underway in terms of energy production from renewables.
The municipality of Biccari has an altitude of 450 m a.s.l. and extends over a land area of 106.64 km² with a population density of 24.76 inhab. /km². From an orographic point of view, the Biccarese territorial system is structured in a composite way and sees an important mountainous relief, made up of the heights of Monte Cornacchia (the highest in Puglia) at 1,151 m a.s.l., a predominantly wooded hilly part (which houses the park Daunia Avventura) and a plain that extends towards the Foggia area. At 900 m a.s.l. north-east of Monte Cornacchia, we find Lake Pescara, a natural lake of about 3 hectares (Fig.1).
Not negligible is the condition of fragility in which part of the territory finds itself and in particular the southern slope, which, due to the current hydrogeological structure, is subject to a landslide risk, which is particularly attentive and is currently the subject of a study conducted by the Department of Civil, Environmental, Land, Construction and Chemical Engineering (DICATECH) of the Polytechnic of Bari following a research agreement stipulated with the Government Commissioner for the hydrogeological emergency of the Puglia Region, relating to the first level framework of the structures geomechanics, on the basis of existing data, of the area in which Lake Pescara is located in the territory of Biccari (FG).

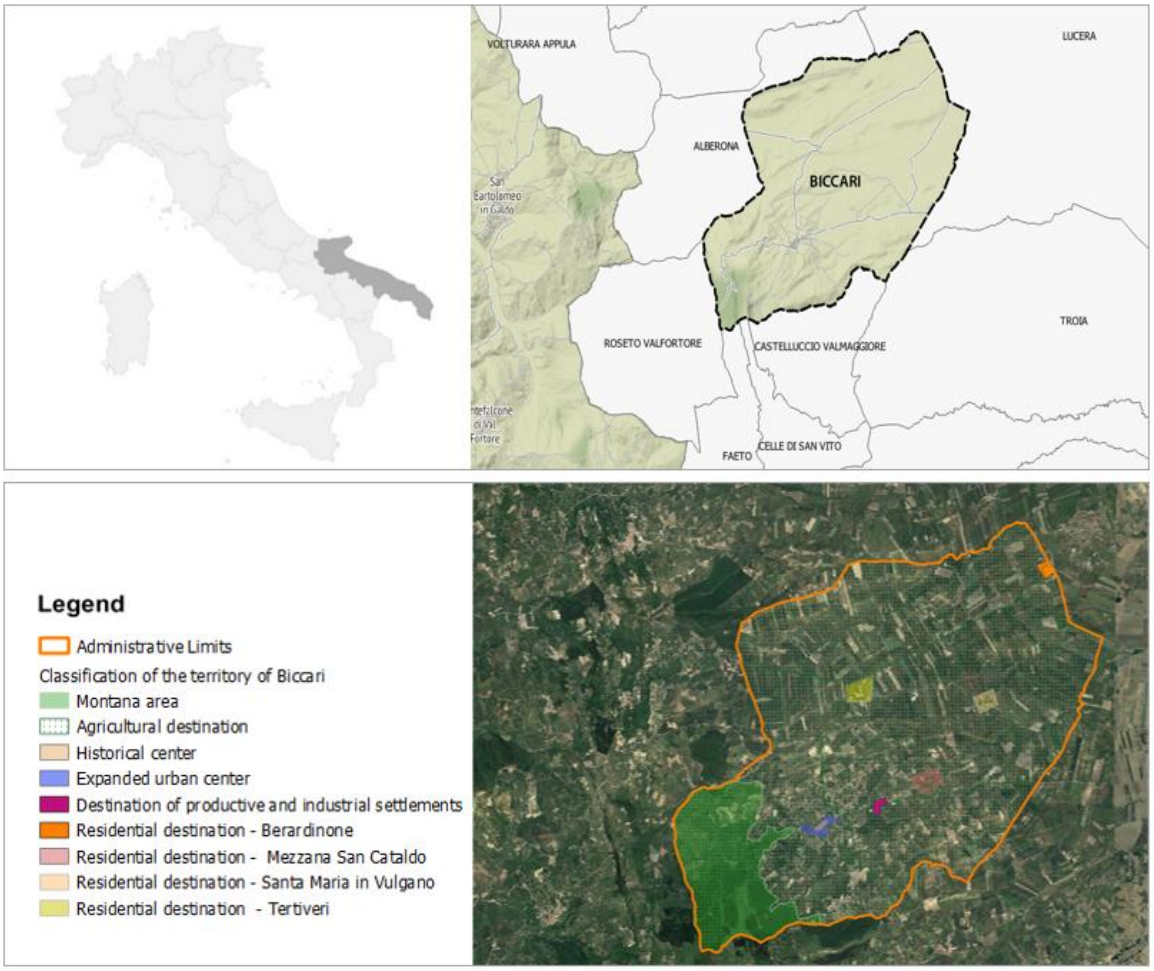


Fig.1 Landscape from the municipality of Biccari

According to National Statistical Institute (ISTAT) data updated on 31 December 2021, the municipality of Biccari has 2627 inhabitants. If we focus on the demographic trend of the resident population from 2001 to 2021, there are no doubts about the ongoing processes of depopulation and decline in births (Fig.2). The average age of the resident population is 47.8 years with an old age index (number of inhabitants over 65/number of inhabitants under 14 * 100) equal to 238.5. This figure reveals a significant process of aging underway, if we consider that for every 100 young residents of Biccari there are almost 239 elderly people.

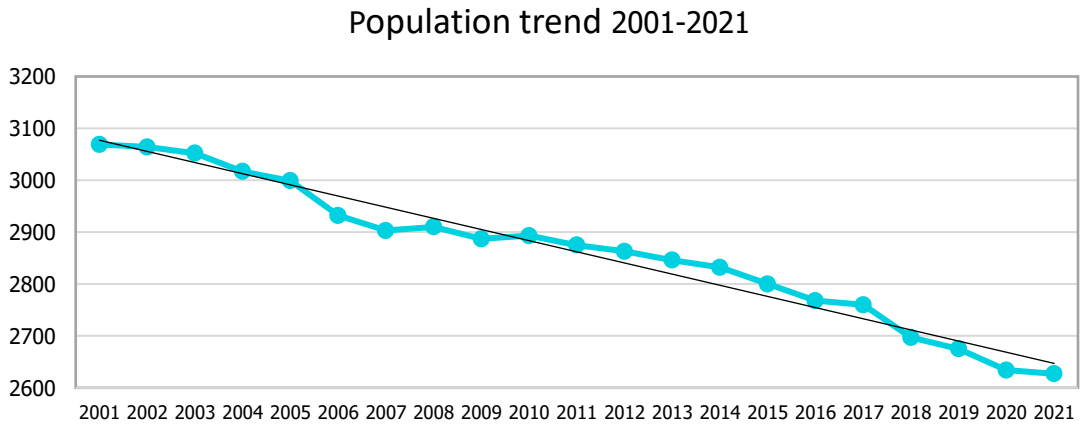


Fig.2 Population trend between 2001 and 2021 (Source: National Statistical Institute)

An analysis of the employment sectors sees most of the Biccaresi engaged in activities relating to the non-commercial tertiary sector and the agricultural sector, in fact the agricultural vocation of the territory is historically connected to olive growing. A large part of the building stock is for residential use and prior to 1945, nevertheless, the quality of the building stock is of a medium-high level if we consider that almost 80% of the buildings are in excellent or good condition. The houses are concentrated almost exclusively in the inhabited center, contrasting all forms of urban sprawl (Fig.3).

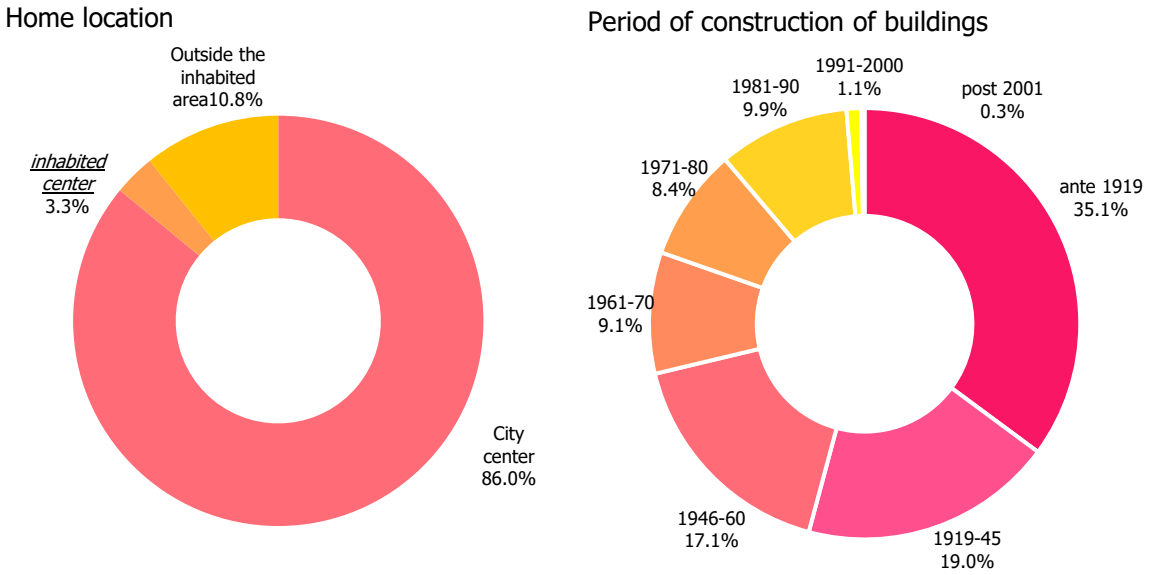


Fig.3 Geographical location of the inhabited center and its period of construction (Source: National Statistical Institute)

Regarding the tourist offer, tourism in Biccari is divided into three main sectors: naturalistic, historical-cultural, and gastronomic. The naturalistic heritage of the Biccarese area is of such great value that it allows numerous and varied activities such as fishing, hunting, excursions, as well as recreational and sporting activities within the "Daunia Avventura" park which allows, among other stay overnight in the woods in suggestive tree houses and Bubble Rooms. The historical-cultural tourism sector is also relevant, a "slow" tourism that aims at the rediscovery of the ancient village, of the local history and culture. Alongside these two sectors, gastronomic tourism is making its way; a minor type of tourism, often daily and characterized by people from the neighboring villages who on their free days, or on festivals and fairs, move to Biccari to enjoy the culinary excellence. The system of mobility by vehicle, in terms of daily journeys, is mainly made up of mobility using private vehicles which, from 1991 to 2011, saw a significant increase both for municipal journeys and above all for inter-municipal journeys, to the detriment of public transport using collective means. The system of mobility by vehicle is accompanied by slow mobility, on foot or by bicycle, limited to the municipal boundaries. The municipality of Biccari is also an important area of energy production, both from renewable and fossil sources. The gas extraction activity, for which the municipality is in second place among the municipalities of the Dauni mountains, seems to be currently underway, and it seems that new research authorizations have been granted by the Ministry for Economic Development totally bypassing the municipal administration in the authorization process. It is also feared that the fracking technique is also being implemented for the extraction of Shale gas; extremely dangerous practice in a seismic area such as the one in question. As far as the production of energy from renewable sources is concerned, 23 wind turbines of 2 MW and about 40 smaller ones of 60 KW are installed and functioning (Fig.4). On the other hand, the project for the "Montaratro" wind farm is in the process of being approved, which will have 23 wind turbines, each with a nominal power of 5.3 MW for a total power of 121.90 MW and will be in the municipal areas of Biccari and nearby centers of Troia

and Lucera. In particular, the Biccari area will be affected by the installation of a single wind turbine in an area located to the east of the town and at 2.8 km from it.

Fig.4 Energy landscape from the Puglia region

Thanks to the spirit of initiative of the Biccari Community Cooperative, the municipal administration promoted in 2020 the establishment of a Renewable Energy Community (CER) thanks to the collaboration with the ènostra energy cooperative. Renewable Energy Communities are currently regulated by art. 42-bis of the Milleproroghe Decree 162/2019, which introduced, in the Italian scenario, the community exchange of renewable energy. Even the PNRR has recognized its fundamental role within the energy transition process and has allocated 2.2 billion for the construction of CERs in small Italian municipalities with fewer than 5 thousand inhabitants. Born with the aim of encouraging sustainable living through practices of self-production and self-consumption of energy from renewable sources, the CERs have become more current following the need to combat energy poverty, understood as the inability to pay primary energy services, which in the last year, due to the ongoing conflict and the related increase in energy costs, involved 14.6% of European households. The members of a CER are called to produce energy from renewable sources to meet their energy needs, as well as to share the excess energy produced with the other members of the community. Each member of a CER therefore becomes what has recently been defined as a prosumer, no longer and not just a simple consumer but a real producer, i.e., someone who owns his own plant and is able to produce energy.
The economic advantages of self-production and self-consumption are obvious, just think that all ancillary costs to actual energy consumption, such as network charges and related taxes, are eliminated from the bill. As evident, and already amply demonstrated, are the environmental benefits deriving from the production of photovoltaic energy in terms of reduction of CO_2 emissions and other climate-altering gases. Within this scenario, the Municipality of Biccari has launched a feasibility study that will lead about 50 resident families to become members of a CER. Thanks to an agreement with Arca Capitanata, manager of public residential housing, the Municipality has obtained, free of charge, the surface right for the roofing of the aforementioned buildings on which approximately 60 kW of photovoltaic panels will be installed which, added to the 30 kW

already installed on municipally owned buildings, will make it possible to set up a small CER whose members will be called to produce, exchange and store energy from renewable sources.
What has been outlined so far gives us back the image of a territory that is partly fragile but characterized by a high eco-environmental value, a remarkable quality of food and wine products and a high tourist potential, as well as the portrait of a community and an administration particularly sensitive to theme of sustainable living and active in the production of energy from renewable sources. This is the context that oriented and guided the project proposal object of this research study illustrated in the following paragraph.

5. The proposal

The theme of renewable energy is one of the priority axes of the plan aimed at enhancing the resources and the territorial context in which the study area is located. The operating procedure illustrated here has supported and directed the public administration in the choices of the Municipal Urban Plan (PUC) in relation to the issue of renewable energy. We started by analyzing the reference regulatory framework regarding the transition to renewable energy in the Puglia Region. First, it must be specified that the Constitutional Law 3/2001 on energy matters attributes the legislative competences to the State and the Regions. For this reason, the Region has the task of defining the sector regulations the rules and as well as the siting, construction and authorization procedures for the construction of energy production plants. In detail, the reference document is contained in the programmatic instrument, called the Regional Environmental Energy Plan (P.E.A.R.), adopted with Resolution of G.R. n.827 of 06-08-07, which contains guidelines and strategic objectives in the energy field over a ten-year time horizon. The PEAR therefore contributes to constituting the reference framework for public and private subjects who, in this field, have taken and are taking initiatives in the territory of the Puglia Region. In a further resolution of the Regional Council of 28 March 2012, n. 602, the methods used to update the Regional Environmental Energy Plan were identified, entrusting the activities to a technical structure made up of the Ecology, Territorial Structure, Energy, Networks and Material Infrastructure services for development and agriculture. The plan focuses on identifying the lines characterizing regional energy planning which is developed on considerations concerning both the demand aspect and the energy supply aspect. As far as energy demand is concerned, the Plan focuses on the needs related to the users of the various sectors: residential, tertiary, industry, and transport. Important are the initiatives aimed at defining the measures and actions necessary to achieve the improvement of the environmental energy performance of urban settlements, as well as measures and actions useful for promoting energy saving. Instead, from the point of view of the offer, the plan aims to define a differentiated energy mix to produce electricity, also focusing on renewable sources, capable of guaranteeing environmental protection by reducing the impacts related to the production itself of energy. Through the planning process outlined, it is possible to assume that the contribution of renewable sources will be able to cover a large part of the consumption of the entire civil sector. In turn, the PEAR regulation governs the authorizations for the installation of wind farms and ancillary works in the Puglia region. The regulation defines two macro-categories of wind farms: those of "large size", if consisting of a single dispenser whose power is greater than 1 MW, and those of small size consisting of a maximum total power of 60 kW with a maximum unit power of 30 kW, rotor diameter not exceeding 10 meters and height of the support pole not exceeding 24 meters. The authorization process for large and small wind farms follows two different procedures. Large-scale plants refer to Legislative Decree 387/03 (environmental law) which requires municipal administrations to equip themselves with Regulatory Plans relating to the installation of Wind Power Plants (PRIE). These plans are drawn up by the municipal administrations individually or jointly between neighboring municipalities (inter-municipal PRIEs). All the Administrations with expertise in the construction and management of RES plants participate in the technical table. In turn, the Environmental Impact Study is mandatory only if the plants fall within 1 km (for large-scale farms) and 500 m (for small-scale farms) from the sites of the Natura 2000 network. This entails the implementation of an

administrative simplification tool aimed at guaranteeing environmental protection and reducing the bureaucratic burden for private and public operators. The plan, in turn, must be consistent with the projects and with the overall framework of planning and programming on the territory of both the vast area and the municipality.

If on the one hand for large-scale plants the interventions are implemented through indirect implementation, for interventions related to small-sized plants the implementation is direct through authorizations. Small farms are subject to having to request Certified Notification of Start of Activity (SCIA): it is a declaration that allows private operators to start, modify or stop a production activity (craft, commercial, industrial), without having to wait for the duration and the implementation of preliminary checks and inspections by the competent authorities, but in turn the private individual will have to have the financial capacity for the complete realization of the project for plants between 200 kW and 1 MW.

As far as the authorization aspects are concerned, it is envisaged that, in general, no authorization is required for wind farms with power lower than or equal to 10 kW if inserted in rural or industrial areas and with power lower than or equal to 5 kW in the other cases. The small wind power technology finds an interesting application at a rural level, at the service of farms since it constitutes a peculiarity of the area of interest in the Apulian territory. An appropriate application of this technology would lead to the creation of integrated energy supply chains from renewable sources. In Italy, electricity from RES is promoted through deductions from value added tax (VAT) and property tax and can be sold on the free market or to the Energy Manager at a guaranteed minimum price. Alternatively, renewable energy producers can opt for on-the-spot metering which provides for economic compensation for the electricity fed into the grid. Instead, small-scale plants can already take advantage of the incentives deriving from the sale of green certificates.

The framework of rules for the definition and construction of large and medium-sized wind farms has been outlined. The second step of the work was aimed at defining the dataset useful for defining the wind farm. In addition, surveys were conducted through satellite images obtained from drones through constant surveys on the area under study also supported by Google Earth images. This dataset was used as a basis for defining where to build a wind farm in accordance with the provisions of the Biccari plan choices developed through territorial geographic tools such as GIS.

The database had the functionality to collect both spatial data from large area and municipal planning. The dataset was structured starting from the Regional Technical Cartography (TRC) produced by the Puglia Region to build the entire database. The basic database has been divided into macro-categories.

As regards the planning of a vast area, the areas subject to restrictions were firstly identified: hydro geological, of archaeological interest, of community importance and deriving from the landscape plan. Secondly, the areas governed by the Territorial plan of provincial coordination (PTCP) in relation to rural contexts, urban fabrics, production centers and special types. From the rules governed by the planning of a vast area, we have moved on to the municipal scale.

In particular, all land use/land cover classes (LULC) have been identified starting from: (a) Residential buildings in compact urban centers; (b) Residential buildings in dispersed urban centers; c) buildings for industrial and commercial use; (d) roads and railways; (e) caves and dumps; (f) gardens and urban green areas; (g) orchards; h) gardens; i) arable land; l) olive groves; m) vineyards; (n) pasture or fallow areas; (o) mixed forests; (p) coniferous woods; (q) hardwood forests; (r) Watercourses. Some geoprocessing operations have been applied which are useful for defining the area to be occupied for the installation of RES plants in relation also to the urban planning instruments in force and already present in the field of renewable energy in relation to the environmental feasibility study. The next step was to define the wind farm categories according to the 'installed capacity' and the relative radius of influence in terms of land use linked to the wind farm, including fields, access road and technical services. In detail, the type of wind power plant that has defined itself in the area, also due to the current technological innovations in the sector, are the Vortex devices. These cutting-

edge devices are born thanks to a Spanish startup that created Vortex Tacoma, capable of capturing wind energy through vibration and transforming it into electricity. The result is a vertical, thin, and cylindrical wind turbine: a fixed base in which the device is anchored to the ground and an upward flexible part that interacts with the air creating an oscillating movement. The internal parts never collide with each other but interact to generate electricity. This plant, designed as a "small wind" generator, is aimed at a residential or rural market with low energy consumption systems and has only an alternator that transforms energy into electricity. The height of each device is approximately 2.75 meters, making it capable of being easily integrated into urban environments. Furthermore, having heights of 3-4 meters they do not create major problems from a landscape point of view in rural areas. Tests show that the turbine can store 40% of the wind and outputting a power of 100W. Thanks to their simplified structure, they are able to significantly reduce production, installation, and maintenance costs, ensuring the production of clean energy at a cost 30% lower than that obtainable with traditional wind turbines. A comparison in terms of efficiency of the two technologies shows that traditional wind turbines have a higher net efficiency value, however, with the same surface area, it is possible to obtain more energy from a Vortex Bladeless field, since the latter can be installed at a smaller distance (Fig.5).

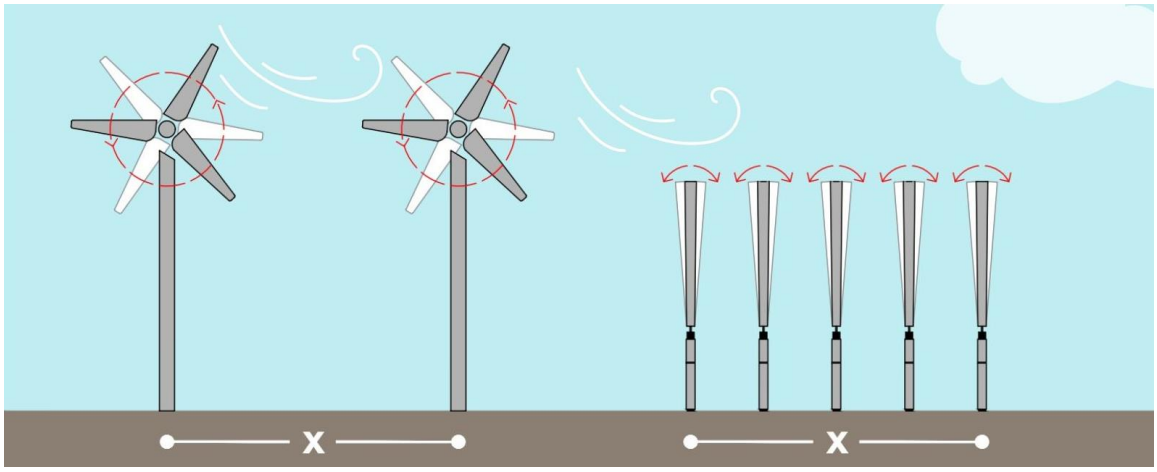


Fig.5 Comparison of technology on wind turbines and Vortex devices

An economic aspect is that, having no gears or moving parts in contact, it does not require lubricants. Implying a reduction in costs and on maintenance hours. The estimated maintenance cost savings are 80% less than existing wind energy systems. In this direction, it was decided to use this technology for the municipality of Biccari with the aim of carrying forward cutting-edge aspects useful for the creation of an organized and planned energy community.

6. Results

In accordance with the previous section, to define the guidelines for drafting the P.U.G. it appears necessary to identify the "territorial invariants". By territorial invariants we mean all those municipal areas which appear to be non-transformable at an urban level linked to the intrinsic characteristics of the context.

The areas subject to restrictions due to the combined provisions of the restrictions and protections deriving from the superordinate planning such as the Basin Excerpt Plan for the Hydrogeological Structure and the regulations of the Provincial Territorial Plan and the Landscape Plan have been identified.

In detail, the municipality of Biccari presents the hydrogeological instability that surrounds the historic and recently formed inhabited center of the Municipality of Biccari throughout the municipal area. In turn, in the hamlet of Tertiveri there is an area of archaeological interest within which, especially in recent years, various artifacts and finds have been found, testifying to the historical importance of the area. In addition, in the south-west part of the Municipality there is a SIC area (Site of Community Importance). The mountainous part

of the municipality of Biccari falls almost entirely within the SCI area called "Monte Cornacchia-Bosco di Faeto". Inside there are also various areas of natural pasture, as identified by the Territorial Landscape Plan of the Puglia Region. The areas subject to this constraint severely limits any type of intervention, considered natural heritage to be protected, resulting in areas that must be subjected to Environmental Impact Assessment (VINCA) for the implementation of such interventions in that area.

As regards, the Territorial Coordination Plan of the Province of Foggia (PTCP) constitutes that act of general planning of the territory defining the strategic guidelines and the physical-functional structure of the territory with reference to the supra-municipal interests.

The municipality of Biccari has a large part of the built-up center of a historic urban fabric, only in the part near S. Lucia and S. Quirico a recently formed urban fabric. In the area above S. Quirico there is a productive urban fabric. The entire area adjacent to it up to the boundaries of the municipal territory appears to be an environmental area with a predominantly traditional forestry and agricultural structure. Fig.6 shows the areas governed by superordinate planning.

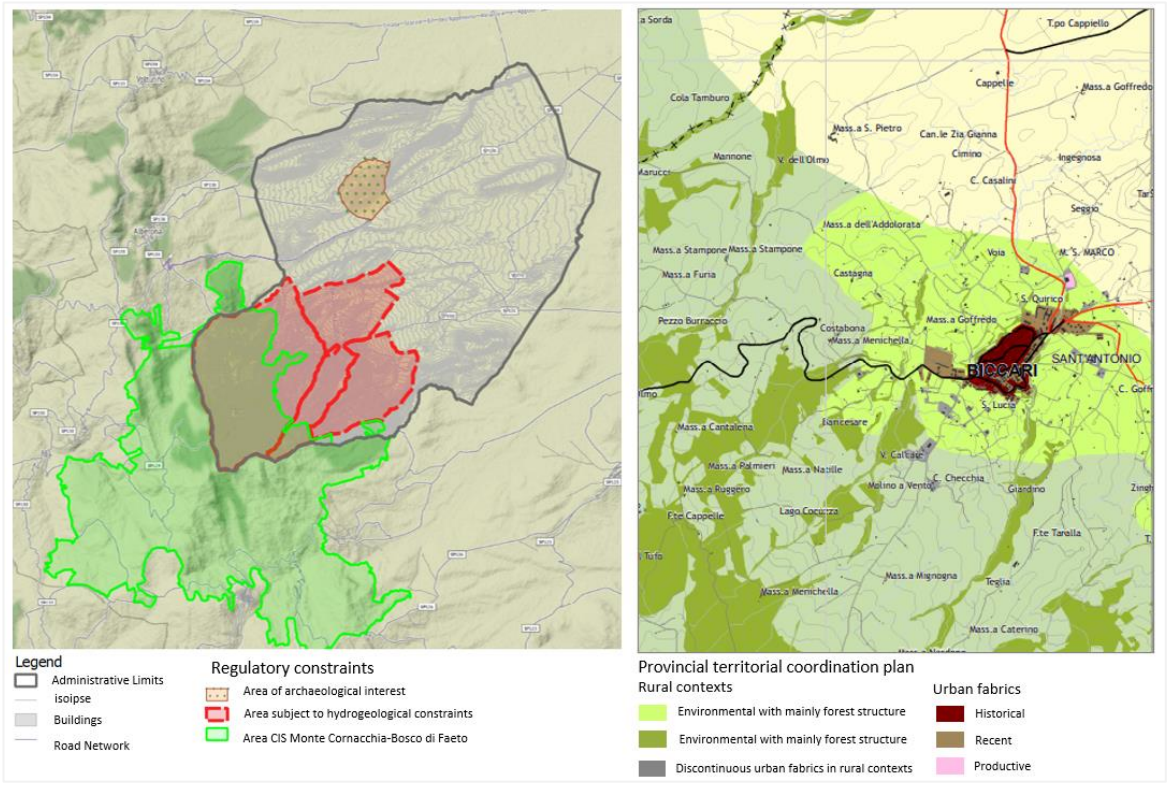


Fig.6 Cognitive framework of superordinate planning

The second step of this work was in the identification of the land use/cover classes (LULC), proving to be a territory mainly of agricultural vocation as shown in Fig.7.

The entire area that goes from the south-west to the south-east of the Tertiveri area falls within those "arable areas in non-irrigated areas" which differ from each other in terms of intensive and extensive agriculture. In the area adjacent to the inhabited center of the municipality of Biccari and on the border of the municipality precisely in the Berdinone area, they have a high value linked both to the characteristics of the agricultural land linked to profitability given the presence of vineyards, orchards and olive groves. Finally, the area of Daunia and Lake Pescara is presented as an area of high landscape and naturalistic value given that they appear to be a "unique settlement" of an environmental type, confirming the high presence of deciduous and coniferous wooded areas.

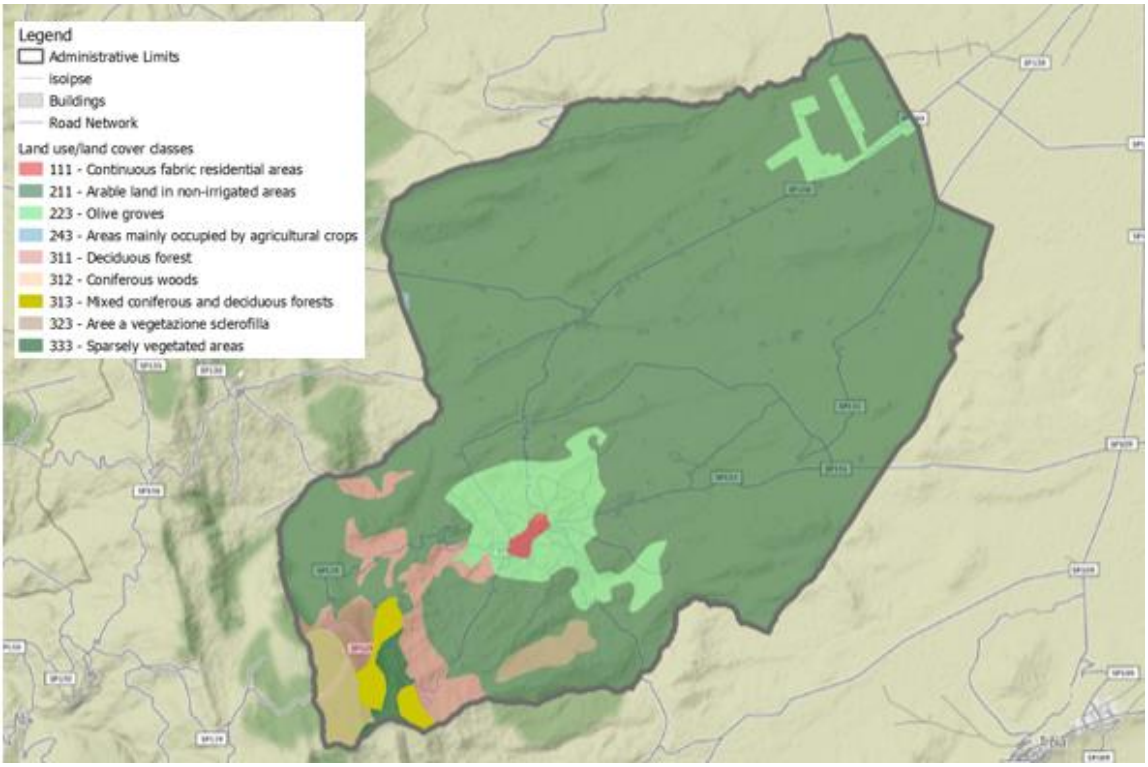


Fig.7 Land use/ Land cover (LULC)

The Biccarese inhabited center was born around that a small community developed around that historical element of the city such as the Byzantine Tower. The cognitive framework of the Municipality of Biccari has made it possible to define the non-transformable areas and the possible transformation areas. In particular, the work is identified in the identification of an area where to insert wind generators in accordance with the mandatory urban planning.

In accordance with the entire previous work, in defining the guidelines for the preparation of the Municipal Urban Plan, the plan itself took into account this aspect and interest in the field of renewable energy, wanting to implement this proposal already in the same area given that the area meets certain requirements such as: (i) Analysis of the inclusion in the landscape; (ii) Visual impact and impact on cultural heritage and landscape; (iii) Analysis and insertion of the project into the environment; (iv) Analysis of geomorphological interactions (v) Landscape impact mitigation measures. The intervention in question envisages for the Municipality of Biccari the installation of a wind turbine east of Biccari in the part below T. Vulgano.

In accordance with the entire previous work, in drafting the Municipal Urban Plan, the plan itself took into account this aspect and interest in the field of renewable energy, wanting to implement this proposal already in accordance with Fig.8. With respect to these analyses, the work defined the number of wind turbines with respect to the average annual and daily energy consumption of families. Biccari estimates several families equal to 1,134.

The average annual energy consumption is approximately 2,700 kWh and the corresponding daily consumption of 8-9.5 kWh per day. To meet the energy demand, it was decided to insert three wind turbines of a height of 150 meters, each with a power of 1 MW, in one of the hamlets of Biccari precisely in the north-west area or Tertiveri and at a distance from the inhabited center of about 2.8 km. Each wind turbine has the capacity and scope to satisfy around 400 homes, defining an overall area of around 168 hectares. The new mini wind farm of Biccari can also be built in the Tertiveri area, for which the wind capacity is satisfactory (https://atlanteeolico.rse-web.it/start.phtml) and will involve the installation of n. 3 Vortex generators capable of producing 1 Mwh of electricity useful for the energy needs of the urban system. The technology adopted will also allow the simultaneous use of the generator installation area, which could be used for the construction

of a Mountain Bike Park capable of representing a further element of sustainable tourist attraction in the city center.

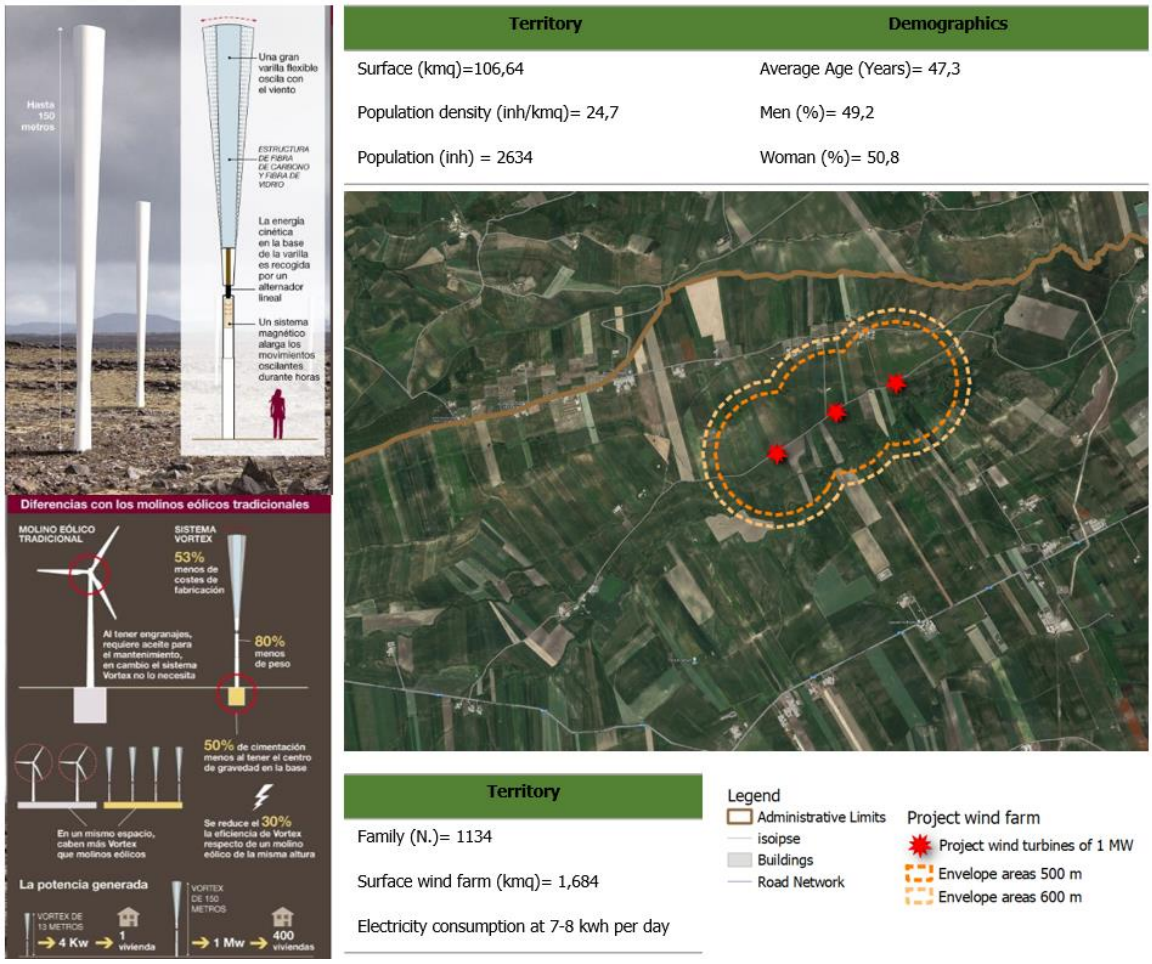


Fig.8 Mini wind farm project in the municipality of Biccari

7. Conclusions

The technical-scientific consultancy activity in support of the Municipality of Biccari has focused on two key objectives, on the one hand, the enhancement of the soil from a sustainable perspective and on the other, the issue of renewable energy. The main objective of this research work, but also innovation, is to propose a cutting-edge technology such as the Vortex Bladeless in the wind power field whose advantages are described within the operating procedure of this work, but at the same time to want to create a positive energy community. Recently, the European community has promoted research projects aimed at optimizing the local energy system through energy efficiency, flexibility, and local production of energy from renewable sources in actions directed towards the (urban) energy transition and climate neutrality, integrating these actions into urban planning processes. Unfortunately, today the real weaknesses can be seen in the reference regulatory framework both at the regional and urban scale. Most urban planning focuses on traditional urban functions (residential, commerce, industry, and services) and promotes a conventional approach. Today there is a strong need for a cultural reversal and a planning process that starts from the local administrations that have a key role in the management of energy and environmental issues, falling within the broader framework of urban planning discipline. This plan aims to take a step forward starting from the premise that urban systems and their processes are constantly evolving with each other, and rural areas change rapidly under unregulated settlement processes, based on different settlement categories. Therefore, the proposal aims to equip an area

like that of Tertiveri through innovative solutions to produce wind energy. The transformation of that urban area indirectly also aims at enhancing the value of the soil and at identifying the set of possible interventions on the territory to also support the farms adjacent to the area. The issue of renewable energy in the production of RES often clashes with political interests and those of small groups of operators. Energy and urban planning must be integrated from a multidisciplinary perspective on normative and methodological bases, supported by effective territorial evaluation tools directly connected with the current problems of land consumption useful for the innovation of environmental evaluation procedures. This work intended to propose a different vision regarding the need to equip urban and territorial systems with low-impact energy production plants, capable of allowing a contemporary functional mixité.

Author's Contributions

The work, although the result of a common reflection, was divided as follows: Fistola R. wrote paragraph 1; Gaglione F. wrote paragraph 2; Fistola R. wrote paragraph 3; Zingariello I. wrote paragraph 4; Gaglione F. wrote paragraph 5.; Fistola R.; Gaglione F and Zingariello I. wrote paragraph 6-7.

References

Ascione, F., De Masi, R. F., De'Rossi, F., Fistola, R., & Vanoli, G. P. (2012). Energy assessment in town planning: urban energy maps. The Sustainable City VII: Urban Regeneration and Sustainability, *WIT Transactions on Ecology and The Environment*, 155, 1205.

Batty, M. (2013). *The new science of cities*. MIT press. https://doi.org/10.7551/mitpress/9399.001.0001

Becchio, C., Bottero, M. C., Corgnati, S. P., & Dell'Anna, F. (2018). Decision making for sustainable urban energy planning: an integrated evaluation framework of alternative solutions for a NZED (Net Zero-Energy District) in Turin. *Land Use Policy*, *78*, 803-817. https://doi.org/10.1016/j.landusepol.2018.06.048

Beck, J., Kempener, R., Cohen, B., & Petrie, J. (2008). A complex systems approach to planning, optimization and decision making for energy networks. *Energy policy*, *36* (8), 2795-2805. https://doi.org/10.1016/j.enpol.2008.02.040

Cheng, S., Chen, Y., Meng, F., Chen, J., Liu, G., & Song, M. (2021). Impacts of local public expenditure on CO2 emissions in Chinese cities: A spatial cluster decomposition analysis. *Resources, Conservation and Recycling*, *164*, 105217. https://doi.org/10.1016/j.resconrec.2020.105217

Connolly, D., Lund, H., Mathiesen, B. V., & Leahy, M. (2010). A review of computer tools for analysing the integration of renewable energy into various energy systems. *Applied energy*, *87* (4), 1059-1082. https://doi.org/10.1016/j.apenergy.2009.09.026

Elleuch, M. A., Mallek, M., & Frikha, A. (2021, December). Energy sources selection for sustainable energy planning using fuzzy multi-criteria group decision-making approach: Tunisia Case Study. In *2021 International Conference on Decision Aid Sciences and Application (DASA)*, 613-617. IEEE. https://doi.org/10.1109/DASA53625.2021.9682399

Fakhari, I., Peikani, P., Moradi, M., & Ahmadi, P. (2021). An investigation of optimal values in single and multi-criteria optimizations of a solar boosted innovative tri-generation energy system. *Journal of Cleaner Production*, *316*, 128317. https://doi.org/10.1016/j.jclepro.2021.128317

Farzaneh, H., Doll, C. N., & De Oliveira, J. A. P. (2016). An integrated supply-demand model for the optimization of energy flow in the urban system. *Journal of Cleaner Production*, *114*, 269-285. https://doi.org/10.1016/j.jclepro.2015.05.098

Fistola, R., Rastelli A., & Zingariello, I. (2021), "Innovazione tecnologica e partecipazione prefigurativa al governo della trasformazione urbana", in: Murgante B., Pede E., Tiepolo M. (a cura di, 2021), Innovazione tecnologica per la riorganizzazione spaziale. Atti della XXIII Conferenza Nazionale SIU DOWNSCALING, RIGHTSIZING. Contrazione demografica e riorganizzazione spaziale, Torino, 17-18 giugno 2021, vol. 09, Planum Publisher e Società Italiana degli Urbanisti, Roma-Milano 2021.

Gaglione, F., & Ayiine-Etigo D. A. (2021). Resilience as an urban strategy: a comparison of resources and interventions in the European Recovery Plans for the green transition. *TeMA - Journal of Land Use, Mobility and Environment*, *14* (3), 501-506. https://doi.org/10.6093/1970-9870/8303

Gaglione, F., & Etigo D. (2022). Accelerate urban sustainability through European action, optimization models and decision support tools for energy planning. *TeMA - Journal of Land Use, Mobility and Environment*, *15* (2), 325-334. https://doi.org/10.6093/1970-9870/9240

Gargiulo, C., & Russo, L. (2017). Cities and energy consumption: a critical review. *TeMA-Journal of Land Use, Mobility and Environment, 10* (3), 259-278. https://doi.org/10.6092/1970-9870/5182

Hettinga, S., Nijkamp, P., & Scholten, H. (2018). A multi-stakeholder decision support system for local neighbourhood energy planning. *Energy Policy*, *116*, 277-288. https://doi.org/10.1016/j.enpol.2018.02.015

Jabareen, Y. R. (2006). Sustainable urban forms: Their typologies, models, and concepts. *Journal of planning education and research*, *26* (1), 38-52. https://doi.org/10.1177/0739456X05285119

Jebaraj, S., & Iniyan, S. (2006). A review of energy models. *Renewable and sustainable energy reviews*, *10* (4), 281-311. https://doi.org/10.1016/j.rser.2004.09.004

Kammen, D. M., & Sunter, D. A. (2016). City-integrated renewable energy for urban sustainability. *Science*, *352* (6288), 922-928. https://doi.org/10.1126/science.aad9302

Lund, H., & Mathiesen, B. V. (2009). Energy system analysis of 100% renewable energy systems—The case of Denmark in years 2030 and 2050. *Energy, 34* (5), 524-531. https://doi.org/10.1016/j.energy.2008.04.003

Lund, H., Duić, N., Krajac, G., & da Graca Carvalho, M. (2007). Two energy system analysis models: a comparison of methodologies and results. *Energy*, *32* (6), 948-954. https://doi.org/10.1016/j.energy.2006.10.014

Lynch, K., (2006). *L'immagine della città*, Marsilio, Padova

Mathiesen, B. V., Lund, H., Connolly, D., Wenzel, H., Østergaard, P. A., Möller, B., ... & Hvelplund, F. K. (2015). Smart Energy Systems for coherent 100% renewable energy and transport solutions. *Applied Energy*, *145*, 139-154.

Mobaraki, A., & Oktay Vehbi, B. (2022). A Conceptual Model for Assessing the Relationship between Urban Morphology and Sustainable Urban Form. *Sustainability*, *14* (5), 2884. https://doi.org/10.3390/su14052884

Mrówczyńska, M., Skiba, M., Sztubecka, M., Bazan-Krzywoszańska, A., Kazak, J. K., & Gajownik, P. (2021). Scenarios as a tool supporting decisions in urban energy policy: The analysis using fuzzy logic, multi-criteria analysis and GIS tools. *Renewable and Sustainable Energy Reviews*, *137*, 110598. https://doi.org/10.1016/j.rser.2020.110598

Noorollahi, Y., Yousefi, H., & Mohammadi, M. (2016). Multi-criteria decision support system for wind farm site selection using GIS. *Sustainable Energy Technologies and Assessments*, *13*, 38-50. https://doi.org/10.1016/j.seta.2015.11.007

Ostadi, B., Moazzami, D., & Rezaie, K. (2007). A non-linear programming model for optimization of the electrical energy consumption in typical factory. *Applied mathematics and computation*, *187* (2), 944-950. https://doi.org/10.1016/j.amc.2006.09.138

Richards, G., Noble, B., & Belcher, K. (2012). Barriers to renewable energy development: A case study of large-scale wind energy in Saskatchewan, Canada. *Energy Policy*, *42*, 691-698. https://doi.org/10.1016/j.enpol.2011.12.049

Salehin, S., Ferdaous, M. T., Chowdhury, R. M., Shithi, S. S., Rofi, M. B., & Mohammed, M. A. (2016). Assessment of renewable energy systems combining techno-economic optimization with energy scenario analysis. *Energy*, *112*, 729-741. https://doi.org/10.1016/j.energy.2016.06.110

Samy, M. M., Almamlook, R. E., Elkhouly, H. I., & Barakat, S. (2022). Decision-making and optimal design of green energy system based on statistical methods and artificial neural network approaches. *Sustainable Cities and Society*, *84*, 104015. https://doi.org/10.1016/j.scs.2022.104015

Schlenzig, C. (1999). Energy planning and environmental management with the information and decision support system MESAP. *International Journal of Global Energy Issues*, *12* (1-6), 81-91. https://doi.org/10.1504/IJGEI.1999.000840

Scorza, F., Pilogallo, A., Saganeiti, L., Murgante, B., & Pontrandolfi, P. (2020). Comparing the territorial performances of renewable energy sources' plants with an integrated ecosystem services loss assessment: A case study from the Basilicata region (Italy). *Sustainable Cities and Society*, *56*, 102082. https://doi.org/10.1016/j.scs.2020.102082

Sethi, M., Lamb, W., Minx, J., & Creutzig, F. (2020). Climate change mitigation in cities: a systematic scoping of case studies. *Environmental Research Letters, 15* (9), 093008. https://doi.org/10.1088/1748-9326/ab99ff

Soares, N., Martins, A. G., Carvalho, A. L., Caldeira, C., Du, C., Castanheira, É., ... & Garcia, R. (2018). The challenging paradigm of interrelated energy systems towards a more sustainable future. *Renewable and sustainable energy reviews*, *95*, 171-193. https://doi.org/10.1016/j.rser.2018.07.023

Tira, M. (2020). About the sustainability of urban settlements. *TeMA-Journal of Land Use, Mobility and Environment,* 361-371. https://doi.org/10.6092/1970-9870/6984

Urban, F. R. M. J., Benders, R. M. J., & Moll, H. C. (2007). Modelling energy systems for developing countries. *Energy policy*, *35* (6), 3473-3482. https://doi.org/10.1016/j.enpol.2006.12.025

Wimmler, C., Hejazi, G., Fernandes, E. D. O., Moreira, C., & Connors, S. (2015). Multi-criteria decision support methods for renewable energy systems on islands. Retrieved from: https://repositorio.inesctec.pt/server/api/core/bitstreams/b48ac2be-a80f-490a-9f03-8932b5bfc908/content

Yuan, M., Liu, Y., He, J., & Liu, D. (2014). Regional land-use allocation using a coupled MAS and GA model: From local simulation to global optimization, a case study in Caidian District, Wuhan, China. *Cartography and Geographic Information Science*, *41* (4), 363-378. https://doi.org/10.1080/15230406.2014.931251

Image Sources

Fig.1: Landscape from the municipality of Biccari;

Fig.2: Population trend between 2001 and 2021 (Source: National Statistical Institute);

Fig.3: Geographical location of the inhabited center and its period of construction (Source: National Statistical Institute);

Fig.4: Energy landscape from the Puglia region;

Fig.5: Comparison of technology on wind turbines and Vortex devices;

Fig.6: Cognitive framework of superordinate planning;

Fig.7: Land use/ Land cover (LULC);

Fig.8: Mini wind farm project in the municipality of Biccari.

Author's profile

Romano Fistola

After earning a Master of Science degree with honors from the Faculty of Architecture at the University of Naples Federico II, he became a full professor at the Department of Civil, Architectural, and Environmental Engineering, also at the University of Naples Federico II. He previously served as an associate professor at the Department of Engineering at the University of Sannio, and as a visiting researcher at the Center for Urban and Regional Development Studies (CURDS) at the University of Newcastle upon Tyne (UK). He has also been elected as a member of the Board of the Italian Regional Science Association (AISRe) and currently serves as an elected member of the regional steering committee of the National Institute of Urban Planning (INU) Campania. Additionally, he collaborates on several research projects in the field of urban and regional planning. His primary research interests include the city as a complex system, smart cities, digital urban twins, augmented reality and the city, urban entropy, temporary cities, urban risk and climate change, and urban functions and transport interactions.

Federica Gaglione

She is an engineer, PostDoc research fellow at Department of Engineering, University of Sannio, Benevento, Italy. She received her Ph.D in Civil Systems Engineering at the University of Naples Federico II. The research topics addressed in recent years refer to accessibility to proximity services for vulnerable groups of the population. From August to December 2019, she served as a Visiting Researcher at the University of Aberdeen (UK) and from July to September 2022 Visiting Researcher at the University of Edinburgh (UK) carrying out research on urban accessibility in the context of climate change and sustainability, leveraging geographic big data through GIS and programming languages.

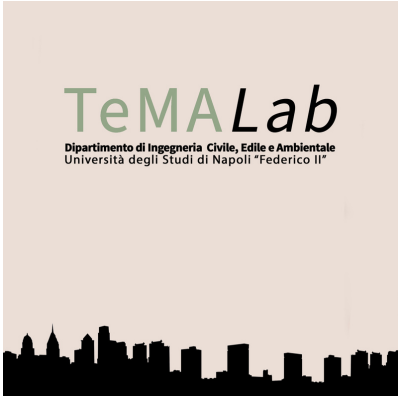
Ida Zingariello

She is architect and BIM expert is PhD Student in Information Technologies for Engineering at the University of Sannio. In 2014 she attended the University Master's in "Progettista Esperto in Tecnologie Emergenti" at IN/ARCH-Istituto Nazionale di Architettura and in 2018 the University Master's "BIM-Building Information Modeling" at Sapienza University of Rome. Expert in Digital Architecture, she collaborated with a lot of architectural offices around the world investigating the interface between real and virtual architecture.

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 (2023) 201-219
print ISSN 1970-9889, e-ISSN 1970-9870
DOI: 10.6093/1970-9870/9469
Received 24th October 2022, Accepted 18th April 2023, Available online 30th April 2023

www.tema.unina.it

Investigating the socio-spatial logic of historic urban areas through space syntax

A comparative analysis of the Roman towns Cosa, Nora, Timgad and Thuburbo Majus

Chiara Garau [a], Alfonso Annunziata [a]*, Claudia Yamu [b], Dario D'Orlando [c], Marco Giuman[c]

[a] Department of Civil and Environmental Engineering and Architecture (DICAAR), University of Cagliari, Italy
email: cgarau@unica.it
ORCID: https://orcid.org/0000-0002-6239-5402
email: annunziata.alfonso@yahoo.it
ORCID: https://orcid.org/0000-0003-4740-4291
* Corresponding author

[b] Department of Built Environment, Oslo Metropolitan University, Norway
e-mail: claudia.yamu@oslomet.no
ORCID: https://orcid.org/0000-0002-2847-4975

[c] Department of Humanities, Languages and Cultural Heritage, University of Cagliari, Italy
email: dario_dorlando@libero.it
ORCID: https://orcid.org/0000-0002-9270-4608
email: mgiuman@unica.it
ORCID: https://orcid.org/0000-0002-0928-2791

Abstract

Starting from the Late Republican and First Imperial ages, the Roman Mediterranean has seen the development and transformation of urbanised areas due to the newly gained stability conferred by the so-called Pax Augusta. This phenomenon has significant consequences in transforming pre-existing urban structures and establishing a large number of newly founded urban areas. This study aims to address a gap in the existing literature by developing a method to analyse the configuration of historical urban sites to understand the social and cultural antecedents of the transformation and development of urban areas in the Roman era. The study builds on Space Syntax theories and techniques to develop an analytical protocol that combines syntactical analysis and statistical analysis to measure and compare spatial, visual and social relationships in four urban Roman sites in the Mediterranean. The selected areas of study are the urban sites of Nora and Cosa in Italy, of Timgad in Algeria and of Thuburbo Maius in Tunisia. The study areas include planned urban sites constituted by a grid structure (Cosa and Timgad) and cities with continuity of life (Nora and Thuburbo Maius) formed by an organic inspired spatial layout. The study significantly contributes to archaeology and urban studies by proposing a combination of methods that associates distinct analytical techniques to investigate the large-scale configurational properties of historical urban environments whose spatial structure and, therefore, social logic have been only partially explored.

Keywords

Roman urbanism; Space syntax; Configuration; Spatial structure; Social logic of space; Movement.

How to cite item in APA format

Garau, C., Annunziata, A., Yamu, C., D'Orlando, D., & Giuman, M. (2023). Investigating the socio-spatial logic of historic urban areas through space syntax. *Tema. Journal of Land Use, Mobility and Environment*, *16* (1), 201-219. http://dx.doi.org/10.6093/1970-9870/9469

1. Introduction

Roman culture can be considered an urban culture (Stoger & Brandimarte, 2015). The Roman Empire included, in fact, more than 2000 urban sites. Intensive investigations on preserved roman urban sites focus on the urban space of roman cities, and on the relation between private and public space (Zaccaria Ruggiu, 1995), to understand social and economic implications of spatial organization (Stoger & Brandimarte, 2015). Urban space is thus considered a place where the relational structure that underpins a culture's political, economic, and social existence manifests and reproduces itself (Battistin, 2021; Stoger & Brandimarte, 2015; Stöger, 2011; Van Nes, 2009). More precisely, focusing on a structuralist approach, spatial structures from the Roman age are increasingly being explored to demonstrate the social logic of urban spaces, and a growing consensus has emerged about the social value of places (Stöger, 2011). From this point of view, space can be defined as an intrinsic component of social and cultural forms. Individual and social practices incorporate specific spatial forms and depend on specific structures of co-presence (Harcharan Pappu, 2018): the actions of congregating, interacting, moving, and socialising constitute spatial configurations (Yamu et al., 2021; B. Hillier & Hanson, 1984; B. Hillier, 2007). Configuration can be defined as the set of topological relations among inter-dependent spatial elements comprised in an overall structure. Topological relations determine access and visual connections among spaces, thus generating patterns of integration and segregation that influence the distribution of movement and co-presence across a spatial system (V. Cutini & G. Rabino, 2012; B. Hillier, 1999, 2007; B. Hillier & Hanson, 1984). As a result, the mutual relation of space and social practices is not understood at the level of the intrinsic, geometric properties of a space, but at the level of its extrinsic configurational properties, resulting from the relative position of a space in a spatial structure (Marshall, 2005). Consequently, from the perspective of archaeological studies, the configurational analysis of space is relevant for understanding the social, political, and economic systems of ancient cultures (Battistin, 2021; Kubat et al., 2019; Stöger, 2011; Van Nes, 2014). Moreover, the configurational analysis of spaces of ancient cultures is relevant, from the perspective of urban studies, to investigate the persistence of specific socio-spatial processes and to recognise configurations respondent to persistent social aspects of urban spaces, including access, encounter, residents and non-residents interactions, diversity, vibrancy, vitality, and control of spaces. Over time, empirical studies have demonstrated the validity of using syntactic analysis through space syntax techniques to investigate the socio-spatial logic of built environments. Therefore, this study builds on space syntax theories and methods to describe the urban layout of four Roman cities.

In particular, the study focuses on the Mediterranean area and investigates the cities of Nora and Cosa in Italy, of Timgad in Algeria and of Thuburbo Maius in Tunisia. Specifically, this article describes the utilisation of axial and segment angular analysis to investigate historic urban sites.

The article is structured in five sections: following the introduction and clarification of the research objective, the section 3 presents Roman Urbanism and to space syntax analysis concepts. The methodology and case study are then described in section 4. The results of the analysis are presented and discussed in sections 5 and 6. Section 7 concludes the paper by summarising the study's findings and presenting hypotheses for future research development.

2. Research aim

This study addresses a gap in the research on the spatial structures of ancient cities. Indeed, the literature on syntactic and statistical analysis applied to investigating the social antecedents and consequences of spatial structures is limited. Web of Science and Scopus databases provide 15 and 21 results, respectively, related to the field of Archaeology, and including the terms "ancient" or "archaeolog*" or "space syntax". Moreover, the studies based on the syntactic analysis of Roman cities are focused on specific locations, in particular Ostia and Pompeii. As a result, the study's relevance for archaeology and urban studies lies in developing a method

that combines distinct techniques of syntactic and statistical analysis and in its application to investigate and compare the configurational properties of Roman cities with largely unexplored spatial structures.

3. Theory

The increasing significance of space as a primary object of research for understanding the social, political and economic structures of ancient cultures has led to the rising use of methods that include space syntax techniques to investigate historical spatial structures (Stöger, 2011). Space Syntax refers to concepts and analytical tools that provide the basis for interpretive models of socio-spatial phenomena (B. Hillier, 2007; B. Hillier & Hanson, 1984; van Nes & Yamu, 2021; Lee et al., 2023). Space Syntax theory is based on two key concepts: i) space is a fundamental aspect of human activities, and ii) the social relevance of space lies not in its intrinsic properties but in the interrelations among the elements of a spatial structure. The first concept implies that each basic action incorporates a specific geometry: movement is linear, interaction requires bi-dimensional convex spaces, and the perception of the environment is mediated by the articulated surface of the visual field, the isovist (B. Hillier, 2007; Hillier & Hanson, 1984; Turner et al., 2001; Turner, 2007).
The second concept implies that spatial configuration is structured by a formal logic that reflects and reproduces the relational structures underpinning social, economic and political systems.
As a result, configurational analysis via space syntax techniques represents a relevant contribution for the understanding of the interdependencies between the structure of spatial systems and social and cultural practices (Francini et al., 2017; Li & Zhang, 2023) in the field of accessibility analysis (Guida & Caglioni, 2020; Gaglione et al., 2019; Boglietti & Tiboni, 2022) urban sustainability assessment (Zali et al., 2016), urban planning and urban regeneration (Gargiulo & Sgambati, 2022; Tsai & Chang, 2023).

In particular, the theories of the movement economy and of centrality as a process explain the relationship between spatial configuration, natural movements, economic activities and space production (B. Hillier, 1996, 1999, 2007; Hillier & Hanson, 1984). The movement economy concept claims that the configuration of the urban layout influences the distribution of movement and that the concentration of movement along specific routes, in turn, influences the distribution of land uses, determining the emergence of vibrant centres and of quieter monofunctional areas. The concentration of movement and urban functions in specific areas can determine, in a sub-sequent stage, the iterative adaptation of the urban spatial structure consisting in the intensification and densification of the spatial grid, thus generating a recursive socio-spatial process denominated centrality as a process (B. Hillier, 1996, 1999, 2007; Hillier & Hanson, 1984).
Space syntax examines the interdependence of public spaces and street segments within a built environment, by measuring three variables: the degree centrality, which refers to the number of spaces contiguous to each street segment; the closeness centrality, which denotes the to-movement potential of a street segment with respect to other segments, and the betweenness centrality, which signifies the through-movement potential of a street segment relative to all other spatial elements. These parameters represent the accessibility potentials of a given spatial system, and are measured, respectively, by the indicators Connectivity, Integration and Choice. Notably, both to- and through-movement potentials can be evaluated using three alternative definitions of distance: metric distance is the number of metric units between an origin and a destination; topological distance is the number of turns – or intermediate spaces– along the route from a space of origin to a space of destination; lastly, geometric distance is the sum of angle deviations along the route from an origin space to a destination space (Hillier, 1999, 2007; Hillier & Hanson, 1984; Turner, 2007; Turner et al., 2001).
Depending on the considered form of spatiality, space syntax offers multiple representations of spaces and specific configurational metrics (Koutsolampros et al., 2019; Turner, 2007; Turner et al., 2001).
A review of the existing literature on the syntactic analysis of ancient urban sites underlines a broad set of metrics utilised to measure configurational properties at both macro and micro scales. Configurational metrics

include density and intervisibility between entrances (Laurence, 2010; Van Nes, 2009, 2014); integration of public and private spaces (Assassi & Mebarki, 2021; Laurence, 2010; Stoger & Brandimarte, 2015; Van Nes, 2014; van Nes & Yamu, 2021); visual integration and connectivity (Assassi & Mebarki, 2021; Battistin, 2021; Crawford, 2019; Stoger & Brandimarte, 2015); axial connectivity, integration and choice (Battistin, 2021; Crawford, 2019; Van Nes, 2009, 2014), segment connectivity, integration and choice (Battistin, 2021; Crawford, 2019); as well as agent-based models (Crawford, 2019). Findings from the investigation of configurational aspects underline the centrality of movement economy and residents and non-residents relation as the fundamental socio-spatial processes that structured Roman cities (Stoger & Brandimarte, 2015; Laurence, 2010; Assassi & Mebarki, 2021), the relevance of visual control as a spatial criterion informing the urban structure at the global and local scale (Assassi & Mebarki, 2021; Stoger & Brandimarte, 2015), and the co-relation among the density of economic activities in a space, number of contiguous spatial elements, density and inter-visibility of building entrances and integration of private and public spaces (Gundogdu & Ozkok, 2017; Van Nes, 2009, 2014). Configurational metrics are also utilised to investigate similarities and differences among urban sites resulting from the spatial manifestation of specific cultural factors (Eskidemir & Kubat, 2020; Kubat, 1997, 2010; Kubat et al., 2019) and the relevance of urban configuration in structuring the ritual landscape in a Roman city (Crawford, 2019). Lastly, Battistin (Battistin, 2021) compares distinct scenarios of reconstruction of the urban layout of Falerii Novi, in terms of an alteration of the centrality of routes and intramural relations among central and marginal areas.

Consequently, configurational indicators, such as Integration, Normalised angular Integration, and Normalised Angular Choice, emerge as central metrics for describing the spatial structure of urban areas. These findings are the basis of a method for comparing the configurational properties of four urban sites of the Roman Imperial Period, presented in the subsequent sections.

4. Materials and Methods

The study develops a quantitative description of the urban layout of four urban sites of the Roman Imperial age by integrating configurational metrics determined by Axial Analysis, Segment Angular Analysis and Visual Graph Analysis. The areas of study include the urban sites of Cosa and Nora in Italy, Timgad in Algeria, and of Thuburbo Maius in Tunisia. The research locations are situated in the Mediterranean area and represent a variety of urban configurations. In fact, both Cosa in Italy and Timgad in Algeria have a regular urban form based on a rectangular grid (grid street plan). Nora, in Italy and Thuburbo Maius in Tunisia, present an organic structure.

Four steps constitute the analysis: i) Selection of study areas, data collection and reconstruction of the site plan of the cities investigated; ii) Construction of the Axial Map and of the Segment Map of the study areas; iii) Measurement of conditions of integration and segregation of spatial elements via the measurement of Connectivity, axial integration (AI) and topological distance or steep depth (SD) of the Forum from the most integrated space; iv) Identification of centre and sub-centres of and main routes via normalised angular integration (NAIN), normalised angular choice (NACH). Global and local relations of intervisibility are part of this study and will be described in a future article.

The reconstruction of the system of open spaces of the urban sites is based on on-site plans retrieved from scientific literature, georeferenced and reproduced in a GIS environment. After importing the plans of public spaces into DepthmapX, the Axial Map, Segment Map, and Visual Graph for the study areas are created.

The axial map reproduces the spatial layout as the minimum set of longest lines of movement intersecting the spaces in the study area (Al-Sayed et al., 2014; B. Hillier, 2007; van Nes & Yamu, 2021). The Segment Map is generated in DepthmapX from the axial map, dividing axial lines at intersections. As a result, the Segment Map represents the urban layout as a set of segments delimited by consecutive intersections.

Segment and axial analysis focus on the metrics of connectivity, integration and choice. Connectivity refers to the number of spaces contiguously connected to a space of origin and measures a local aspect of centrality, denominated degree centrality. Integration expresses the distance between any origin space and all destination spaces in a global spatial system; segment angular integration, in particular, measures distance among spatial elements in terms of the sum of angular deviations along the routes from any space of origin to all spaces of destination.

Choice measures the probability that a space is comprised of the least cost routes from any space of origin to any space of destination. As a consequence, integration measures the to-movement potential of a space, and, thus, its significance as a destination; choice measures the through movement potential of a space and hence its relevance as a space of movement.

Choice and Integration are normalised to enable the comparison of distinct spatial layouts. Normalised measures, in fact, account for the influence, on integration, of the size of the spatial layout considered and of the type of configurational structure on choice values (Hillier et al., 2012; van Nes & Yamu, 2021).

Moreover, the co-relation of global and local choice – calculated, respectively, at radius n and at the metric radius of 200 meters – is measured to identify spatial elements with a significant potential for the intensification of socio-economic activities. The 200 meters radius is selected to discern local and global patterns. Due to the limited surface area of the excavated parts of the selected urban sites, the coincidence of global and local metrics is determined by the superior values of the local analysis radius. Specifically, the coefficient of determination R^2, which measures the co-relation of NACH at radius n and of NACH at radius 400 meters, varies from 0.92, for the urban site of Cosa, to 0.99 for Nora and Thuburbo Majus. Moreover, the 200 meters radius is a relevant parameter for measuring NACH, commonly used in walkability research (Bielik et al., 2018; Dhanani et al., 2017).

Axial Intelligibility measures the extent to which the global structure of a spatial system can be inferred from its local configurational properties. It is formalised as the co-relation between local connectivity and global integration. An intelligible space is a system where the perceivable properties of a space, and the number of spatial elements it is connected; it is a good predictor of its non-perceivable properties, related to its functional significance in the global structure (Hillier, 2007). The selected areas of study are described via a set of configurational metrics and compared via measures of central tendency and dispersion. The following section discusses the criteria for selecting the case study.

4.1 Selection of the areas of study

The Roman expansion in the Mediterranean resulted in the formation of several urban landscapes, each with its own distinct traits and development. The analysis of four cities investigates the issues of spatial and perceptual interdependency in Roman cities: the foundation cities of Cosa and Timgad and the organic evolving cities of Thuburbo Maius and Nora. The criterion is to prioritise cities situated in the southern part of the Empire in Punic-culture areas (Thuburbo Maius, Timgad and Nora) and presenting optimal grid street plans (Timgad and Cosa). The authors concentrate on two distinct types of urban evolution in order to verify if spatial alterations, during the Roman age of the organic evolving cities can be framed in terms of specific cultural identifiers. From this perspective, the four cities can be perceived as two main case studies (Nora and Thuburbo Maius) and two control samples (Cosa and Timgad) (Fig.1).

4.2 The case studies: a deeper focus on the 'organic' cities Thuburbo Majus and Nora)

Thuburbo Majus is one of the main towns of Tunisia known during the Late Imperial period as Colonia Iulia Aurelia Commoda Thuburbo Maius. The city, originally a Punic centre (Gascou, 1988), is located in the Fahs plan in the Miliane ouad, 60 km south-west from Tunis-Carthage (Ben Akacha, 2011). After the Roman conquest, the city becomes first a municipium thanks to the emperor Hadrianus (117-138 AD) and lately a

Colonia under Commodus (See Figg.1 and 2). The promotion generated several benefits for Thuburbo, including the installation of the forum, which altered the urban plan (Ben Akacha, 2011) and the concurrent construction of a temple dedicated to Mercurius Augustus to commemorate the emperor. The town's history suggests the complexity of its urban plan, which has developed over many centuries and experienced extensive reconstruction after the Roman conquest.

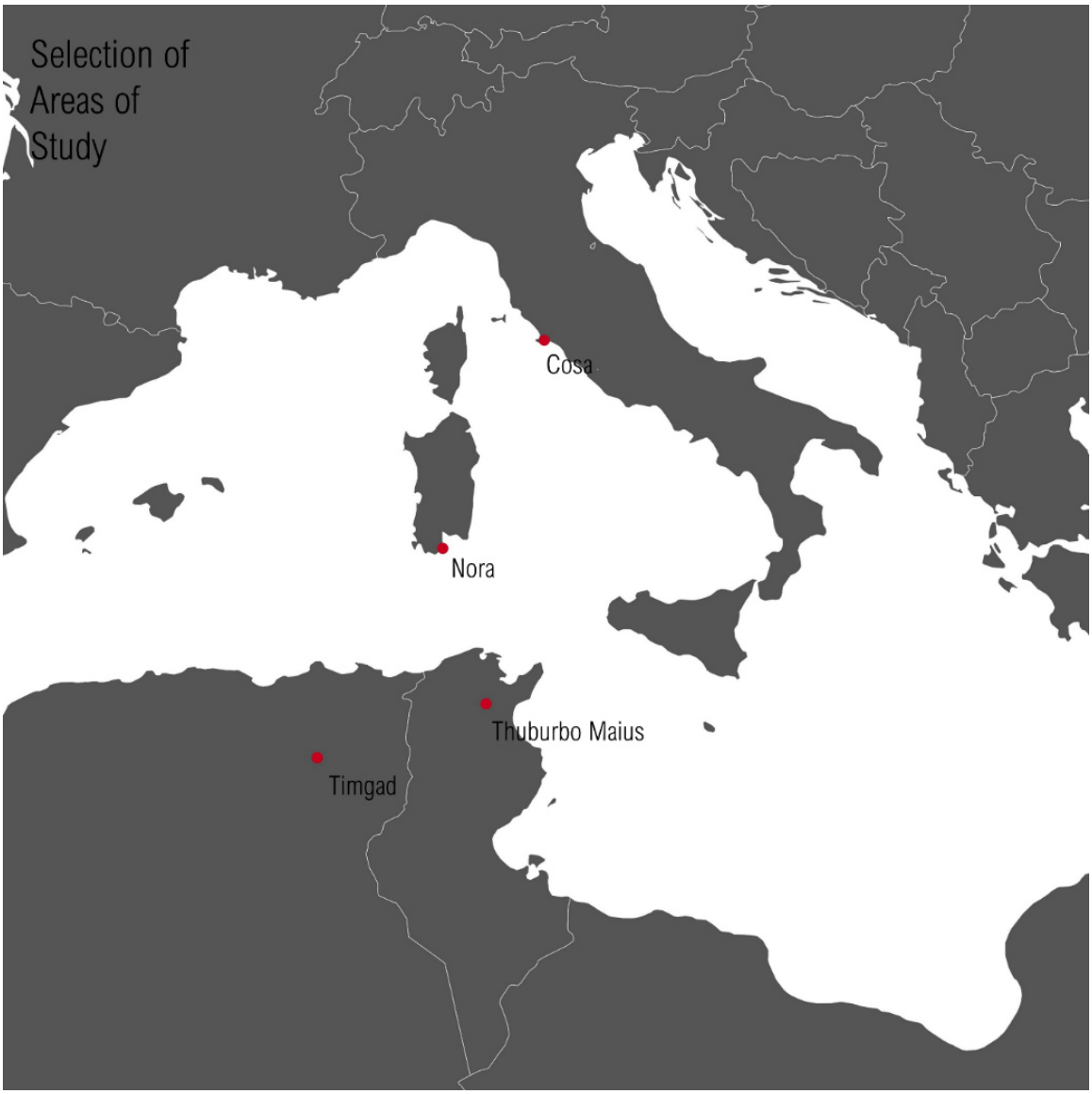


Fig.1 Selection of the areas of study

Nora is one of Sardinia's major Punic-Roman urban towns. The city is situated on the island's southern coast (Bonetto, 2009) (See Figg.1 and 2). The city's southern section (Bonetto, 2009) was significantly altered by the construction of the Roman Forum in the first century BCE (Ghiotto, 2009). A sensitive issue in Nora's study is the ancient coastline and the bradyseism phenomenon that affects the isthmus, mostly in the southern and eastern gulfs. Although the harbour's position is unknown, scholars hypothesised that the docks may be in either the western or eastern gulfs (Finocchi, 1999), (Bonetto et al., 2014, 2017).

The city was subjected to a massive urban expansion during the Punic period (late 6th-3rd century BCE). The resulting intricated configuration of roads and built-up areas of the central district, denominated 'kasbah' (Pesce, 1957), has informed the city's urban plan throughout its history. After the Roman conquest (238/237 BCE), the settlement reached the status of municipium in the 1st century BCE. In this same period, it is possible

to identify the construction of the Roman Forum and the modification of the orientation of buildings and roads. A deep renewal of the urban structure dates back to Severan times, when various traces suggest the construction of a paved road throughout the settlement and the readjustment of the northern blocks (Angiolillo et al., 2014; Bonetto et al., 2017).

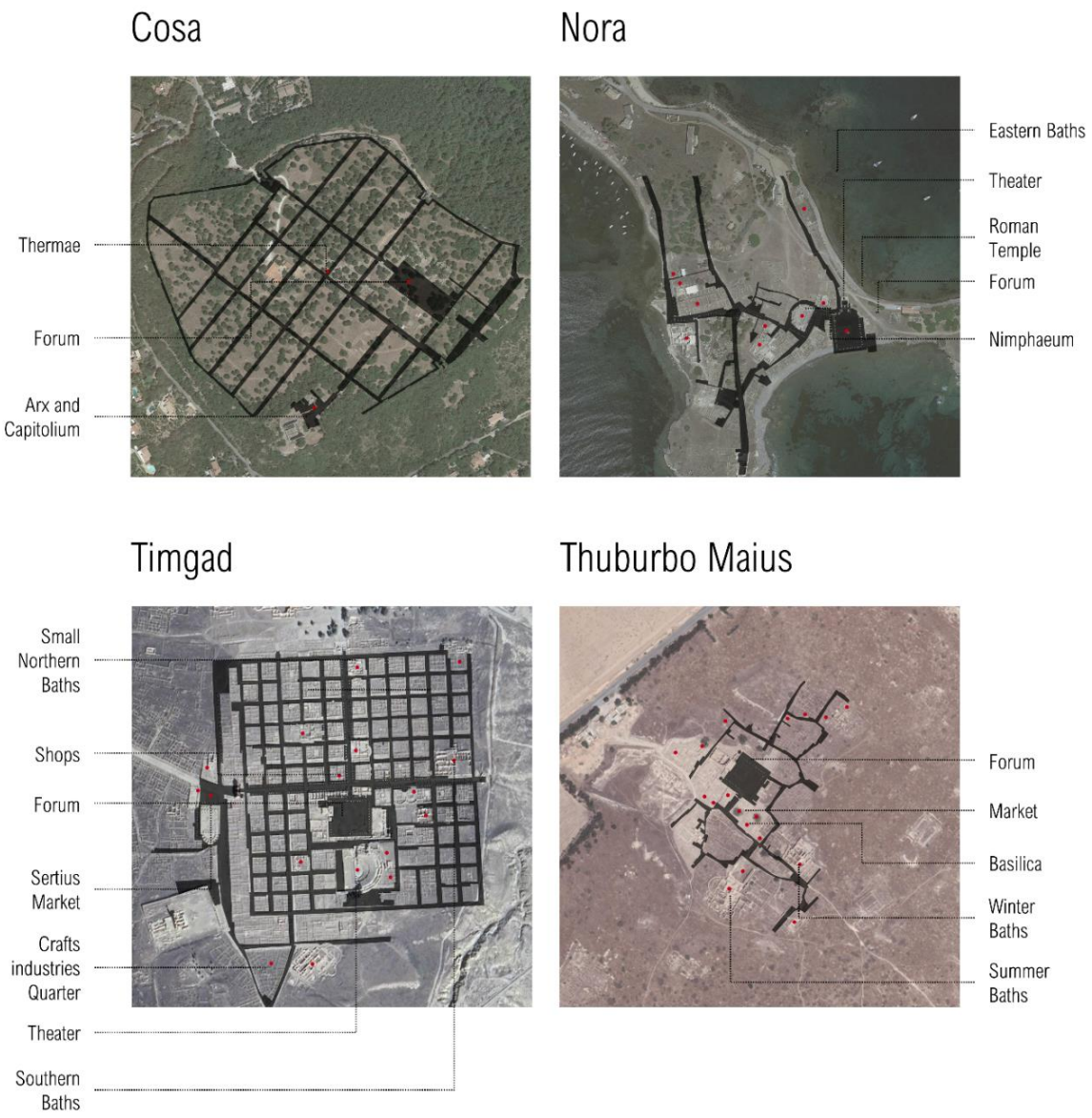


Fig.2 The system of public spaces in the selected urban sites

The city of Cosa, situated in the area of the contemporary Ansedonia harbour (Figg.1 and 2), is the focal point of a large agricultural production area (Carandini et al., 2002; Casarotto et al., 2016). The city was founded in 273 BCE as a Colonia Latina on the lands of the former territory of Vulci and then became a colony in 197 BCE (Fentress & Perkins, 2016(Conventi, 2004). The city of Cosa is an excellent example of an ex-Novo middle-Republican grid settlement and provides insight into the issues and features of an integrated urban design. Excavations in this area in the last 50 years, have been mainly conducted by the archaeologist Frank Brown and the American Academy in Rome (Brown, 1980; Dyson, 2013).

Material is abundant about the major structures in Cosa's urban plan, but there is a paucity of data on the remaining areas. Moreover, during the Republican era, important elements of numerous Cosa's public structures are disregarded. (Fentress & Perkins, 2016).

The Arx, in the city's south-western district, one of the city's holiest monuments, acting as the Capitolium's seat [44], is connected to the Forum via the Via Sacra. (Dyson, 2013). However, the Forum/Curia-Comitium complex, located in the eastern part of the city, is the main focus of the city's excavation effort, allowing a comprehensive view of those structures' development (Brown et al., 1993; Fentress & Bodel, 2003; Fentress & Perkins, 2016) and their visual integration with the road system. The Forum, excavated since 1950, was constructed soon after the city's demise in the first quarter of the 2nd century BCE. The curia was reconstructed a few years later (after 180 BCE) above a previous private house on the north-eastern side of the Forum (Fentress & Perkins, 2016). The Forum (m 88 x 35) had a monumental entrance in the form of a three-aisled arch (fornix) made in concrete (Brown et al., 1993) on the western side of the portico and a secondary entrance in the north-western corner linked to the street Q, which entered in the Forum and was later incorporated in the colonnade (Brown et al., 1993).

The city of Thamugadi, in contemporary Algeria, is one of the best examples of a Roman-era grid street plan (Figg.1 and 2). In the words of J.B. Ward Perkins, Timgad represents a "textbook example" of an organised city designed to establish a proper relation between domestic and civil spaces. The settlement has been used as a model for understanding the geometrical indications of how to build a city. Pierre Gros has highlighted how this sentence must be contested due to the obvious inconsistencies in the urban layout, which nonetheless conveys a positive impression of a Roman colonial city (Gros & Torelli, 1988). Around 100 AD, the Legio III Augusta under the emperor Trajanus established the Colony on the plateau of Aurès, a border region of North Africa that had not yet been pacified. The city is 328x317 meters in dimensions and is divided into four blocks by two major roadways that intersect not far from the forum. The original design probably foresees the construction of 144 blocks measuring 20 meters on each side, but the western section was left incomplete. This original design has regular spaces for the realisation of civic spaces. Four spa complexes, a market, and one library are located on the normal grid, while a regular lot is set aside for the theatre, which was completed 50 years after the colonisation.

The spread of the city beyond the city walls is significant from the perspective of this article. The Capitolium, for example, was built extramoenia, years after the Colony's foundation, and had the same dimensions as the Forum. Furthermore, the Decumanus' southern entrance is decentralised from the Forum, emphasising its distinctiveness from the military castra's layout. (Ballu, 1897; Ballu et al., 1905). The grid street plan is the object of several studies, resulting in a vast literature on the proper interpretation of the grid's design and its relationship to military camps (Rezkallah & Marmi, 2018).

5. Results

The configurational metrics provide a quantitative description of the spatial structure of the four studied urban sites (Tab.1). Axial analysis reveals the structure of integrated and segregated spaces (Figg. 3 and 4). In Timgad and in Cosa, the Decumanus is the most integrated space, with integration values of 3.33 and 2.09, respectively. In Nora, the Decumanus emerges as the most integrated space (AI= 2.76), and in Thuburbo Majus, the forum and the contiguous spaces are the most integrated elements. As a result, the topological distance of the forum from the most integrated spatial elements is 0, in Thuburbo Majus, 1, in Timgad, 2 in Cosa and 3 in Nora.

Measures of central tendency reveal a superior average integration in Timgad. Thuburbo Majus has modest values. The standard deviation and the variation coefficient underline a clear distinction of integrated, vibrant spaces and of quieter segregated areas in Nora.

Indicator	Statistic	Area of Study			
		Cosa	Nora	Thuburbo Maius	Timgad
Axial Integration	Number of Lines	43	40	43	56
	Min Value	0.636	0.581	0.473	0.678
	Max Value	2.099	2.763	1.177	3.326
	Mean	1.247	1.290	0.787	1.741
	Median	1.223	1.218	0.768	1.678
	Standard Deviation	0.371	0.429	0.182	0.501
	Variation Coefficient	0.297	0.333	0.231	0.288
	IQR	0.459	0.598	0.281	0.639
		Cosa	Nora	Thuburbo Maius	Timgad
Relativised Entropy (Axial)	Min Value	1.483	1.292	1.887	1.349
	Max Value	2.871	2.988	3.152	3.177
	Mean	1.972	1.979	2.520	1.877
	Median	1.941	1.930	2.536	1.771
	Standard Deviation	0.309	0.360	0.327	0.408
	Variation Coefficient	0.157	0.182	0.129	0.217
	IQR	0.366	0.512	0.500	0.380

Tab.1 Results of the axial analysis and of the segment angular analysis

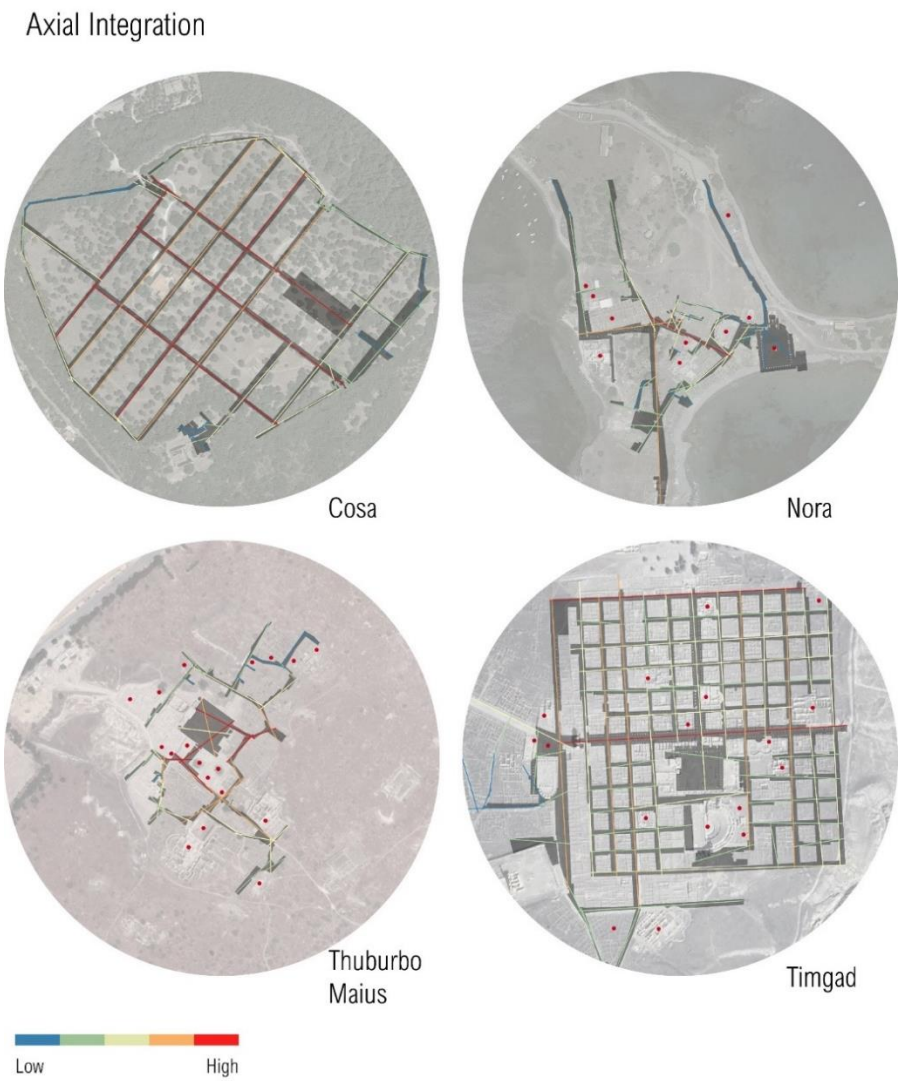


Fig.3 Distribution of values of Axial Integration in the selected urban sites

Cosa presents a clear distinction between the integrated elements of the regular grid that define the core area and the segregated spaces of the Arx and along the perimetral fortifications. In Timgad, a distinction emerges between the rectilinear continuous streets, that form the grid structure of the original urban core, and the spaces that form the organic structure of the later urban development. The organic structure of Thuburbo Majus reveals a more subtle differentiation.

However, the edge effect might limit the understanding of a spatial layout via Axial Integration. The edge effect refers to the disproportionate segregation of spaces at the axial model's edge (B. Hillier, 2007).

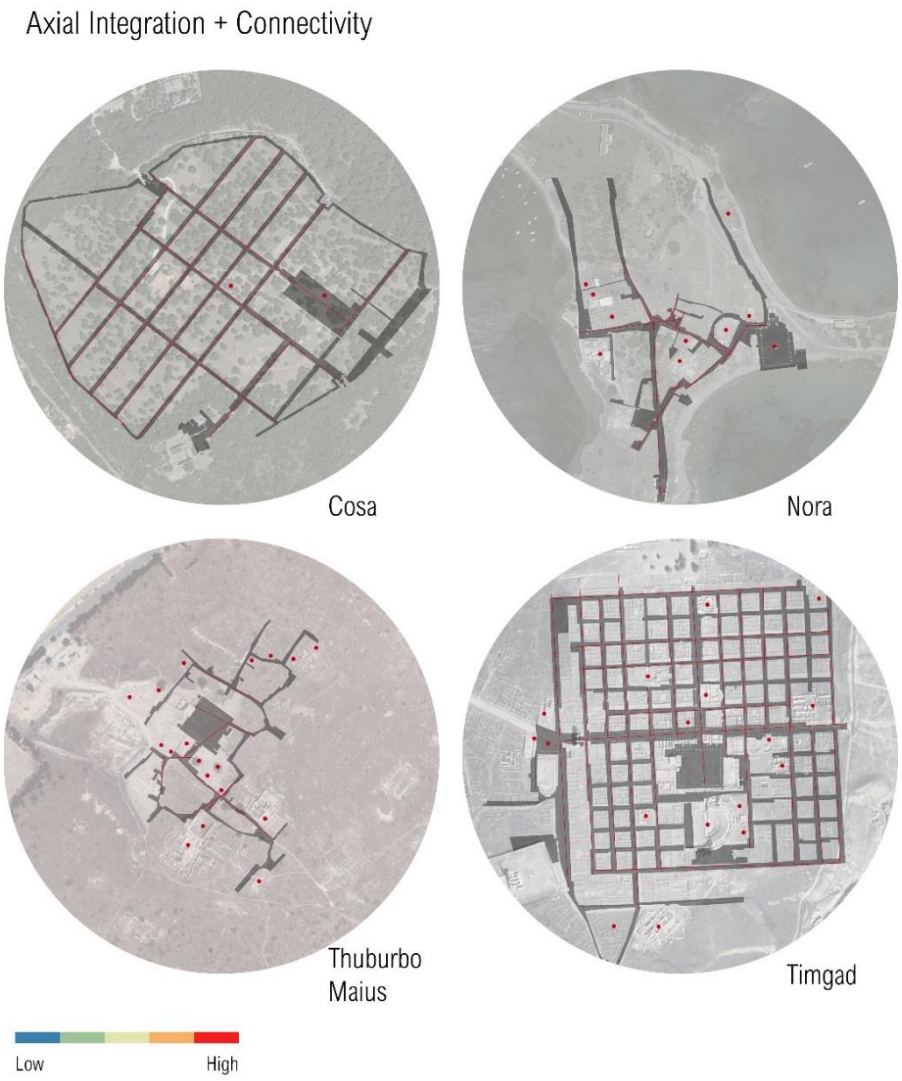


Fig.4 Emergence of spatial structures constituted by the most connected and integrated lines

The correlation between global axial integration and local connectivity underlines that the regular grid structure of Timgad and Cosa as well as the urban layout of Nora are more understandable than the organic structure of Thuburbo Majus. The coefficient of determination R^2 is 0.77 for the urban layout of Timgad, 0.79 for Nora, 0.74 for Cosa and 0.33 for the spatial layout of Thuburbo Majus (See Fig.4).

Moreover, by selecting the axial lines comprised in the first and second quintiles of the values of Integration and Connectivity, a spatial sub-structure of spaces relevant for orientation across the urban sites emerges.

In Cosa, this spatial sub structure presents a coefficient of determination R^2 equal to 0.87 and it comprises 12 spaces, including the Cardo and the Decumanus and the longest longitudinal north-south and transversal east-west routes. In Nora 13 spaces present significant local and global configurational properties including the

main east-west street, the perpendicular street directed towards the coast and the spaces contiguous to the Theater.

The Coefficient of determination R^2, measured for this spatial sub-structure, is equal to 0.73. In Thuburbo, a spatial structure emerges comprising 8 spaces, including the main east-west street and the spaces contiguous to the Forum. Yet, the co-relation of connectivity and integration, measured in Thuburbo is marginal. The Coefficient of determination R^2 is equal to 0.13. Thus, the analysis underlines that the function of a space in the urban layout cannot be inferred from the number of spaces it is contiguous to. Lastly, in Timgad, the sub-structure of spaces relevant for spatial orientation is constituted by 19 spaces, including the Cardo and the Decumanus and the long linear streets that structure the regular grid of the center of original formation. Yet, this spatial sub-structure presents a modest coefficient of determination R^2, equal to 0.47.

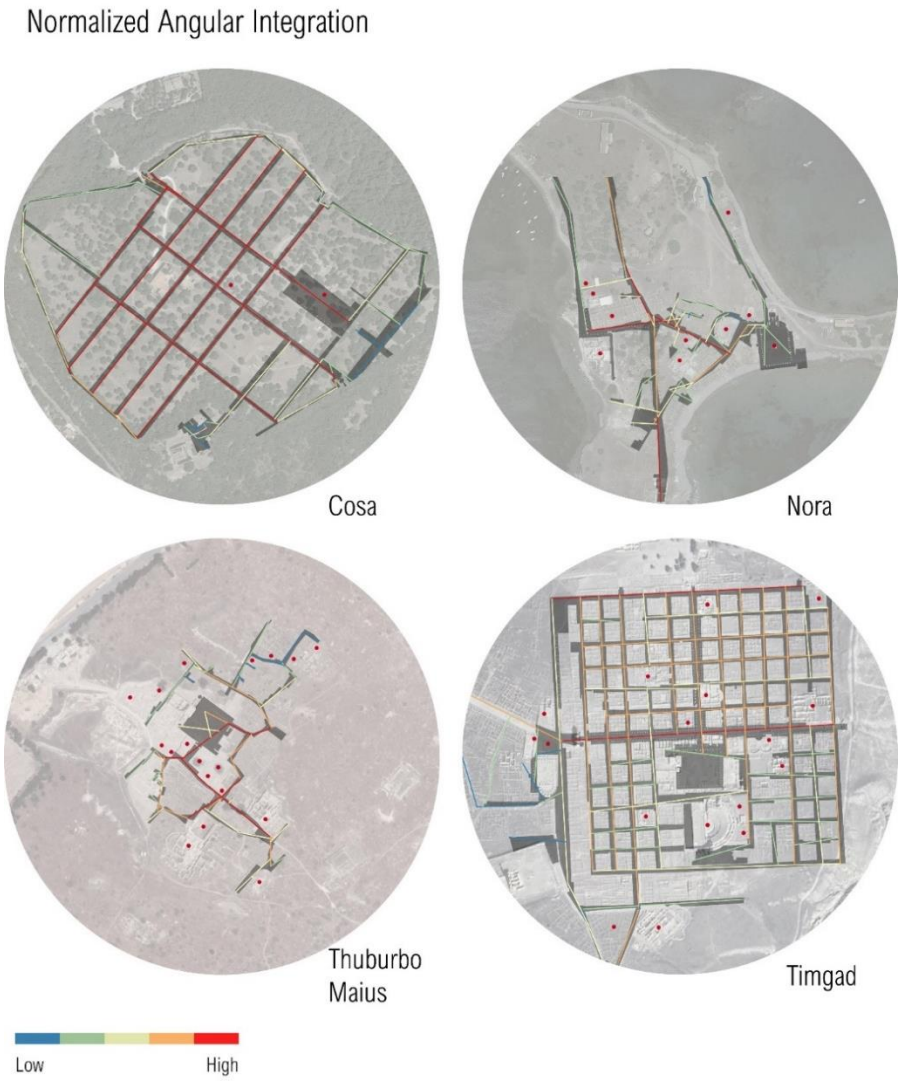


Fig.5 Distribution of Values of Normalized Angular Integration (NAIN)

At the global scale, normalised angular integration (Fig.5) underlines the emergence of integrated spatial structures concentrated around the Decumanus and the Cardo in Nora, in Timgad, and in Cosa. In Thuburbo, an integrated structure emerges, comprising portions of the Forum and of the main east-west street. Measures of central tendency and of dispersion underline the isotropy of the regular grid structure of Timgad and its general condition of significant integration. Vice versa, Thuburbo Majus presents a more segregated structure. Nora and Cosa demonstrate a more evident distinction of segregated, quieter areas and integrated spaces: the system of spaces contiguous to the Amphitheatre in Nora, and the Arx and the spaces along the perimetral

fortifications in Cosa emerge as segregated areas. A structure of central spatial elements concentrated around the Cardo and the Decumanus is underlined by the values of Normalised Angular Choice in Nora (See Fig.6 and Tab.1). In Cosa, the Forum and the Decumani emerge as central spaces. In Timgad, an emerging urban center is constituted by the Decumanus and a set of roads parallel to the Cardo. Lastly, in Thuburbo Majus, the Forum and the contiguous streets constitute a system of central spaces.

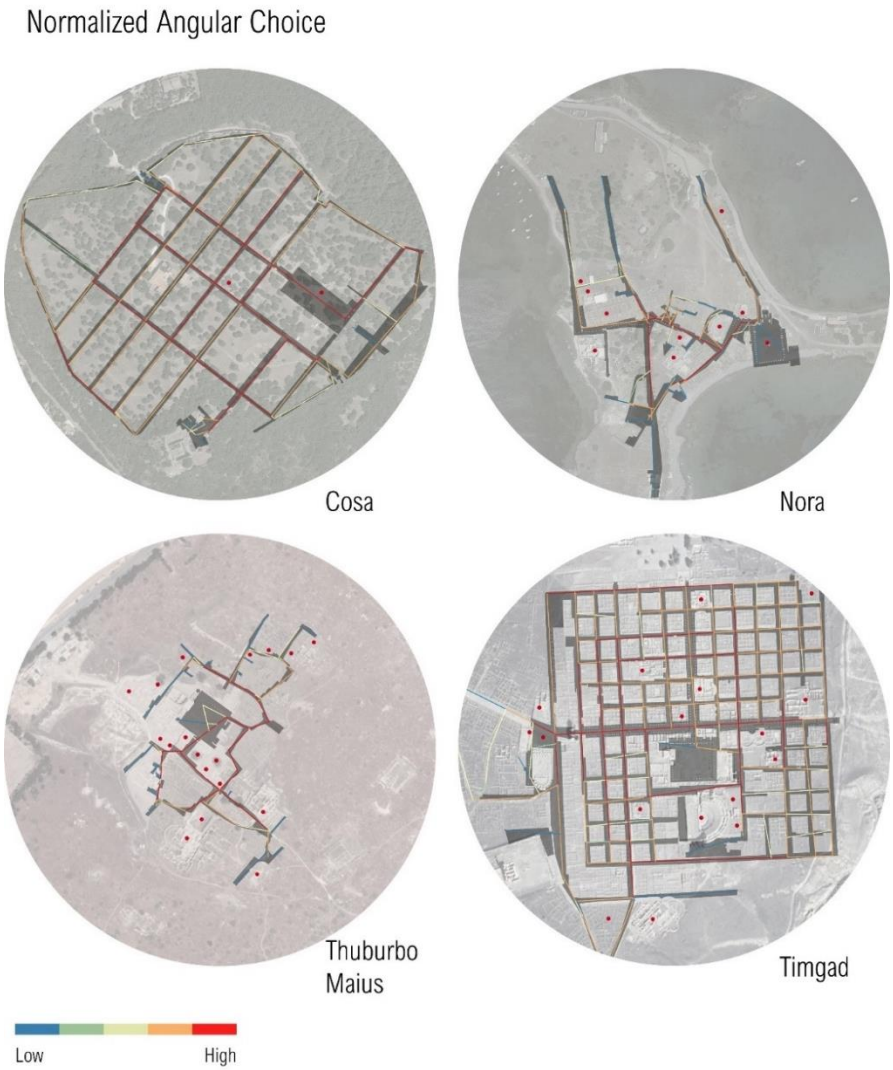


Fig.6 Distribution of Values of Normalized Angular Choice (NACH)

The distribution of NACH values (see Figg.6 and 7) demonstrates the isotropy and permeability of the regular grid structure and the anisotropy and marginal availability of alternative routes in organic urban structures.
Moreover, the analysis of the relation of NACH at radius n and at radius 200 meters, and the selection of spaces presenting values of NACH at radius 200 meters and at radius n comprised in the first and second quintiles underlines the sub-structure of spaces central both at the local and at the global scale. These spaces emerge as potential centres, presenting spatial conditions conducive to the intensification and diversification of socio-economic activities.
In Cosa, this trans-scalar structure of central spaces comprises 29 segments and includes the Decumanus, the streets parallel to the Decumanus, and part of the street parallel to the Cardo. Moreover, a relevant co-relation of local and global centrality emerges. The Coefficient of determination R2 is equal to 0.61. A minor co-relation, presenting a coefficient R^2 of 0.23, emerges in relation to the set of segments central at the local and global scale.

In Thuburbo Majus and in Nora, the strong co-relation among values of NACH calculated at radius 200 meters and at radius n, determining a coefficient R^2 equal, respectively, to 0.96 and to 0.95, can result from the modest size of the portion of the urban structure investigated, that prevents the distinction of global and local spatial structures of central streets.

Lastly, in Timgad, the Coefficient of determination R^2 equal to 0.68 indicates a clearer distinction of spaces central at the local scale and of spaces important at the global scale. The trans-scalar system of central spaces presents a modest co-relation of local and global choice, indicated by a value of 0.26 of the R^2 coefficient. This spatial structure comprises 72 segments, including the Decumanus, and a dendritic structure of segments located in the western area of the urban site.

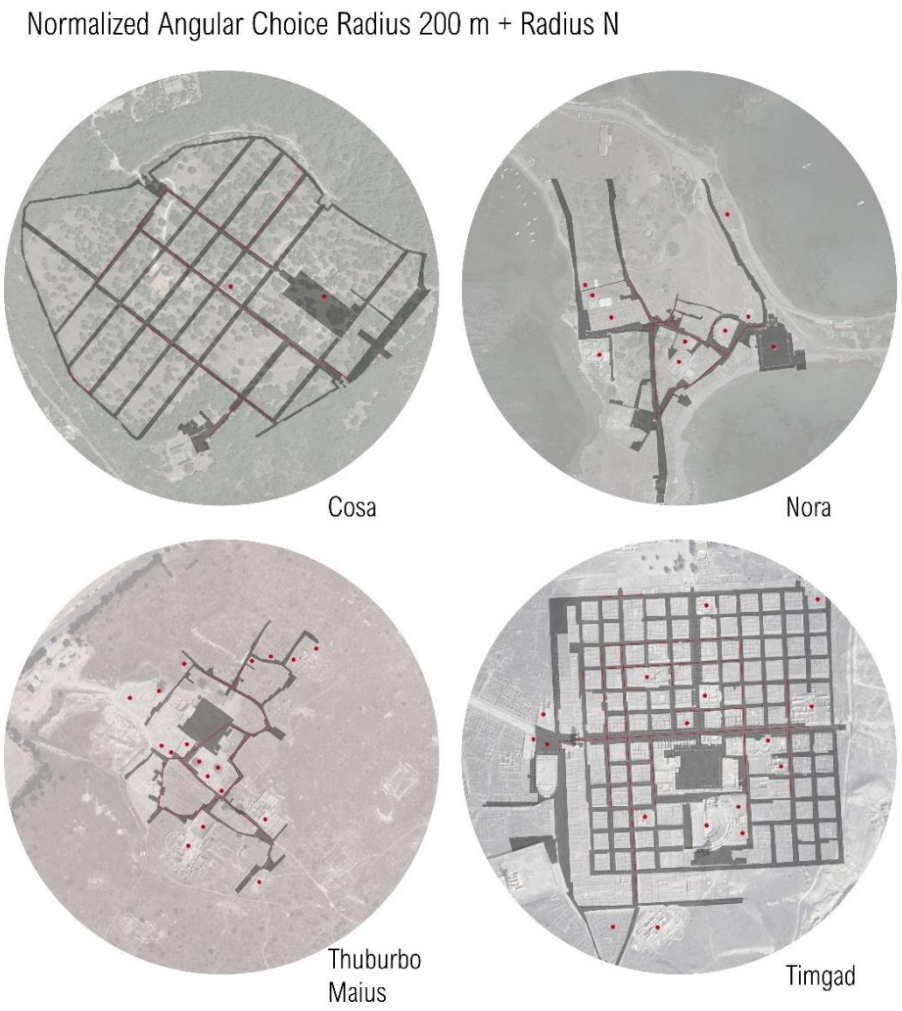


Fig.7 Emergence of spatial structures composed by the most central spaces at the local and global scale

6. Discussion

The results presented in the previous section underline significant specific configurational properties of the investigated urban sites. Firstly, the Forum emerges as a space central and integrated into, and distinct, from the urban structure. Thuburbo Majus presents a specific situation: the most central segments, in terms of integration and significance as spaces of movement, intersect the Forum.

In Thuburbo Majus a strong contrast in terms of dimension and form exists between the regular, monumental space of the Forum and the discontinuous spaces that comprise the organic structure of the urban site. A similar scalar and morphological contrast is also in Nora, underlining the adaptation of the original urban

structure and the insertion of forms of public space, specific to Roman urbanism, in a layout produced by a diverse spatial culture.

A relevant observed aspect concerns the emergence of the Decumanus as the most integrated and central space in the grid structure of Cosa, Nora and Timgad. In Thuburbo Majus, the Forum and the contiguous spaces are the most integrated and central spaces. Moreover, in Cosa and Timgad, an eccentric rectilinear road, perpendicular to the Decumanus, represents an integrated space and a central space for urban scale movements.

The Cardo is a less integrated and central space, in relation to movement, and a central space in relation to intersecting long visual lines. In Cosa, the distribution of segment integration evidences the strategies of distinction and separation of the Arx, reflecting a symbolic use of distance and segregation to convey the sacrality of the religious space.

The distribution of centrality underlines the permeability and isotropy of grid structures and the anisotropy of organic structures. In Cosa and Timgad, continuous spatial elements forming the regular grid constitute a structure of integrated and central spaces distinct from the system of segregated spaces comprising side local streets and spaces of the later urban development, in Timgad, and spaces along the perimetral fortifications in Cosa. A strong distinction between integrated and vibrant spaces and quieter and segregated areas is observed in Nora and Thuburbo Majus.

A preliminary investigation related to the location of functions and civic and public buildings, reveals the combination of general models, criteria of positional convenience and local conditions as the determinant of urban form. In Timgad the Forum and 5 civic buildings, including four commercial spaces and a vast bath complex are located along the Decumanus.

The small northern baths and the public library are located along the Cardo. The theatre and the Temples of Ceres and Mercury are close to a street, rotated in relation to the Decumanus, that results as a central and relevant space in terms of urban scale movement.

Several Civic buildings are located outside the urban core of ancient foundation, indicating the absence, inside the ancient core, of adequate spaces for the construction of monumental civic buildings as a central aspect of the rapid urban development of the III century, and of the radical alteration of the urban form. In Thuburbo, economic activities are contiguous to the central and integrated segments intersecting the Forum. The Basilica, the Baths of Labyrinth, the Winter Baths are located along the east-west main street. Production spaces, vice versa, are contiguous to spaces presenting poor levels of global centrality.

As a result, in the four investigated urban sites, economic and recreational, social functions are located along central movement spaces, or along spaces integrated in terms of long visual lines. Production spaces are located along segregated spaces in Thuburbo Majus Nora, and in Timgad. A relevant limitation of this study is related to the availability of spatial datasets. For instance, the scarcity of complete data related to the function of buildings and on the position and orientation of entrances, prevented the identification of constituted and un-constituted streets and the measure of the co-relation of axial integration and density and inter-visibility of entrances. Lastly, the limited quantity of data related to the configuration of spaces, location of public buildings and function, in a specific time period, of investigated buildings, also limits the analysis of the co-relation between the distribution and diversity of land uses and configurational properties. For instance, in Timgad, studies are focused on monumental buildings, and omit to investigate the configuration of spaces in the area of urban development outside the core of the ancient foundation. In Nora and Thuburbo Majus the reconstruction of the site plan concerns a specific, limited area close to the Forum and to pre-eminent public buildings. In Nora the alteration of the coastline determines a peculiar situation, further limiting the prospect for a precise and complete reconstruction of the urban structure.

7. Conclusions

The findings from this study underlines the relevance of methods combining distinct configurational metrics for identifying spatial patterns and transformations that manifest and reproduce cultural, political and socio-economic processes. Several studies demonstrate the validity of Configurational metrics as a tool for describing the spatial structure of cities and its influence on urban functionings including patterns of avoidance and encounter (Hillier, 2007), mobility (Dhanani et al., 2017; Cutini & Rabino, 2012; Hillier, 1989) and distribution of land uses (Bielik et al., 2018; Pappu, 2018; Hillier, 2007). The proposed study investigates the relevance of configurational metrics for the understanding of the spatial culture of ancient civilizations. As a result, this study significantly contributes to the fields of urban studies and archaeology in two ways: firstly, this study addresses a gap in the research on the urban form of ancient cities, consisting in the limited utilization of syntactic and statistical analysis for understanding the social antecedents and consequences of the configuration of spaces. The combination of specific configurational metrics, in fact, encompasses a quantitative description of spaces that is instrumental to the understanding of the specific socio-spatial configurations of ancient civilizations. Moreover, the study focuses on historical Roman urban sites whose spatial structure is mostly unexplored. Secondly, by identifying spatial structures related to specific socio-cultural meanings, this study contributes to the understanding of the persistence and evolution of specific socio-spatial configurations, related, in particular, to the distribution of land uses and the formation of centres as a function of the configuration of spaces, the symbolic value of distance in relation to the position of sacred sites, the systems of encounter and avoidance among social groups, and the separation of particular functions, for instance entertainment spaces, based on specific systems of compatibility and incompatibility of land uses. By underlining the distinction of integrated, vital spaces and segregated and monofunctional residential zones, the study demonstrates the intrinsic relevance of spatial configuration in influencing the distribution of urban functions, as a result of urban structure's impact on the distribution of natural movement. Hence, the findings of the study underline the relevance of Hillier's concept of movement economy, for understanding urbanity and the socio-spatial structure of urbanized environments (Cutini & Rabino, 2012; Hillier, 1999, 2007; Hillier & Hanson, 1984). The measurement of the topological distances of the forum from most integrated axial lines, and the analysis of the location of religious buildings confirm Van Nes' findings on the separation of sacred political and religious spaces from main movement spaces (Van Nes, 2014). Moreover, the study of configurational properties can underline the transformation of urban structures as a consequence of socio-political events. For instance, the distribution of integration in Nora and in Thuburbo Majus underlines the emergence of sub-structures of regular and monumental urban public spaces that represent the most evident spatial sign of the adaptation to the criteria of Roman spatial culture of pre-existing urban systems. In Timgad configurational variables can be used to understand the impact of the rapid economic development, on the crisis of the spatial organization based on the regular grid model, by underlining the specific configurational and structural properties of the center of ancient formation and of the districts built outside the fortified perimeter as a consequence of the increased demand for larger residential buildings and for larger, more specialized and representative spaces for cultural, social and recreational activities, (Zanker, 2013; Gros & Torelli, 1988). In general terms, the proposed set of configurational variables can be used to identify and describe the criteria constituting a spatial culture, hence the criteria of organization of spaces that produce and reproduce the principles for ordering social relations (Hillier, 1989). In particular, the future development of the study will be focused on the use of configurational variables to conduct synchronic and diachronic analyses of the spatial structures of Roman cities. The objectives will include: i) the definition of a set of tools for demonstrating and describing the principles of spatial organization constituting the Roman Spatial culture; ii) understanding, from a synchronic perspective, the relation between general models of spatial organisation and local factors, and the impact of local cultural, socio-economic factors on the adaptation and alteration of

general models; and iii) understanding, from a diachronic perspective, the evolution and transformation of Roman spatial culture as a result of general cultural, social, political and economic processes.

References

Al-Sayed, K., Turner, A., Hillier, B., Iida, S., & Penn, A. (2014). *Space syntax methodology*. Bartlett School of Architecture, UCL.

Angiolillo, S., Giuman, M., Carboni, R., & Cruccas, E. (2014). Prima campagna di ricognizione e scavo dell'Università di Cagliari. Relazione preliminare 2013. *Quaderni Norensi*, *5*(1), 191–199. http://dx.doi.org/10.14658/pupj-quno-2014-1-22

Assassi, A., & Mebarki, A. (2021). Spatial configuration analysis via digital tools of the archeological roman town Timgad, Algeria,. *Mediterranean Archaeology & Archaeometry*, *21*(1), 117–130. https://doi.org/10.5281/zenodo.4284429

Ballu, A. (1897). *Les Ruines de Timgad*. E. Leroux.

Ballu, A., Cagnat, R., & Boeswillwald, E. (1905). *Timgad, une cite africaine sous l'Empire Romain*. E. Leroux.

Battistin, F. (2021). Space Syntax and buried cities: The case of the Roman town of Falerii Novi (Italy). *Journal of Archaeological Science: Reports*, *35*, 102712. https://doi.org/10.1016/j.jasrep.2020.102712

Ben Akacha, W. (2011). Promotion coloniale, frénésie évergétique et aménagement urbanistique à Thuburbo Maius. *Dialogues d'histoire Ancienne*, *37*(2), 89–118.

Bielik, M., König, R., Schneider, S., & Varoudis, T. (2018). Measuring the Impact of Street Network Configuration on the Accessibility to People and Walking Attractors. *Networks and Spatial Economics*, *18*(3), 657–676. https://doi.org/10.1007/s11067-018-9426-x.

Boglietti, S., & Tiboni, M. (2022). Public spaces critical issues analysis for soft mobility. *TeMA - Journal of Land Use, Mobility and Environment*, 131-145. https://doi.org/10.6093/1970-9870/8643.

Bonetto, J. (2009). L'insediamento di età fenicia, punica e romana repubblicana nell'area del foro. In J. Bonetto (Ed.), *Nora. Il Foro Romano: Storia di un'area urbana dall'età fenicia alla tarda antichità: 1997-2006. I. Lo scavo.: Vol. I* (Issue 3). Italgraf. http://paduaresearch.cab.unipd.it/4106/

Bonetto, J., Bertelli, A., Deiana, R., & Mazzariol, A. (2014). Rilievo topografico e geofisico presso i quartieri settentrionali. Prime indagini dell'Università di Padova. *Quaderni Norensi*, *5*(1), 201–209. http://dx.doi.org/10.14658/pupj-quno-2014-1-23

Bonetto, J., Sanna, I., Carraro, F., Metelli, M. C., Minella, I., Arcaini, R., Soro, L., Del Vais, C., Fanni, S., & Sirigu, M. (2017). Nora e il mare. Le indagini nelle aree sommerse e subacquee 2014-2015. *Quaderni Norensi*, *6*(1), 201–212. http://dx.doi.org/10.14658/pupj-quno-2014-1-22

Brown, F. E. (1980). *Cosa, the making of a Roman town* (Vol. 13). University of Michigan Press.

Brown, F. E., Richardson, E. H., & Richardson, L. (1993). *Cosa III: the buildings of the forum: Colony, municipium, and village* (Vol. 37). Pennsylvania State University Press.

Carandini, A., Celuzza, M., Fentress, E., & Attolini, I. (2002). *Paesaggi d'Etruria. Valle dell'Albegna, Valle d'Oro, Valle del Chiarone, Valle del Tafone*. Edizioni di Storia e Letteratura.

Casarotto, A., Pelgrom, J., & Stek, T. D. (2016). Testing settlement models in the early Roman colonial landscapes of Venusia (291 B.C.), Cosa (273 B.C.) and Aesernia (263 B.C.). *Journal of Field Archaeology*, *41*(5), 568–586. https://doi.org/10.1080/00934690.2016.1211474

Conventi, M. (2004). *Città romane di fondazione*. L'Erma di Bretschneider.

Crawford, K. A. (2019). Visualising Ostia's Processional Landscape Through a Multi-Layered Computational Approach: Case Study of the Cult of the Magna Mater. *Open Archaeology*, *5*(1), 444–467. https://doi.org/10.1515/opar-2019-0028

Rabino, G., & Cutini, V. (2012). Searching for Ariadne's thread. Some remarks on urban resilience and orientation. *TeMA - Journal of Land Use, Mobility and Environment, 5*(2), 7-22. https://doi.org/10.6092/1970-9870/889

Dhanani, A., Tarkhanyan, L., & Vaughan, L. (2017). Estimating pedestrian demand for active transport evaluation and planning. *Transportation Research Part A: Policy and Practice*, *103*, 54–69. https://doi.org/10.1016/j.tra.2017.05.020

Dyson, S. L. (2013). Cosa. In J. Derose Evans (Ed.), *A Companion to the Archaeology of the Roman Republic* (pp. 472–484). Wiley Blackwell.

Eskidemir, K., & Kubat, A. S. (2020). Urban form and culture: A comparative analysis of Anatolian and Italian towns. *Urban Morphology*, *24*(1), 53–69.

Fentress, E., & Bodel, J. P. (2003). *Cosa V: An Intertmittent Town, Excavations 1991-1997* (Vol. 2). University of Michigan Press.

Fentress, E., & Perkins, P. (2016). Cosa and the ager cosanus. In *A Companion to Roman Italy* (pp. 378–400). Wiley Blackwell.

Finocchi, S. (1999). La laguna e l'antico porto di Nora: Nuovi dati a confronto. *Rivista Di Studi Fenici*, *27*(2), 167–192.

Francini, M., Chimirri, R., Palermo, A., & Viapiana, M. F. (2017). Between Community Spaces: Squares of Minor Centers of Calabria. *TeMA - Journal of Land Use, Mobility and Environment*, 10(2). https://doi.org/10.6092/1970-9870/5087.

Gaglione, F., Gargiulo, C., & Zucaro, F. (2019). Elders' quality of life. A method to optimize pedestrian accessibility to urban services. *TeMA - Journal of Land Use, Mobility and Environment*, 12(3), 295-312. https://doi.org/10.6092/1970-9870/6272.

Gargiulo, C. & Sgambati, S. (2022). Active mobility in historical districts: Towards an accessible and competitive city. The case study of Pizzofalcone in Naples. *TeMA - Journal of Land Use, Mobility and Environment*, 31-55. https://doi.org/10.6093/1970-9870/8395

Gascou, J. (1988). Y avait-il un pagus Carthaginois à Thuburbo Maius? *Antiquités Africaines*, *24*, 67–80.

Ghiotto, A. R. (2009). Il complesso monumentale del foro. In J. Bonetto (Ed.), *Nora. Il foro romano: Storia di un'area urbana dall'età fenicia alla tarda antichità : 1997-2006. I. Lo scavo.: I* (4). Italgraf. http://paduaresearch.cab.unipd.it/4107/

Gros, P., & Torelli, M. (1988). *Storia dell'Urbanistica. Il Mondo Romano*. Giuseppe Laterza & Figli.

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

Gundogdu, H. M., & Ozkok, M. K. (2017). The relationship between functional structural properties and spatial configuration properties in ancient cities: The case of Pompeii city. *Art-Sanat*, *8*, 51–72.

Hillier, B. (1989). The architecture of the urban object. *Ekistics*, *56 (334-335)*, 5-21.

Hillier, B. (1996). Cities as movement economies. *URBAN DESIGN International*, *1*(1), 41–60. https://doi.org/10.1057/udi.1996.5

Hillier, B. (1999). Centrality as a process: Accounting for attraction inequalities in deformed grids. *URBAN DESIGN International*, *4*(3), 107–127. https://doi.org/10.1057/udi.1999.19

Hillier, B. (2007). *Space is the machine: A configurational theory of architecture*. University College of London.

Hillier, B., & Hanson, J. (1984). *The Social Logic of Space*. Cambridge University Press; Cambridge Core. https://doi.org/10.1017/CBO9780511597237

Hillier, B., & Vaughan, L. (2007). The city as one thing. *Progress in Planning*, *67*(3), 205–230. https://doi.org/10.1016/j.progress.2007.03.001

Hillier, W. R. G., Yang, T., & Turner, A. (2012). Advancing DepthMap to advance our understanding of cities: Comparing streets and cities and streets with cities. In M. Greene, J. Reyes, & A. Castro (Eds.), *Proceedings: Eighth International Space Syntax Symposium*. Pontificia Universidad Catolica de Chile:

Koutsolampros, P., Sailer, K., Varoudis, T., & Haslem, R. (2019). Dissecting Visibility Graph Analysis: The metrics and their role in understanding workplace human behaviour. *Proceedings of the 12th International Space Syntax Symposium*, *12*.

Kubat, A. S. (1997). The morphological characteristics of Anatolian fortified towns. *Environment and Planning B-Planning & Design*, *24*(1), 95–123. https://doi.org/10.1068/b240095

Kubat, A. S. (2010). The study of urban form in Turkey. *Urban Morphology*, *14*(1), 31–48.

Kubat, A. S., Kurtuluş, İ., Akay, M., & Akdoğan, E. (2019). Visual impact analysis in the context of Space Syntax. *Proceedings of the 12th International Space Syntax Symposium*. 12th International Space Syntax Symposium, Beijing, China.

Laurence, R. (2010). *Roman Pompeii: Space and society*. Routledge. https://doi.org/10.4324/9780203813294

Lee, J. H., Ostwald, M. J., & Zhou, L. (2023). Socio-Spatial Experience in Space Syntax Research: A PRISMA-Compliant Review. *Buildings*, 13(3), 644., 1-20

Li, X., & Zhang, Y. (2023). Urban Morphology and Historical Urban Landscape Conservation and Management. In *Conserving and Managing Historical Urban Landscape: An Integrated Morphological Approach* (pp. 7-32). Singapore: Springer Nature Singapore.

Marshall, S. (2005). *Streets and Patterns*. Spoon Press.

Pappu, H. (2018). Analysing the Spatial structure of the Street network to understand the Mobility pattern and Landuse - A case of an Indian city - Mysore. *TeMA - Journal of Land Use, Mobility and Environment, 11*(2), 231-246. https://doi.org/10.6092/1970-9870/5652

Penn, A., Hillier, B., Banister, D., & Xu, J. (1998). Configurational Modelling of Urban Movement Networks. *Environment and Planning B: Planning and Design*, *25*(1), 59–84. https://doi.org/10.1068/b250059

Pesce, G. (1957). *Nora: Guida agli scavi*. Edizioni" La Zattera".

Rezkallah, Y., & Marmi, R. (2018). Building Materials and the Ancient Quarries at Thamugadi (East of Algeria), Case Study: Sandstone and Limestone. *ASMOSIA XI, Interdisciplinary Studies on Ancient Stone, Proceedings of the XI International Conference of ASMOSIA*, 673–682.

Stoger, H., & Brandimarte, E. (2015). Two ancient city blocks under the magnifying glass: A space syntax analysis of Ostia's urban quarters and their social life. *Arquelogia de La Arquitectura*, *12*, e034. https://doi.org/10.3989/arq.arqt.2015.125

Stöger, J. (2011). *Rethinking Ostia: A spatial enquiry into the urban society of Rome's imperial port-town*. Leiden University Press.

Tsai, M. T., & Chang, H. W. (2023). Contribution of accessibility to urban resilience and evacuation planning using spatial analysis. *International journal of environmental research and public health*, *20*(4), 2913.

Turner, A. (2007). To move through space: Lines of vision and movement. *Proceedings, 6th International Space Syntax Symposium, 12-15 June, 2007*, 037.001-037.012.

Turner, A., Doxa, M., O'Sullivan, D., & Penn, A. (2001). From Isovists to Visibility Graphs: A Methodology for the Analysis of Architectural Space. *Environment and Planning B: Planning and Design*, *28*(1), 103–121. https://doi.org/10.1068/b2684

Van Nes, A. (2009). Measuring the degree of street vitality in excavated towns: How can macro and micro spatial analyses tools contribute to understandings on the spatial organization of urban life in Pompeii? In D. Koch, L. Marcus, J. Steen, & ARK. Trita (Eds.), *Proceedings of the 7th International Space Syntax Symposium*. Forskningspublikationer.

Van Nes, A. (2014). Indicating street vitality in excavated towns: Spatial configurative analyses applied to Pompeii. In *Spatial analysis and social spaces: Interdisciplinary approaches to the interpretation of prehistoric and historic built environments* (pp. 277–296). de Gruyter. https://doi.org/10.1515/9783110266436.277

van Nes, A., & Yamu, C. (2021). *Introduction to space syntax in urban studies*. Springer Nature.

Yamu, C., van Nes, A., & Garau, C. (2021). Bill Hillier's Legacy: Space Syntax—A Synopsis of Basic Concepts, Measures, and Empirical Application. *Sustainability*, *13*(6), 1–25.

Zaccaria Ruggiu, A. (1995). Spazio privato e spazio pubblico nella città romana, 210 (1). Persée-Portail des revues scientifiques en SHS.

Zali, N., Gholami, N., Karimiazeri, A.R., & Azadeh, S.R. (2016). Planning According to New Urbanism: The Ostadsara Neighborhood Case Study. *TeMA - Journal of Land Use, Mobility and Environment*, 9(3), 323-341. https://doi.org/10.6092/1970-9870/4023.

Zanker, P. (2013). *La Città Romana.* Editori Laterza.

Authors' contribution

This paper is the result of the joint work of the authors. In particular, "Materials and Methods", and "Results" are written jointly by the authors. Chiara Garau wrote "Research aim", "Selection of the areas of Study" and "Discussion", Alfonso Annunziata wrote "Theory", Claudia Yamu wrote the "Introduction", Dario D'Orlando wrote "The case studies: a deeper focus on the 'organic' cities Thuburbo Majus and Nora)", and Marco Giurman wrote the "Conclusions".

Acknowledgement

This study was supported by the MIUR through the project "WEAKI TRANSIT: WEAK-demand areas Innovative TRANsport Shared services for Italian Towns (Project protocol: 20174ARRHT_004; CUP Code: F74I19001290001), financed with the PRIN 2017 (Research Projects of National Relevance) programme. We authorize the MIUR to reproduce and distribute reprints for Governmental purposes, notwithstanding any copyright notations thereon. Any opinions, findings, and conclusions, or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the MIUR. This study was developed within the Interdepartmental Center of the University of Cagliari "Cagliari Accessibility Lab".

Image Sources

Fig.1: Elaborated by the authors via the Software QGIS 3.16.8. Background Image from Google Earth;

Fig.2: Elaborated by the authors via the Software QGIS 3.16.8. Background Image from Google Earth;

Fig.3: Elaborated by the authors via the Software Depthmap X and QGIS 3.16.8. Background Image from Google Earth;

Fig.4: Elaborated by the authors via the Software Depthmap X and QGIS 3.16.8. Background Image from Google Earth;

Fig.5: Elaborated by the authors via the Software Depthmap X and QGIS 3.16.8. Background Image from Google Earth;

Fig.6: Elaborated by the authors via the Software Depthmap X and QGIS 3.16.8. Background Image from Google Earth;

Fig.7: Elaborated by the authors via the Software Depthmap X and QGIS 3.16.8. Background Image from Google Earth.

Author's profile

Chiara Garau

She is an associate professor in Urban and Regional Planning at the DICAAR of the University of Cagliari, Italy. She was a scientific and technical adviser to Observatory Smart Cities of Rome (2013-2014) and she held several postdoctoral fellowships, before being a researcher and then a professor at the University of Cagliari. She was the principal investigator of several international projects, among which Governing the smart city: a governance-centred approach to smart urbanism "GHOST" 2015-2019 by the MIUR (Italian Ministry of Education, Universities and Research) and financed with the SIR (Scientific Independence of young Researchers) programme. Her main research interests are focused on issues of the Scientific Disciplinary Sector of Urban and Regional Planning, particularly on smart cities; participatory processes; cultural heritage; urban governance and urban policies. A referee of several international scientific journals, she is author of over one hundred and ten publications, including monographs, conference proceedings, articles in books, national and international journals.

Alfonso Annunziata

He is a post-doc fellow at the Department of Civil and environmental engineering and architecture of the University of Cagliari His research focuses on the topics of landscape infrastructure, landscape urbanism, configurational analysis and spatial analysis. In particular, three aspects are investigated in Annunziata's research: i) the configurational, material, functional and social features of the urban realm impacting residents' quality of life; ii) the development of metrics to assess the quality of public spaces in terms of their usability; iii) the analysis of social, economic and spatial trends related to the decline of inland rural areas.

Claudia Yamu

She is a full professor at Oslo Metropolitan University. She is an architect and urban planner. She is an expert on transport land use planning including people's behaviour in cities combining space syntax with a wide-range of analytical techniques including method and tool development at the forefront of virtual modelling. As a former project consultant, she excels in combining the theoretical innovations with practice-oriented solutions and has been involved in numerous international projects. Yamu was awarded the prestigious Michael Breheny Prize in 2015 for her work on multiscale, multifractal urban planning models. She is an editorial board member for Springer's The Urban Book Series and has been a reviewer for national research funding agencies in Europe and the Middle East. She holds a PhD in Architecture from TU Wien connecting architecture, urban planning and computer science and a PhD in Geography and Regional Planning in complexity-based modelling from Université de Franche-Comté. She dedicates her work to the development of sustainable cities and regions.

Dario D'Orlando

He is an independent researcher. He took his PhD degree at University of Cagliari in 2021. His interests include Roman landscape and urbanistic aspects, iconology of the Greek world and reconstruction of cult and rites of Greek religion. He is author of many papers, a book and editor of a monograph about the excavation of an urban context of Cagliari (Italy, Sardinia). He also has been a trainee for the Online Digital Field Survey Archaeology led by KNIR in 2021.

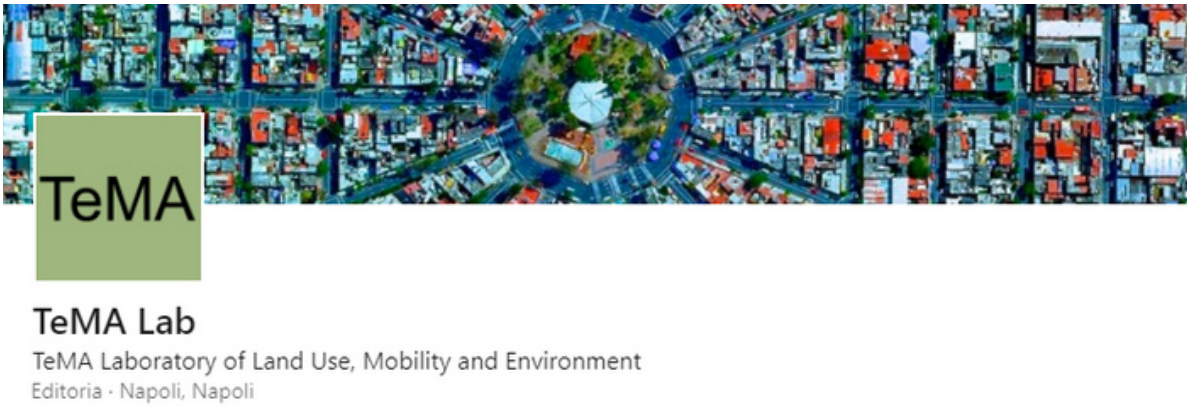
Marco Giuman

He is a full professor at the Department of Humanities, Languages and Cultural Heritage, University of Cagliari. Since 2021 he is Full Professor in Classical Archaeology at the same University. He took his PhD degree at the University of Perugia in 2002. His interests cover different aspects of Greek and Roman antiquities including urbanistc and sacred landscapes, iconology of the classical images and the relationship between image, cult and rite in Ancient Greece. He is author of several papers and books on the ancient world and the reuse of classical culture. He has been a member of different research projects including the PRIN project about "Il barbaro e il sacro. Fonti, spazi, monumenti, oggetti, immagini dei santuari indigeni della periferia greca" (COFIN MIUR 2007).

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 (2023) 221-226
print ISSN 1970-9889, e-ISSN 1970-9870
10.6093/1970-9870/9836
Received 11th February 2023, Available online 30th April 2023

www.TeMA.unina.it

REVIEW NOTES – Urban planning literature review

City vs Energy consumptions: the role of new technologies

Carmen Guida [a*], Valerio Martinelli [b]

[a] Department of Civil, Building and Architectural Engineering
University of Naples Federico II, Naples, Italy
e-mail: carmen.guida@unina.it
ORCID: https://orcid.org/0000-0002-8379-7793
*Corresponding author

[b] Department of Civil, Architectural and Environmental Engineering
University of Naples Federico II, Naples, Italy
e-mail: val.martinelli@studenti.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, the Urban planning literature review section presents recent books and journals on selected topics and issues within the global scientific panorama.
This contribution aims at delving into the relationship between urban environments and energy consumption. Cities consume about 75% of global primary energy and emit between 50% and 60% of total greenhouse gases. As drivers of economic and social changes, cities play a key role in reducing energy consumption and increase energy efficiency. For the first issue of TeMA Journal volume no. 16, this Review Notes section is dedicated to books highlighting the role of new technologies in managing good-quality energy data, essential to support reliable decision-makers.

Keywords

Energy crisis; New technologies; Urban energy.

How to cite an item in APA format

Guida, C., & Martinelli, V. (2023). City vs Energy consumptions: the role of new technologies. *TeMA. Journal of Land Use, Mobility and Environment*, *16* (1), 221-226. http://dx.doi.org/10.6093/1970-9870/9836

1. Introduction

Energy consumption and its efficiency have become increasingly important in recent years due to a variety of factors. One of the most pressing reasons is the impact of climate change-related phenomena on cities and communities around the world. Extreme weather events such as heatwaves, floods, and hurricanes are becoming more frequent and severe, causing significant damage to urban infrastructure and putting people's lives at risk. In response, there is an urgent need for concrete solutions to mitigate and adapt urban environments to these extreme events (Batta & Mazzeo, 2022; Guida, 2022).

Another factor that has made the energy issue more urgent than ever is the current energy crisis. Albeit the crisis had a global outbreak with the Russian attack on Ukraine, its roots can be found in late 2021 when the price of fossil-fuels increased sensibly, due to postponed maintenance interventions and financial issues. The still ongoing war has led to a spike in energy and basic commodities prices in Europe and beyond, contributing, among others, to a global supply chain crisis, to unsustainable production in the sectors hardest hit and resulting in runaway inflation spread throughout the world. As a result, this crisis has delivered an unprecedented shock to the industrialised West, leading to power outages, supply chain disruptions, and higher costs of living. It has highlighted the vulnerability of our energy systems and the need for more resilient and sustainable solutions.

Urban areas are significant contributors to global energy demand and energy-related emissions. Cities consume about 75% of global primary energy and emit between 50% and 60% of total greenhouse gases. In the European Union, cities take up only 4% of the land area yet are home to 75% of the population, making their energy footprint significant, particularly in sectors such as buildings and private motorised transport (Sgambati & Gargiulo, 2022).

The IPCC's Sixth Assessment Report (2021) highlights the close linkage between the energy performance of urban environments and their resilience when climatic events occur. The report states that urban areas need to reduce their energy consumption and shift towards renewable energy sources to mitigate the impact of climate change-related events. This is important for complying with the Paris Agreement (UN, 2015) and limiting global temperature increase and addressing the ongoing energy crisis and its impact on urban areas.

Cities are responsible for a significant portion of global energy consumption, and as such, they have the potential to play a critical role in addressing the energy crisis. Sustainable energy solutions are becoming increasingly important as traditional energy sources such as fossil fuels are finite and contribute to environmental degradation, including climate change.

Promoting sustainable energy solutions can help cities reduce their carbon footprint and contribute to the global effort to reduce greenhouse gas emissions. Sustainable energy solutions, such as renewable energy sources like solar, wind, and hydropower, can help cities reduce their reliance on fossil fuels and move towards a more sustainable energy future.

In addition to the environmental benefits, promoting sustainable energy solutions can also bring economic benefits to cities. For example, investing in renewable energy infrastructure can create jobs and stimulate economic growth.

Overall, cities have a critical role to play in addressing the energy crisis by promoting sustainable energy solutions. By taking action to reduce their carbon footprint and increase energy efficiency, cities can contribute to a more sustainable future for all.

One such solution is to increase the use of renewable energy sources such as solar, wind, and hydro power. Urban planning tools may promote the installation of solar panels on buildings, building wind farms on the outskirts, and investing in hydroelectric power plants to generate clean energy. These sources can reduce the reliance on fossil fuels, which not only produce greenhouse gas emissions but also contribute to air pollution, which can lead to health problems.

Another solution is to improve energy efficiency in buildings. Buildings consume significant energy, and improving their efficiency can lead to significant energy savings. This can be achieved through measures such as insulation, efficient lighting, and energy-efficient appliances. Cities can also promote the use of green buildings, which are designed to minimise energy consumption and environmental impact (Papa et al., 2016; Pilogallo et al., 2019).

In addition, cities can encourage sustainable transportation options, such as public transport, cycling, and walking. Private motorised transport is a significant contributor to greenhouse gas emissions and air pollution, and promoting sustainable alternatives can reduce the reliance on cars and other vehicles (Coppola & De Fabiis, 2020). To achieve these goals, cities need to invest in sustainable infrastructure and technologies, and promote policies that incentivise the adoption of sustainable practices. This requires a collaborative effort between government, businesses, and citizens and international cooperation to share knowledge and resources.

For example, Amsterdam is one of the most sustainable cities in Europe, with a long history of promoting sustainable solutions. The city has invested heavily in renewable energy sources, with over 100,000 solar panels installed on public buildings and over 200 wind turbines in the surrounding areas. Amsterdam also has an extensive network of bike lanes and promotes cycling as a sustainable transportation option. In addition, the city has implemented policies to encourage energy efficiency in buildings, such as offering insulation subsidies and promoting green roofs. Another significant example comes from Denmark: Copenhagen has set a goal to become carbon-neutral by 2025 and has implemented a variety of sustainable energy solutions, including wind turbines, district heating systems, and a comprehensive bicycle infrastructure. From other territorial contexts, Vancouver (Canada) and San Francisco (California, US) have set challenging goals. Vancouver has a goal of 100% renewable energy by 2050 and has implemented policies to encourage the use of electric vehicles, green buildings, and renewable energy sources; San Francisco has implemented a range of sustainable energy solutions, including a comprehensive recycling program, a public transportation system that runs on renewable energy, and a goal to achieve 100% renewable energy by 2030.

Promoting sustainable approaches for reducing energy consumption in urban areas is heavily dependent on high-quality data and analysis. However, managing energy data can be difficult from a scientific perspective, given the dearth of reliable sources, excessive data aggregation, and the potential inaccuracy of models. In this issue of the TeMA Journal, the reviewed books center on how technology and artificial intelligence impacts energy consumption and efficiency.

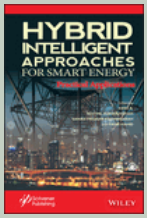
To sum up, the main ways new technologies may collaborate in scientific advancements are:

- *Data Collection*: predicting energy consumption requires data collection, and new technologies are making it easier to collect data on energy consumption. Smart meters, for example, can provide real-time data on energy use, which can be used to predict future energy consumption patterns;
- *Data Analytics*: new technologies such as machine learning and artificial intelligence can analyse energy consumption data to identify patterns and trends. This can help predict future energy consumption and enable energy providers to optimise their energy generation and distribution systems;
- *Energy Modeling*: energy modeling is a method for predicting energy consumption by simulating energy use under different scenarios. New technologies are making energy modelling more sophisticated, allowing for more accurate energy consumption predictions.

As urbanisation continues to accelerate, finding sustainable solutions to meet the growing energy demand is becoming increasingly important. New technologies play a crucial role in addressing the energy crisis in urban areas, as they offer innovative ways to increase energy efficiency, promote the use of renewable energy sources, predict and manage energy consumption, and optimise energy use. By harnessing the power of new technologies, cities can reduce their carbon footprint, improve air quality, and create a more sustainable future for all.

In conclusion, the energy crisis in urban areas is a pressing issue that requires innovative and sustainable solutions. As presented in the reviewed books, new technologies, best practices, and multidisciplinary approaches offer a practical and coherent framework for addressing this challenge. By promoting sustainable energy transition planning, cities can increase energy efficiency, utilise renewable energy sources, and reduce their carbon footprint, ultimately creating a more sustainable future. Policymakers, academics, and practitioners must work together to implement these solutions, creating a net-zero energy balance at the neighbourhood and district level, to ensure a cleaner, healthier, and more prosperous urban environment. Doing so can create a sustainable and resilient urban society that benefits us all.

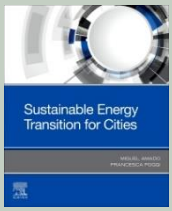
Hybrid Intelligent Approaches for Smart Energy: Practical Applications



Authors/Editors: Mohan, S. K., John, A., Padmanaban, S., & Hamid, Y.
Publisher: John Wiley & Sons
Publication year: 2022
ISBN code: 9781119821243

"Hybrid Intelligent Approaches for Smart Energy: Practical Applications" is a valuable reference book that covers the latest trends in green technologies and efficient energy systems. The book focuses on energy optimisation and consumption prediction and how smart computing technologies such as artificial intelligence, machine learning, deep learning, and IoT are replacing traditional computational methods in these areas.
The book provides solutions to the limitations, issues, and challenges of traditional energy consumption methods by incorporating smart computation techniques. The authors have successfully bridged the gap between traditional power consumption methods and modern consumption methods using smart computation methods. The book is written for engineers, scientists, students, and other professionals in various industries and engineering areas.
It provides practical applications of smart computation technologies in different fields such as distributed environment, healthcare, smart cities, and agriculture.
Overall, the manuscript is a must-have book for anyone interested in staying up-to-date with the latest trends in green technologies, efficient energy systems, and smart computing techniques. It provides a comprehensive overview of the use of smart computation methods in energy optimisation, consumption, scheduling, and usage, and offers practical solutions for various issues in these areas.

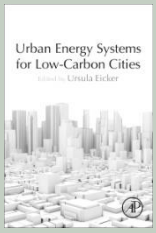
Sustainable Energy Transition for Cities



Authors/Editors: Amado, M. & Poggi, F.
Publisher: Elsevier
Publication year: 2022
ISBN code: 9780128242773

"Sustainable Energy Transition for Cities" is an insightful and comprehensive guide that provides a framework for planning and implementing sustainable energy systems in urban areas.
The book's multidisciplinary approach offers a holistic understanding of the issues and opportunities involved in urban energy transition, making it a valuable resource for academics, practitioners, and policymakers interested in promoting sustainable energy in cities.
The authors provide a range of best practices for sustainable energy transition planning, drawing on empirical and applied research in urban planning and sustainable energy. The book's focus on achieving a net-zero energy balance at the neighbourhood and district level provides a practical and coherent approach for implementing sustainable energy systems in urban areas. The book covers a range of topics, including the use of renewable energy sources, building efficiency improvements, and transportation innovations. It also addresses the challenges and opportunities associated with the transition to sustainable energy systems, providing valuable insights for policymakers and practitioners.
Overall, "Sustainable Energy Transition for Cities" offers practical solutions and best practices for promoting sustainable energy in urban areas. By adopting the multidisciplinary framework presented in the book, cities can work towards achieving a low-carbon urban society and create a more sustainable future for all.

Urban Energy Systems for Low-Carbon Cities



Editor: Ursula Eicker
Publisher: Elsevier
Pubblication year: 2022
ISBN code: 9780128115541

"Urban Energy Systems for Low-Carbon Cities" addresses the challenges associated with urban energy transition, which include analysing energy efficiency options and the potential of renewable energy systems within the existing building stock. As cities become increasingly important actors in the transition towards a low-carbon future, the book introduces indicators for evaluating urban energy performance and discusses monitoring and efficiency valuation schemes. The book covers a range of key topics in the field of urban energy systems, including energy demand and consumption mapping and monitoring, optimisation of design and operation of urban supply and distribution systems, integration of renewable energy, and demand-side management strategies. The book provides case studies from cities such as Vienna, Geneva, New York, and Stuttgart to illustrate these concepts in practice. One of the key features of the book is its use of innovative modelling methods, which provide a bottom-up approach to simulating energy consumption, energy conversion systems, and distribution networks using engineering methods. The book also explores the potential of energy management strategies in urban areas, highlighting their importance in better matching renewable supply and demand and increasing flexibilities. Overall, "Urban Energy Systems for Low-Carbon Cities" is a valuable resource for anyone interested in the field of urban energy systems and the transition to a low-carbon future. The book provides practical guidance on issues related to energy demand, consumption mapping and monitoring, and energy management strategies in urban areas. The case studies and innovative modelling methods used in the book provide real-world examples of how these concepts can be applied in practice to achieve a more sustainable urban energy system.

References

Amado, M., & Poggi, F. (2022). Sustainable Energy Transition for Cities. *Elsevier*. ISBN: 9780128242773.

Battarra, R., Mazzeo, G. (2022). Challanges of Mediterranean metropolitan systems: smart planning and mobility. In M. Tira, G. Maternini, M. Tiboni (eds.), New scenarios for safe mobility in urban areas. Proceedings of the XXV International Conference Living and Walking in Cities (LWC 2021), Septem-ber 9-10, 2021, Brescia, Italy, Transportation Research Procedia, 60, 93-99. https://doi.org/10.1016/j.trpro.2021.12.013.

Coppola, P., & De Fabiis, F. (2020). Evolution of mobility sector during and beyond Covid-19 emergency: a viewpoint of industry consultancies and public transport companies. *Sustainability*, *12*(22), 9517. https://doi.org/10.3390/su12229517

Eicker, U. (Ed.). (2022). Urban Energy Systems for Low-Carbon Cities. Elsevier. ISBN: 9780128115541.

Guida C. (2022). Energy saving and efficiency in urban environments: integration strategies and best practices. *TeMA - Journal of Land Use, Mobility and Environment*, *15*(3), 517-531. https://doi.org/10.6093/1970-9870/9549

Intergovernmental Panel on Climate Change. (2021). Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Masson-Delmotte, V., Zhai, P., Pirani, A., Connors, S.L., et al. (eds.)]. *Cambridge University Press.* Retrieved from: https://www.ipcc.ch/report/ar6/wg1/

Mohan, S. K., John, A., Padmanaban, S., & Hamid, Y. (2022). Hybrid Intelligent Approaches for Smart Energy: Practical Applications*. John Wiley & Sons*. ISBN: 9781119821243

Papa, R., Gargiulo, C., & Battarra, R. (2016). Città Metropolitane e Smart Governance: Iniziative di successo e nodi critici verso la Smart City. *FedOA – University Press*, Naples (Italy). https://doi.org/ 10.6093/978-88-6887-005-8

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. https://doi.org/10.6092/1970-9870/6117

Sgambati, S., & Gargiulo, C. (2022). The evolution of urban competitiveness studies over the past 30 years. A bibliometric analysis. Cities, 128, 103811. https://doi.org/10.1016/j.cities.2022.103811

United Nations Framework Convention on Climate Change. (2015). Paris Agreement. Retrieved from: https://unfccc.int/sites/default/files/english_paris_agreement.pdf

Author's profile

Carmen Guida

She is an engineer, Ph.D. in Civil Systems Engineering and Postdoctoral Researcher at Department of Civil, Architectural and Environmental Engineering of University of Naples Federico II. Her research activities concern adaptation of urban environment to climate change-relates hazards and accessibility to urban services for elderly people, with the aim of minimising social exclusion and inequalities within urban areas.

Valerio Martinelli

He obtained a master's degree in Building Engineering-Architecture at the Department of Civil, Architectural and Environmental Engineering of the University of Naples Federico II.

TeMA Journal of Land Use, Mobility and Environment

TeMA 1 (2023) 227-231
print ISSN 1970-9889, e-ISSN 1970-9870
DOI: 10.6093/1970-9870/9822
Received 3td February 2023, Available online 30th April 2023

www.tema.unina.it

REVIEW NOTES – Town Planning International Rules and Legislation

Policies and practices of transition towards climate-neutral and smart cities

Federica Gaglione

Department of Engineering
University of Sannio, Benevento, Italy
e-mail: fgaglione@unisannio.it
ORCID: https://orcid.org/0000-0002-7067-7784

Abstract

Starting from the relationship between urban planning and mobility management, TeMA has gradually expanded the view of the covered topics, always following a rigorous scientific in-depth analysis. This section of the Journal, Review Notes, is a continuous update about emerging topics concerning relationships among urban planning, mobility, and environment, thanks to a collection of short scientific papers written by young researchers. The Review Notes are made up of five parts. Each section examines a specific aspect of the broader information storage within the main interests of the TeMA Journal. In particular: the Town Planning International Rules and Legislation. Section aims at presenting the latest updates in the territorial and urban legislative sphere. The current challenges of the city can be enclosed under a single umbrella called "Smart city" which can be a useful approach to define new forms of organizing the complexity of urban life and in turn implement solutions in urban areas ranging from energy consumption to climate change to achieve environmental sustainability goals. In this direction, this review focuses on the involvement of local authorities in the development of urban strategies that focus on smart city objectives within of the Europe2020 strategy and the climate neutral & smart cities mission.

Keywords

Urban sustainability; Smart city; Climate neutrality; Urban Agenda.

How to cite item in APA format

Gaglione, F. (2023). Policies and practices of transition towards climate-neutral and smart cities. *Tema. Journal of Land Use, Mobility and Environment*, *16* (1), 227-231. http://dx.doi.org/10.6093/1970-9870/9822

1. Transiting through smart cities

The "great challenges" of the future, such as climate change, the limited availability of resources, the lack of physical infrastructure, the increase in social inequalities especially for vulnerable groups of the population require a significant effort in the world where cities must be managed, governed and designed (Stilgoe, 2018; Orsetti et al., 2022). Added to this is the urbanization process which today occurs with diversified rhythms in the various territorial contexts, being considerably faster in developing regions than in developed ones. Recent studies carried out by the United Nations estimate that in 2030 about 60% of the world's population will live in urban areas and by 2050, about 68%. High urbanization indirectly generates high consequences on all the components of the urban system from that of the built, infrastructural, functional and environmental environment (Gargiulo & Papa, 2021). The continuous growth of the population is combined today also with the current standards of sustainability to which cities must aim with respect to the recent European and national objectives, above all there is an increasing need to move from traditional forms to more innovative and efficient forms of planning and urban management (Bibri & Krogstie, 2017; Gaglione & Etigo, 2022). The responses to face the current challenges can be enclosed under a single umbrella named "Smart city" which can be a useful approach to define new forms of organization of the complexity of urban life and in turn implement solutions for multidisciplinary problems in urban areas ranging from energy consumption, resource management, environmental protection, safety, quality of life, efficiency of urban operation and the availability of a wide variety of services. The term smart city appeared in the scientific debate around 1992 in a book entitled "The Technopolis Phenomenon: Smart Cities, Fast Systems, Global Networks" (Gibson et al., 1992). Since then, this concept research work has aroused several research areas, but also many stakeholders, from governmental organizations supporting the growing interest of the "Smart City" concept in the framework of global sustainable development (Patrão et al., 2020). A strong scientific interest is felt subsequently around 2010 including the multiple incarnations of the city, including the intelligent city, the digital city, the sustainable city, the ubiquitous city and the knowledge city (Han Kim, 2021). In the last decade there has been an exponential growth taking on different perspectives. In most of the studies the theme of the smart city is developed on four macro-areas of interest which are: the technological aspect, including the technological infrastructure (with a great emphasis on ICT) and the support network for the construction of cities intelligence, the sociocultural aspect, i.e. citizen involvement, the political-institutional aspect, such as government support and policies, and the economic-entrepreneurial aspect, i.e. business models and profitability. Indeed, we can identify two generations of smart cities. The first generation called "smart city 1.0" which was largely based on the diffusion of digital technology and the economic and business potential of smart city projects. Instead, smart city 2.0 has moved towards a decentralized and human-centric approach aimed at promoting collaboration and community engagement (Zhao et al., 2021). This in turn identified a paradigm shift of the smart city moving from a focus mainly centered on technology based on maximizing the efficiency of heavy urban infrastructures (e.g. example, transport, communications, waste, energy, water, etc.) to the adoption of a more global approach, in which the central role of people and soft infrastructures is recognized (institutions, data, social innovation, knowledge economy, justice, etc.) (Echebarria et al., 2021). By integrating the multiple dimensions on which the concept of smart city has moved, they can become an element of strategic transformation to increase competitiveness and quality of life and to aim at the objectives of environmental sustainability. In turn, the scientific research of reference has tried to define methods, indicators and decision support tools that could best define and measure intelligence at different scales such as regional, urban, neighborhood and building and therefore the necessary characteristics of different urban contexts (Aldegheishem, 2019). On the one hand, the scientific letter has tried to define the characteristics that identify the possibility of being able to make a city "smart" by trying to define the improvement interventions on the different territorial contexts and on the other to provide a framework of indicators and tools useful for the classification of smart cities (Romero et al., 2020; Deren et al., 2021). Some studies have

provided further details regarding the typology and thematic distribution of the indicators (Sharifi, 2019). In particular, the study by Stratigea et al. (2017) investigated and classified the different indicators on six areas of interest (economy, mobility, environment, people, life and governance) and found that most of them are related to the themes of "living" and of the "environment". Conversely, fewer indicators on "governance" and "people" have been defined. Instead, the study by Albino et al. (2015) provides an overview of the classification tools of smart cities examples the Intelligent Community Forum's Smart 21, the Global Power City Index, the Smarter Cities Ranking, the World's Smartest Cities, the IBM Smart City and the McKinsey Global Institute Rankings are also significant Studies by Akande et al. (2019); Li et al. (2019); Mohan et al. (2017) who have developed composite indicators of smart cities across different spatial contents such as Lisbon, China and India. Most of these studies aggregate the score of individual indicators to obtain an composite index that can be used to indicate the overall performance. Obtaining aggregated index scores often requires normalization of individual indicator scores. Commonly used normalization techniques are the 'min-max' technique and the 'z-score' method. In turn, both within the supporting tools and in the development of indicators different weights are assigned to different indicators to recognize their different levels of significance and incidence. If, on the one hand, scientific research has tried to define the most exhaustive cognitive scenarios, on the other, the institutions are making considerable efforts to ensure that the different territorial contexts aim in a synergistic way to become "smart" and neutral cities from a climate. The vision of urban space in relation to the general objective of an intelligent city is also an expression of innovation in territorial policy and in the use of resources and in environmental protection. However, concretely the problem arises of bringing the various smart interventions back to an overall vision of the city of the future that guides citizens towards an effective innovative dimension. In this direction, this review focuses on the involvement of local authorities in the development of urban strategies that focus on the smart city objectives within the Europe2020 strategy and the climate neutral & smart cities mission.

Europe 2020: the strategy of the European Union

This idea of a smart European city emerged in some specific references in intervention projects starting from 2000 and perfected in the 2007 Leipzig Charter, a programmatic document on the sustainable development of cities and on the promotion of integrated urban policies, up to the recent European strategies. One of the significant documents is the "Europe 2020" strategy for urban regeneration through energy efficiency, improvement of transport and renewal in the management of services and the objectives contained in the Territorial Agenda of the European Union 2020 in the form of energy savings and sustainability of the development of urban territories, of progressive reduction of soil consumption, according to an integrated vision that involves various sectors, administrative authorities, not only local authorities, and economic operators. The Europe 2020 strategy aims to ensure that the European Union's (EU) economic recovery following the economic and financial crisis is accompanied by a set of reforms that establish solid foundations for growth and job creation by 2020 while addressing structural weaknesses in the EU economy and economic and social issues, the strategy also considers longer-term challenges such as globalization, resource wars and ageing. To achieve this aspiration, the EU has set itself five major objectives to be achieved by 2020: (i) to bring the employment rate of people aged between 20 and 64 to at least 75%; (ii) invest 3% of gross domestic product in research and development; (ii) reduce greenhouse gas emissions by at least 20%, increase the share of renewable energies to 20% and increase energy efficiency by 20%; (iii) reduce the dropout rate to less than 10% and bring the rate of young graduates to at least 40%; (iv) reduce the number of people at risk of poverty or social exclusion by 20 million. One of the results of this strategy can be identified in the "Mapping Smart Cities in EU" which aims to define standards of the term smart city, a common model of intelligent city and a series of guidelines for the implementation of dedicated projects. In particular, the study was conducted for all urban areas divided into three population groups from 100,000 to 500,000 inhabitants) which had launched intervention plans in the following areas: public administration, governance, energy, social innovation, smart community, urban livability, sustainable mobility, smart economy, and protection/enhancement of the environment. Furthermore, it emerged that most of the large cities showed higher smart city indexes than the medium-small ones and that their distribution is fragmented and unequal among the Member States. As regards announced projects, two-thirds of these often remain on paper, due to bureaucratic, economic, and organizational limitations. In turn, the strategy has led to an

increase in EU sectoral actions (cities, environment, energy, transport, etc.) because of a specific European policy for smart cities. The most recent European guideline, on the other hand, decisively pursues the overcoming of sectoral policies and the involvement of local authorities in the elaboration of urban strategies that focus on the objectives of smart cities and on the European Urban Agenda, as an overall vision of intervention aimed at to cities and urban areas, to be implemented in the long term as an overall policy and discipline at European level.

Climate Neutral & Smart Cities

Compared to the policies issued in 2020, today the theme of the smart city has joined that of climate change. A significant example is the recent strategy issued by the European Union called "100 climate-neutral and smart cities by 2030". This strategy assumes that urban areas are home to 75% of EU citizens. They consume over 65% of the world's energy and account for over 70% of CO_2 emissions. To balance the emissions produced with those naturally absorbed by the planet, and reduce them to a minimum, it is necessary to undertake concrete actions such as those proposed by the EU Missions. The mission has as its main objective the reduction of the climate and that it depends heavily on urban action, in order to accelerate their transition to green and digital. In order for this mission to be implemented in a concrete way, the Cities mission also aims at the involvement and coordination between local authorities, citizens, businesses, investors, as well as regional and national authorities. In turn, the very ambitious goal of reaching 100 climate-neutral and smart cities by 2030 has a twofold purpose on the one hand to ensure that these cities act as centers of experimentation and innovation to enable all European cities to follow suit by 2050 and on the other hand to create synergies between existing initiatives and basing their activities on the real needs of cities as foreseen in the implementation plan. The mission finances a budget of 70 million euros on two themes. A first theme concerning co-designed intelligent systems and services for user-centred shared zero-emission mobility in urban areas, with an indicative budget of €50 million. A second theme, however, positive clean energy district (PED) digital twins, with an indicative budget of €20 million. Clean mobility, energy efficiency and green urban planning are the key topics for implementing common initiatives and enhancing collaborations in synergy with other EU programmes. The mission also offers networking opportunities, allows for the exchange of good practices between cities and supports citizen participation. The Commission will now invite the 100 selected cities to draft "Climate City Contracts" it will invite them to draft a plan for climate neutrality in all sectors, such as energy, buildings, waste management and transport, including plans of investment. The process will involve citizens, research organizations and the private sector. Among the advantages for cities are the possibility of receiving tailor-made advice and assistance from a dedicated mission platform managed by NetZeroCities, which will indirectly make it possible to give new possibilities and opportunities to obtain grants and funding and the possibility of joining major innovation actions and pilot projects. In the recent announcement by the Commission of the selected cities, nine Italian cities have been included in the European mission "100 climate-neutral and smart cities by 2030": Bergamo, Bologna, Florence, Milan, Padua, Parma, Prato, Rome and Turin.

The widespread interest in the smart city model also derives from the looming environmental problems such as climate change which are combined with the difficulties of combining public and private interests at stake; this justifies the constant attention of the Community institutions and European legislators to the most suitable instruments. The policy developed over the years, through concrete financial incentives, is aimed at a process of urban transformation that integrates, according to a systemic vision, the economic, environmental, social and "cultural" perspective; the evolution towards a smart dimension offers public administrations the opportunity to make the services provided to citizens more efficient and to encourage the introduction of innovative services, in order to improve competitiveness and the quality of urban life.

References

Akande, A., Cabral, P., Gomes, P., & Casteleyn, S. (2019). The Lisbon ranking for smart sustainable cities in Europe. *Sustainable Cities and Society*, *44*, 475-487. https://doi.org/10.1016/j.scs.2018.10.009

Albino, V., Berardi, U., & Dangelico, R. M. (2015). Smart cities: Definitions, dimensions, performance, and initiatives. *Journal of urban technology*, *22* (1), 3-21. https://doi.org/10.1080/10630732.2014.942092

Aldegheishem, A. (2019). Success factors of smart cities: a systematic review of literature from 2000-2018. *TeMA-Journal of Land Use, Mobility and Environment*, *12* (1), 53-64. https://doi.org/10.6092/1970-9870/5893

Bibri, S. E., & Krogstie, J. (2017). Smart sustainable cities of the future: An extensive interdisciplinary literature review. *Sustainable cities and society*, *31*, 183-212. https://doi.org/10.1016/j.scs.2017.02.016

Carmen Echebarria, Jose M. Barrutia & Itziar Aguado-Moralejo (2021) The Smart City journey: a systematic review and future research agenda, Innovation: *The European Journal of Social Science Research*, 34:2, 159-201. https://doi.org/10.1080/13511610.2020.1785277

Communication (COM(2010) 2020 final) - Europe 2020: A strategy for smart, sustainable and inclusive growth. Retrivied from: https://eur-lex.europa.eu/IT/legal-content/summary/europe-2020-the-european-union-strategy-for-growth-and-employment.html

Deren, L., Wenbo, Y., & Zhenfeng, S. (2021). Smart city based on digital twins. *Computational Urban Science*, *1*, 1-11. https://doi.org/10.1007/s43762-021-00005-y

Gaglione F., & Etigo D. (2022). Accelerate urban sustainability through European action, optimization models and decision support tools for energy planning. *TeMA - Journal of Land Use, Mobility and Environment, 15*(2), 325-334. https://doi.org/10.6093/1970-9870/9240

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

Gibson, D. V., Kozmetsky, G., & Smilor, R. W. (Eds.). (1992). *The technopolis phenomenon: Smart cities, fast systems, global networks*. Rowman & Littlefield. Publishers, Inc: Lanham, MD, USA, 1992.

Han, M. J. N., & Kim, M. J. (2021). A critical review of the smart city in relation to citizen adoption towards sustainable smart living. *Habitat International*, *108*, 102312. https://doi.org/10.1016/j.habitatint.2021.102312

Li, X., Fong, P. S., Dai, S., & Li, Y. (2019). Towards sustainable smart cities: An empirical comparative assessment and development pattern optimization in China. *Journal of Cleaner Production*, *215*, 730-743. https://doi.org/10.1016/j.jclepro.2019.01.046

Mohan, A., Dubey, G., Ahmed, F., & Sidhu, A. (2017). Smart cities index: a tool for evaluating cities. *Indian School of Business: Hyderabad, India*.

Orsetti, E., Tollin, N., Lehmann, M., Valderrama, V. A., & Morató, J. (2022). Building resilient cities: climate change and health interlinkages in the planning of public spaces. *International journal of environmental research and public health*, *19*(3), 1355. https://doi.org/10.3390/ijerph19031355

Papa, R., Gargiulo, C., & Galderisi, A. (2013). Towards an urban planners' perspective on Smart City. *TeMA Journal of Land Use, Mobility and Environment*, *6*(01), 5-17. https://doi.org/ 10.6092/1970-9870/1536

Patrão, C., Moura, P., & Almeida, A. T. D. (2020). Review of smart city assessment tools. *Smart Cities*, *3*(4), 1117-1132. https://doi.org/10.3390/smartcities3040055

Romero, M., Guédria, W., Panetto, H., & Barafort, B. (2020). Towards a characterisation of smart systems: A systematic literature review. *Computers in industry*, *120*, 103224. https://doi.org/10.1016/j.compind.2020.103224

Sharifi, A. (2019). A critical review of selected smart city assessment tools and indicator sets. *Journal of cleaner production*, *233*, 1269-1283. https://doi.org/10.1016/j.jclepro.2019.06.172

Sharifi, A. (2019). A critical review of selected smart city assessment tools and indicator sets. *Journal of cleaner production*, *233*, 1269-1283. https://doi.org/10.1016/j.jclepro.2019.06.172

Stilgoe, J. (2018). Machine learning, social learning and the governance of self-driving cars. *Social studies of science*, *48*(1), 25-56. https://doi.org/10.1177/0306312717741687

Stratigea, A., Leka, A., & Panagiotopoulou, M. (2019). In search of indicators for assessing smart and sustainable cities and communities' performance. In *Smart Cities and Smart Spaces: Concepts, Methodologies, Tools, and Applications* (pp. 265-295). IGI Global. 10.4018/978-1-5225-7030-1.ch012

United Nations. The World 's Cities in 2018. World's Cities 2018—Data Booklet (ST/ESA/SER.A/417). 2018. Available online: https://www.un.org/en/events/citiesday/assets/pdf/the_worlds_cities_in _2018_data_booklet.pdf, (accessed on 8 April 2020).

Zhao, F., Fashola, O. I., Olarewaju, T. I., & Onwumere, I. (2021). Smart city research: A holistic and state-of-the-art literature review. *Cities*, *119*, 103406. https://doi.org/10.1016/j.cities.2021.103406

Author's profile

Federica Gaglione

She is an engineer, PostDoc research fellow at Department of Engineering, University of Sannio, Benevento, Italy. She received her Ph.D. in Civil Systems Engineering at the University of Naples Federico II. The research topics addressed in recent years refer to accessibility to proximity services for vulnerable groups of the population. From August to December 2019, she served as a Visiting Researcher at the University of Aberdeen (UK) and from July to September 2022 Visiting Researcher at the University of Edinburgh (UK) carrying out research on urban accessibility in the context of climate change and sustainability, leveraging geographic big data through GIS and programming languages.

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 (2023) 233-237
print ISSN 1970-9889, e-ISSN 1970-9870
DOI: 10.6093/1970-9870/9837
Received 13th February 2023, Available online 30th April 2023

www.tema.unina.it

REVIEW NOTES – Urban practices

European cities and e-scooters at the crossroad

Gennaro Angiello

Systemica, Bruxelles, Belgium
e-mail: gennaro.angiello@unina.it

Abstract

Starting from the relationship between urban planning and mobility management, TeMA has gradually expanded the view of the covered topics, always following a rigorous scientific in-depth analysis. This section of the Journal, Review Notes, is the expression of a continuous updating of emerging topics concerning relationships among urban planning, mobility and environment, through a collection of short scientific papers. 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 producing, analyzing and reporting data on recent and relevant policies in the urban domain.

The present note analyses the complex relationships between European cities and electric scooters and reports on the case study of Paris where, in a recent non-binding referendum, Parisians opted overwhelmingly to ban e-scooters in the French capital. In doing so, the note tracks the roots of the current e-scooters expansion and reports on the massive deployment of 500,000 free-floating electric vehicles on the European streets (and sidewalks) operated by few private mobility companies in less than three years. After this, the note provides a focus on Paris, the city that pioneered electric scooters in Europe and that will likely take them off the street as of September 2023. The note concludes that the relationship between e-scooters and European cities is at a turning point and provides some suggestions to move forward.

Keywords

E-scooter; Paris; Ban; Regulation; European cities; Micro mobility.

How to cite item in APA format

Angiello G. (2023). European cities and e-scooters at the crossroad. *Tema. Journal of Land Use, Mobility and Environment*, *16* (1), 233-237. https://doi.org/10.6093/1970-9870/9837

1. Introduction

Standing electric scooters (henceforth e-scooters) are electrically powered vehicles with a handlebar, deck, and two wheels. They are light (less than 35 kg), travel at a convenient speed (about 25 km/h) and have relatively low operating costs. As such they provide an alternative for short trips and are particularly suitable for solving the last-mile transit problem (Garcia et al., 2022). Although they have been present in urban areas for at least a century, their impact on urban mobility and quality of life has been negligible until recently, when the convergence of various sociotechnical and political-economic factors – such as the proliferation of smartphone-based mobility services, increments in traffic congestion in urban areas, and the amount of private financing available (Hodson & McMeekin, 2020) – made this form of transportation increasingly popular in many cities worldwide.

As a form of shared and dockless micro mobility service, e-scooter systems were first introduced in the United States in 2017 (Dowling, 2018). In Europe, they have been proliferating initially in France, with the arrival of the first provider in Paris in the summer of 2018 (ADEME, 2019). Since then, e-scooters fleets have been deployed in over 600 European cities and towns (EIT, 2023), with Oslo, Rome, Madrid, Zurich and Lisbon hosting the largest fleets of vehicles in Europe, as of October 2022 (O'Brien, 2022). This massive deployment of electric vehicles – operated by privately-owned mobility companies – has sharply transformed the mobility landscape of major European cities. According to Lime for instance, e-scooters exceeded 100 million rides in Europe in 2019, and in Madrid, Prague and Athens, more than 1 million rides using e-scooters were made in just one year of operation (Lime, 2019).

The rapid proliferation and adoption of e-scooters has brought about a number of welcome changes, from positive impacts on the environment and the economy, to better options for getting around more easily and inexpensively (Dias et al., 2021). However, a worrying number of injuries (Coelho et al., 2021), coupled with uncertain regulations (Orozco-Fontalvo et al., 2022) and concerns over data sharing and privacy (Li et al., 2021), generated, in the past few years, a heated debate about the long-term success and practicality of this form of transportation in urban areas.

2. European cities and e-scooters at a crossroad: how we got there?

European cities have become catalysts of the e-scooter services expansion, as extended bicycle networks, compact and walkable urban settlements, and pleasant city landscapes provided the perfect environment for the adoption of this type of mobility services in urban areas (Hosseinzadeh et al., 2021). The roots to the current expansion can be found in the years 2010s when the first wave of sustainable urban mobility plans – introduced and widely promoted by the European Commission since 2013 – fostered the expansion of bicycle infrastructures and the experimentation of alternatives to conventional forms of transportation (Cirialli et al., 2018). Later in the same decade, the smart mobility paradigm became a prominent concept in European transport planning (Battarra et al., 2018). As an approach mainly focused on electric vehicles, on demand ride services and the ubiquitous use of modern information and communication technologies (Angelidou, 2017), smart mobility planning provided further ground to the current wave of dockless bikes and scooters expansion. With sustainable and smart mobility becoming the mainstream agenda of many European cities, an increasing number of municipal e-bike-sharing programmes were introduced in Europe, while conventional bike-sharing services were rapidly replaced by e-bikes ones (Mátrai & Tóth,2016).

In 2017, free-floating e-bike sharing fleets were deployed in Europe, namely in the United Kingdom, Italy, Germany and Belgium. Unlike public bikes which were often housed at fixed docking stations, free-floating bikes were owned and run by private mobility companies and were easier to put into place, as they required no infrastructural installations. As such, free-floating e-bikes started flooding European cities' streets. In just two years, according to field data gathered by Zagorskas & Burinskienė (2020), free-floating e-bikes became

equally popular or even more popular than conventional bikes in many European cities, accounting up to 45–60% non-motorized vehicle trips in central Paris and Barcelona.

These privately-owned, dockless e-bike schemes however had a rough start in Europe with sidewalks being littered with bicycles and riders encroaching public spaces meant for pedestrians, thus causing significant safety concerns both for themselves and the pedestrian (Coelho et al., 2021). In a certain way, the massive deployment of e-bikes in urban areas anticipated most of the issues that emerged few years later with e-scooters. Yet, shared free-floating e-bikes systems, either public or private, have been incorporate in that years in several sustainable urban mobility plans as a measure to curb car dependency and increase the use of environmentally friendly transport (Mozos-Blanco et al., 2020, Angiello, 2022).

No one in Europe however anticipated the massive uptake of e-scooters and their disruptive effects on the urban environment (MC Kinsey,2022). At the end of 2018, shortly after the successful experiences in more than 90 US cities (citation), US e-scooters companies such as Lime and Bird started to look at European cities as the next market for e-scooter services expansion. Few months later (and after a banner 2019 of mega funding rounds for European e-scooter start-ups), European companies such as Dott, Tier, Wind and Voi, also entered the market and – in only three years – they implemented the fastest rollout in the history of mobility services.

Pushed by massive venture capital investments (Gössling, 2020), and in a context of increasing demand and scarce regulation, these companies harshly compete between themselves for customers. As rental rates tended to level off, coverage (and thus the number of vehicles deployed) became the ultimate strategy for winning the market, which ultimately lead to mobility companies rolling out larger and larger fleets of vehicles in shorter period of time. Compared with their predecessors (the e-bikes), e-scooters were thus deployed at a much faster rate and their level of adoption was estimated to be 2.5 higher than that e-bikes (MC Kinsey,2022). Challenges posed by e-scooters to the urban environment were consequentially much bigger.

In the years 2020 and 2021, the growing e-scooter trend (and that of micro-mobility in general) was further reinforced by the Covid-19 pandemic, where the need of keeping social distance and avoiding crowded public transport further boosted the usage of micro mobility services in Europe (Fazio et al., 2021). Shortly after, when the lock-down and other forms of restriction introduced by government to contain the spread of the virus were removed and European citizens started to come back to their pre-pandemic life, the challenges and the transformations to the urban environment brought by the e-scooters become evident (Zagorskas & Burinskienė, 2020) and European cities started to take diverging paths. From one side cities such as Milan, Paris decided to expand micro-mobility options as a form of recovery strategy aimed at promoting at the same time sustainability and resilience of the urban transport sector (Angiello, 2021). On the other side, cities like Stockholm and Riga started to introduce restrictive measures (EIT, 2023).

These diverging paths are still present today, with cities such London (which is currently running an e-scooter trial involving three private operators) that are embracing the opportunities brought by e-scooters and other such as Paris that are banning them from the streets (The Guardian, 2023). In the meanwhile, a heated and polarized debate is mounting in Europe, with enthusiastic users who consider electric micromobility vehicles "fun" and "easy to use" and recalcitrant public opinion wherein electric micromobility vehicles are deemed "unsafe" and "dangerous". With research on e-scooters impacts on mobility and quality of life in urban areas still in its infancy, lack of harmonized data on e-scooter operations across Europe (further aggravated by the tendency of mobility providers to not open their data, if not forced to) and fragmented regulation, the debate on the role of e-scooters in European cities is far from an ultimate conclusion.

The Paris' ban on e-Scooter

Paris is the capital and most populous city of France, with an estimated population of 2.1 million inhabitants. Spanning on a surface of 105 km2, it is the 9th denser city in the world (World Atlas, 2018). Its region, Île-de-France, concentrates 23% of the jobs in France, 31% of the growth domestic product (IAURIF, 2017), and is highly attractive to tourists (IAURIF, 2019). Consequently, mobility needs are high, with an estimate of 40 million daily trips made only by locals (DRIEA, 2013). The city is very well served by public transport with 16 metro lines, 5 suburban railway lines, 4 tramway lines, and over 65 bus lines (OMNIL, 2018), and can boast a long track record of shared mobility initiatives.

The city successful history of shared mobility in Paris started in 2007 with the implementation of the Vélib' scheme, a large-scale docking bike-sharing system equipped with smart card contactless technology. The system was lately enlarged to some 16,000 bicycles and 1,200 rental stations (roughly one station every 300 meters) making Vélib' the third-most-extensive system of its kind in the world in 2013 (citation). In 2018 the program (meanwhile rebranded as Vélib' Métropole) was further expanded to 64 surrounding municipalities while 40% of the fleet was converted in e-bikes. The trend toward shared mobility continued in the years 2011–2018 with the introduction of several free-floating electric cars schemes such as Free2Move, Car2Go and Zity, and free-floating electric motor scooters fleets, since 2016. The subsequent advent of free-floating e-bike services in 2017 and free-floating e-scooter services in 2018 appeared, at least at the beginning, a coherent prosecution of this trend.

Micro-mobility services landed in Paris during the first mandate of the mayor Anne Hidalgo of the France's Socialist party. During her first mandate, Paris went through a series of policies that banned the most polluting vehicles from entry to the city, freed the quayside of the Seine from cars, and regained the space of the streets for more trees, extended cycling infrastructures and pedestrian space (Pisano, 2020). Within this context, the first fleet of free-floating e-bikes was brought to the city by Lime in December 2017. Few months later, Dott, Zoov and Pony joined the race.

After the massive operation of shared bicycles in the city, in July 2018, Lime introduced its first fleet of 4,000 shared e-scooters. Since then and up to September 2019, Parisians rode Lime more than 12 million times, an average of over 32,000 daily trips, travelling over 20 million kilometers (Lime, 2020). As for other cities, the battle to win the market was however just at the beginning: it only took one year for the number of e-scooter to reach 20,000 units operated by 12 different companies that become 17 later in 2020 (citation). Overall, e-scooters become at the same time a popular mode of transportation in Paris, but also a controversial one, with supporters arguing that they provide a convenient and eco-friendly way to get around the city, while critics raise concerns about safety and the impact on pedestrians and the environment.

Pushed by negative headlines about vandalism, theft, occupation of public space and safety, the Paris City Council introduced in 2020 new regulations aimed at reducing the number of e-scooters on the streets and improving safety. These regulations required scooters' speeds to be capped at 20 km/hour and introduced stricter enforcement of rules around parking and on rider behaviors. Furthermore, the number of operators was reduced from 17 to three (Dott, Lime, and Tier) and a cap on the maximum number of e-scooters allowed in the city was set to 15,000, as each company was allowed to operate maximum 5,000 vehicles simultaneously. Paris Council signed with these companies a three-years trial contract (running until September of this year, 2023) that would have been reviewed annually.

Despite this, complaints did not subside. In 2021, 24 people died in e-scooter-related accidents in France, including one in Paris. The year after, Paris registered 459 accidents with e-scooters and similar vehicles, including three fatal ones (citation). In an effort to rewin the public, operators offered further regulations, including checking users were over 18, fixing license plates so police could identify traffic offenders and limiting the use of e-scooters to one passenger. But as the city reviewed the program late last year, it became clear that Mayor Anne Hidalgo was leaning toward ending the trial. Rather than killing it outright, Hidalgo eventually announced a referendum.

The companies operating the scooters feared the referendum as its result could potentially lead their profitable businesses to an end. As such, among other initiatives, they decided to recruit paid influencers to help promote the pro-scooter vote online to younger voters who make up the core of their market. Lime – which cites Paris as one of the cities with the highest usages of its services in the world (Lime, 2020) – even offered free rides to users who register to vote. "Prove you're registered to vote and get a free 10-minute ride, on us" said the text of the email that the company sent to thousands of Parisian users. Despite these efforts, on the 16th of April 2023, 89% of referendum's voters voted in favor of ending the program that allowed the three electric scooter companies to offer their services. However, only about 100,000 voters casted a ballot, about 7.5 of all registered voters in the city.

Technically, the referendum is advisory and therefore non-binding. However, in a post-election speech, the mayor Hidalgo praised voters and said she intended to honor the outcome. "Thank you to the more than 100,000 Parisians who spoke, it's a great victory for local democracy," she said on Twitter. "Once again, Paris has been able to innovate! Parisians have overwhelmingly spoken out against self-service scooters; we will put an end to it by September 1st.".

3. European cities and e-scooters at a crossroad: how we got there?

Electric scooters provide a convenient and easy way to navigate a city. Beside their convenience, e-scooters can play an important role in the transition toward sustainable and smart transportation in cities (citation). E-

scooters indeed are powered by electricity and emit fewer greenhouse gases compared to gas-powered vehicles. Furthermore, e-scooters take up less space on the road and can move through traffic more efficiently, reducing congestion and travel time. Empirical research on their impacts on modal share remain relatively scarce. In Hamburg for instance researchers have identified that people use shared e-scooters in place of cars at substantial rates (citation). Other research in Paris however noted that e-scooters have replaced waling and public transport trips, the latter provides better environmental performances when the full lifecycle of the service is considered (citation). Yet, despite their potential contribution to urban sustainability, e-scooters creates a host of problems that cities must navigate.

While some commentors have seen in the Paris' ban the end of "a love affair" between e-scooters and European cities (citation), it is most likely that e-scooters will continue to ride European streets in the future. Yet, the Paris' ban certainly marked an emblematic turning point: the city that pioneered electric scooters will likely take them off the street in the next few months.

What will happen after this event it is hard to predict. Certainly, the Paris' ban – together with other regulating initiatives introduced across Europe – can be helpful in identifying how we can move forward, and a number of lessons can be learned from Paris and other international case studies [refine after]:

- First, the diverging path to e-scooters by major cities in Europe reflects the technology's chaotic rollout over the last few years and an inability for cities to keep up with sufficient regulations. It's also illustrative of how the path to sustainable and smart transportation won't look the same everywhere.
- Second, proper regulations and the inclusion of additional measures can be a game changer: ensuring that operators take responsibility for improperly parked vehicles, limiting vehicle fleets' size, strengthening law enforcement in sensitive areas are some examples of measures that can provide valuable contribution in addressing the problems caused by the massive and fast-paced deployment of e-scooters in urban areas.
- Third, to address the negative impact and opinions currently associated with e-scooter use, it is fundamental that private mobility companies become more transparent on the performances of their fleets and operations in terms of safety and sustainability, as well as their contribution to modal shift. To this aim it is extremely important that e-scooters operators provide open access to their operational data. This will further support research on e-scooters and their impacts on mobility and quality of life in the cities, an emerging research field where lack of open and harmonized data represents still one of the main challenges.
- Finally, it is extremely important for local authorities to set clear rules and establish positive collaborations with mobility companies in order to develop shared solutions that benefit all parties involved. Furthermore, local authorities should govern and regulate these services in an integrated manner, framing micro mobility services planning in the broad context of smart and sustainable multimodal transport planning and in connection with land use planning and urban design.

Image Sources

All images are from wekipedia.org.

Author's profile

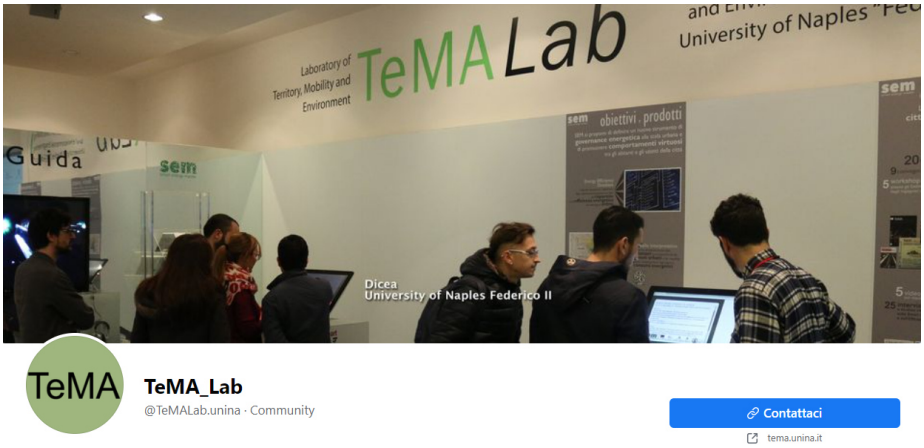
Gennaro Angiello

Gennaro Angiello is a Senior IT Consultant, currently auditing for the European Commission, where he leads the analysis and design of information technologies aimed at supporting data-driven policymaking in the domain of environment, public health and food safety. Prior to moving to the private sector, Gennaro has worked as researcher at the Department of Civil, Architectural and Environmental Engineering of the University of Naples Federico II and has been Visiting Fellow at the Department of Human Geography of the Complutense University of Madrid.

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 (2023) 239-243
print ISSN 1970-9889, e-ISSN 1970-9870
DOI: 10.6093/1970-9870/9821
Received 3rd February 2023, Available online 30th April 2023

www.tema.unina.it

REVIEW NOTES – Economy, business and land use

Circular economy in urban areas: evidence from global cities

Stefano Franco

Department of Mechanics, Mathematics and Management
Politecnico di Bari, Italy
e-mail: stefano.franco@poliba.it
ORCID: https://orcid.org/0000-0001-7341-8318

Abstract
Starting from the relationship between urban planning and mobility management, TeMA has gradually expanded the view of the covered topics, always following a rigorous scientific in-depth analysis. This section of the Journal, Review Notes, is the expression of a continuous updating of emerging topics concerning relationships among urban planning, mobility and environment, through a collection of short scientific papers. 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 Economy, business and land use section aims at presenting recent advancements on relevant topics that underlie socio-economic relationships between firms and territories. The present note aims at addressing the issue of circular economy in urban contexts describing theoretical approaches and identifying best practices from cities across the world.

Keywords
Circular economy; Cities; Net zero; Waste reduction.

How to cite item in APA format
Franco, S. (2023). Circular economy in urban areas: evidence from global cities. *Tema. Journal of Land Use, Mobility and Environment*, *16* (1), 239-243. http://dx.doi.org/10.6093/1970-9870/9821

1. Introduction

Circular economy is a rapidly emerging concept in the field of urban studies that seeks to create a more sustainable and efficient system for resource management (Guida & Caglioni, 2020; Petit-Boix & Leipold, 2018). It is a regenerative approach that aims to minimize waste, optimize resource use, and increase the longevity of products and materials. In this research note, we will provide an overview of circular economy in urban studies, its principles, and its potential applications. Circular economy is based on three core principles: designing out waste and pollution, keeping products and materials in use, and regenerating natural systems (Christensen, 2021). The first principle focuses on reducing waste and pollution by designing products and materials that can be easily reused or recycled. The second principle emphasizes the importance of extending the life of products and materials through repair, refurbishment, and remanufacturing. The third principle involves regenerating natural systems by restoring ecosystems, protecting biodiversity, and reducing carbon emissions (Pilogallo et al., 2019). Urban areas are particularly well-suited for the implementation of circular economy principles. Cities are centers of economic activity, and they generate significant amounts of waste and emissions (Tira, 2020). However, they also offer opportunities for collaboration and innovation that can drive circular economy solutions. For example, urban areas are home to large concentrations of consumers and businesses that can participate in circular economy networks, such as sharing platforms and product-service systems (Williams, 2019). They also offer a diverse range of waste streams, such as food waste and construction materials, that can be repurposed or recycled. Circular economy in urban studies has numerous potential applications (Wang et al., 2018). For example, circular economy principles can be applied to the design of buildings and infrastructure to reduce waste and energy consumption. Materials used in construction can be selected for their recyclability, and buildings can be designed to incorporate renewable energy sources and to maximize energy efficiency. In addition, circular economy principles can be applied to waste management systems to increase the recovery and recycling of materials. Innovative approaches to waste management, such as waste-to-energy technologies, can also help to reduce the amount of waste sent to landfills. Thus, circular economy is a promising approach for achieving more sustainable and efficient resource management in urban areas. It offers opportunities for collaboration and innovation that can help to reduce waste, optimize resource use, and regenerate natural systems. As cities continue to grow and face increasing environmental challenges, circular economy principles can play an important role in creating a more sustainable and resilient urban future (Pirlone & Spadaro, 2020).

2. Approaches to circular economy in cities

The circular economy in cities is a complex and multifaceted concept that draws on several theoretical frameworks (Corvellec et al., 2022). Some of the key theoretical frameworks that underpin the circular economy in cities include: Urban Metabolism (Kennedyt al., 2011), Industrial Ecology (Petit-Boix & Leipold, 2018), System Thinking (Bassi et al., 2021), Social-Ecological System (Folkeet al., 2005), Service Dominant Logic (Ekman et al., 2019). Urban metabolism is a framework that views cities as complex systems that consume resources and produce waste. The circular economy in cities aims to reduce the resource consumption and waste production of cities by creating closed-loop systems. Industrial ecology is a framework that views industrial systems as ecosystems that can learn from natural ecosystems. The circular economy in cities draws on this framework by promoting the use of waste as a resource, mimicking natural systems in which waste is used by other organisms in the ecosystem. Systems thinking is a framework that views systems as interconnected and interdependent. The circular economy in cities draws on this framework by promoting the creation of circular value chains, where waste from one business becomes a resource for another business. Social-ecological systems is a framework that views the interactions between social systems and ecological systems as interdependent. The circular economy in cities draws on this

framework by promoting the creation of circular systems that are socially and environmentally sustainable. Service-dominant logic is a framework that views economic systems as focused on the creation of value for customers through services rather than the production of goods. The circular economy in cities draws on this framework by promoting the creation of circular business models that focus on providing services rather than selling products. These theoretical frameworks provide a basis for understanding the circular economy in cities and its potential benefits for sustainability, economic development, and social well-being. They help to identify the challenges and opportunities associated with transitioning to a circular economy in cities and guide the development of strategies and policies that can promote this transition. In the following boxes we provide some practical applications of these approaches to different urban contexts. In particular, we describe circular economy strategies of Seoul, Ljubljana, and Rotterdam.

Seoul

Seoul, the capital city of South Korea, has implemented a range of circular economy initiatives aimed at reducing waste, promoting sustainable production and consumption, and creating a more resource-efficient city. Among other initiatives, the city of Seoul implemented:

- food waste recycling: Seoul has implemented a program to convert food waste into biogas, which is used to generate electricity and heat. The city has installed food waste collection systems in apartment buildings and other public facilities, and the collected waste is then transported to biogas plants for processing. This program has significantly reduced the amount of food waste sent to landfills and has helped to create a new source of renewable energy for the city;
- sharing economy platform: Seoul has launched a sharing economy platform called "ShareHub," which connects individuals and businesses to share resources and services. The platform includes a range of services, such as shared workspaces, tool libraries, and car sharing services. By encouraging resource sharing, the platform helps to reduce waste and promote a more sustainable and resource-efficient city;
- upcycling: Seoul has implemented a program to upcycle waste materials into new products. The program includes initiatives such as "upcycling villages," where local artisans create new products from waste materials such as plastics, textiles, and metal. The upcycling program helps to reduce waste and promote sustainable production practices;
- circular economy education: Seoul has implemented a range of educational programs to raise awareness of the circular economy and promote sustainable production and consumption practices. These programs include workshops, seminars, and other educational events aimed at businesses, students, and the general public.

Overall, Seoul's circular economy initiatives demonstrate the city's commitment to creating a more sustainable and resource-efficient urban environment. By implementing programs such as food waste recycling, sharing economy platforms, and upcycling initiatives, the city is reducing waste, promoting sustainable production and consumption, and creating a more resilient and sustainable city for its residents.

Ljubljana

Ljubljana, the capital city of Slovenia, is a leading example of circular economy principles being implemented on a city-wide scale. In 2017, Ljubljana was awarded the title of European Green Capital in recognition of its efforts to promote sustainability and implement circular economy principles. One of the key initiatives implemented by Ljubljana is its "Zero Waste" program, which aims to divert all waste from landfills by 2025. The program includes a range of measures to reduce waste generation, increase recycling, and promote composting. For example, the city has implemented a system of separate waste collection, with separate bins for organic waste, paper, plastic, metal, and glass. The city also provides residents with composting bins and organizes educational programs to promote composting. Ljubljana has also implemented a number of initiatives to promote sustainable consumption and production. The city has developed a circular economy strategy that includes measures to promote sustainable tourism, reduce resource consumption in construction, and support sustainable procurement practices. The city also supports a range of circular business models, including sharing and rental services. Another key initiative implemented by Ljubljana is the renovation of its historic city center. The renovation project, which was completed in 2018, included the implementation of energy-efficient lighting, the installation of green roofs and facades, and the use of sustainable building materials. The project also included the installation of a district heating and cooling system, which uses waste heat from a nearby waste-to-energy plant to provide heating and cooling to buildings in the city center. Overall, Ljubljana's circular economy initiatives demonstrate that it is possible to implement circular economy principles on a city-wide scale. The city's Zero Waste program, circular economy strategy, and sustainable building renovation project are just a few examples of the innovative initiatives that have been implemented. These initiatives have helped to reduce waste, promote sustainable consumption and production, and create a more resilient and sustainable city.

Rotterdam

Rotterdam is a city that has been at the forefront of the circular economy movement. The city has implemented various initiatives to promote a circular economy, such as:

- Rotterdam Circular: This is a platform for businesses, organizations, and citizens to collaborate and share knowledge and resources to promote a circular economy. The platform offers various services, including circular procurement advice, circular design support, and circular innovation.
- BlueCity: This is a business park that is dedicated to the circular economy. It is a hub for innovative businesses that focus on circular design, circular production, and circular business models. BlueCity aims to create a closed-loop system where waste from one company becomes the input for another company.
- Circular Buildings: Rotterdam is promoting the construction of circular buildings that are designed for disassembly, reuse, and recycling. The city has set a target to make all new buildings in Rotterdam circular by 2050.
- Circular Food: Rotterdam has launched several initiatives to promote a circular food system. For example, the city has set up urban agriculture projects, such as rooftop gardens, and it is promoting the use of food waste as a resource.
- Waste-to-energy: Rotterdam has several waste-to-energy plants that convert waste into energy. The city is also exploring the use of other waste-to-product technologies, such as chemical recycling and biorefining.
- The Circular Hub is an initiative in Rotterdam that aims to accelerate the transition to a circular economy by connecting businesses, entrepreneurs, and researchers. It is a physical space located in the city center where circular economy stakeholders can meet, network, and collaborate on circular projects. The Circular Hub was launched in 2019 by Rotterdam Partners, a not-for-profit organization that promotes the economic development of Rotterdam. The hub offers various services to its members, including access to funding, mentoring, and matchmaking events. One of the key objectives of the Circular Hub is to facilitate the creation of circular value chains. This involves connecting businesses that produce waste with businesses that can use that waste as a resource. By creating these circular value chains, the hub aims to reduce waste and create new economic opportunities. The Circular Hub also provides a platform for circular innovation. It hosts events and workshops to promote knowledge-sharing and collaboration between circular economy stakeholders. The hub has a circular innovation lab where entrepreneurs can experiment with circular business models and develop new circular products and services. In summary, the Circular Hub is an important initiative in Rotterdam's circular economy ecosystem. It plays a vital role in connecting circular economy stakeholders and promoting circular innovation and value creation.

3. Conclusion

Circular economy in cities is a growing body of literature and an increasingly relevant issue in practice. The abundance of theoretical approaches and the growing number of best practices offer new perspective on how to develop sustainable practices in cities aimed at achieving the net zero goal. To this aim, the joint work of urban stakeholders, i.e., administrations, firms and citizens is fundamental to create closed loops aimed at reducing wastes and optimizing the use of natural resources that could create sustainable urban environments.

References

Bassi, A. M., Bianchi, M., Guzzetti, M., Pallaske, G., & Tapia, C. (2021). Improving the understanding of circular economy potential at territorial level using systems thinking. *Sustainable Production and Consumption*, *27*, 128–140. https://doi.org/10.1016/j.spc.2020.10.028

Christensen, T. B. (2021). Towards a circular economy in cities: Exploring local modes of governance in the transition towards a circular economy in construction and textile recycling. *Journal of Cleaner Production*, *305*, 127058. https://doi.org/10.1016/j.jclepro.2021.127058

Corvellec, H., Stowell, A. F., & Johansson, N. (2022). Critiques of the circular economy. *Journal of Industrial Ecology*, *26*(2), 421–432. https://doi.org/10.1111/jiec.13187

Ekman, P., Rondell, J., & Yang, Y. (2019). Exploring smart cities and market transformations from a service-dominant logic perspective. *Sustainable Cities and Society*, *51*. https://doi.org/10.1016/j.scs.2019.101731

Folke, C., Hahn, T., Olsson, P., & Norberg, J. (2005). Adaptive governance of social-ecological systems. *Annual Review of Environment and Resources*, *30*, 441–473. https://doi.org/10.1146/annurev.energy.30.050504.144511

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.

Kennedy, C., Pincetl, S., & Bunje, P. (2011). The study of urban metabolism and its applications to urban planning and design. *Environmental Pollution*, *159*(8–9), 1965–1973.

Petit-Boix, A., & Leipold, S. (2018). Circular economy in cities: Reviewing how environmental research aligns with local practices. *Journal of Cleaner Production*, *195*, 1270–1281. https://doi.org/10.1016/j.jclepro.2018.05.281

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. https://doi.org/10.6092/1970-9870/6117

Pirlone, F., & Spadaro, I. (2020). The resilient city and adapting to the health emergency. *TeMA Journal of Land Use Mobility and Environment*, (TeMA Special Issue), 305–314. https://doi.org/10.6092/1970-9870/6856

Tira, M. (2020). About the Sustainability of Urban Settlements. *TeMA Journal of Land Use, Mobility and Environment*, 361–371. https://doi.org/10.6092/1970-9870/6984

Wang, N., Lee, J. C. K., Zhang, J., Chen, H., & Li, H. (2018). Evaluation of Urban circular economy development: An empirical research of 40 cities in China. *Journal of Cleaner Production*, *180*, 876–887. https://doi.org/10.1016/j.jclepro.2018.01.089

Williams, J. (2019). Circular cities. *Urban Studies*, *56*(13), 2746–2762. https://doi.org/10.1177/0042098018806133

Authors' profile

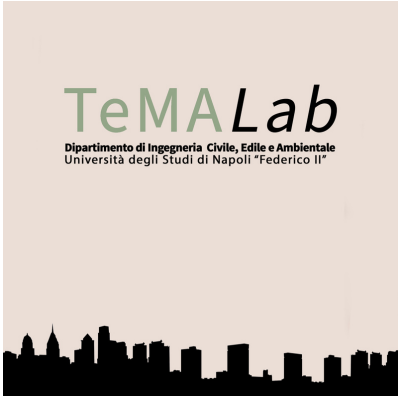
Stefano Franco

PhD, is an Assistant Professor at Politecnico di Bari. He has been visiting researcher at Rey Juan Carlos University, Madrid. His main research interests are in the areas of sustainability and innovation. His papers have appeared in international refereed journals, among others *IEEE Transactions on Engineering Management, Business Strategy and the Environment, Journal of Cleaner Production.*

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 (2023) 245-250
print ISSN 1970-9889, e-ISSN 1970-9870
DOI: 10.6093/1970-9870/9814
Received 30th January 2023, Available online 30th April 2023

www.tema.unina.it

REVIEW NOTES – Urban development and NextGenerationEU

The interventions of the Italian Recovery and Resilience Plan: digitalization in cities

Sabrina Sgambati [a*], Tonia Stiuso [b]

Department of Civil, Architectural and Environmental Engineering
University of Naples Federico II, Naples, Italy
e-mail: sabrina.sgambati@unina.it
ORCID: https://orcid.org/0000-0001-8900-278X
*Corresponding author

[b] Department of Civil, Architectural and Environmental Engineering
University of Naples Federico II, Naples, Italy
e-mail: t.stiuso@studenti.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 following a rigorous scientific in-depth analysis. This section of the Journal, Review Notes, is the expression of a continuous updating of emerging topics concerning relationships among urban planning, mobility and environment, through a collection of short scientific papers. 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.

This section of the Review Notes deals with the new frontiers of urban development through the lenses of the European program NextGenerationEU.

In particular, this contribution deepens the topic of digitalization in urban areas within the framework of the Italian National Recovery and Resilience Plan. It provides an overview of the proposed reforms, strategies and interventions to boost the digital economy and digitalize public services within the urban context.

Keywords

Digitalization; Innovation; Smart city; Italian Recovery and Resilience Plan.

How to cite item in APA format

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.
http://dx.doi.org/10.6093/1970-9870/9814

1. Digitalization as a new frontier of urban development

The recent global experience of COVID-19 has imposed new challenges for cities (Lai et al., 2020; Bailey et al., 2021), accelerating already ongoing processes such as the digital transition (Allam & Jones, 2021; Fernandes, 2021), which has confirmed its role as a key factor for urban development (Dana et al., 2022). Since the 1990s, the diffusion of innovative means of communication and new technologies triggered renewed competitive processes in cities that have evolved till today, generating new models of economic organisation and social interaction, and configuring a new field of competition, in which cities positioned themselves as attractive and highly competitive poles (Gargiulo et al., 2022). As a result, cities have adapted to the new demands of digitalization as demonstrated by the growth of the information sector and the knowledge economy in the urban economy (Raspe & Van Oort, 2006; Yigitcanlar et al., 2008), as well as the rise of paradigms such as that of the smart city (Aldegheishem, 2019). Regarding the diffusion of the knowledge economy as one of the main pillars of economic development, many soft factors of urban systems have flanked and, to a certain extent, prevailed over the infrastructural component that in the past influenced the establishment of industrial and production activities (Malecki, 2002). Among these soft factors, it may be cited the digitisation of institutional structures, as well as the availability of innovative technologies, or the presence of qualified, educated and skilled workforce, and, finally, innovation in the academic and research centres.

The paradigm of the smart city refers, at first glance, to the possibility, in urban environments, to optimise and improve citizen livability, services and infrastructures thanks to technological innovation (Halegoua, 2020). However, this definition is reductive if we do not consider that a smart city is also and above all a sustainable, efficient and innovative city (Guida, 2021), capable of guaranteeing high levels of quality of life for its citizens thanks to the use of connected and integrated solutions and systems (Batty et al., 2012). In smart cities, digitalization goes hand in hand with innovation, and both are key elements for human, social and economic development (Kim et al., 2021). The binomial innovation/digitalization, in this sense, acquires great importance in cities as a synonym for the efficiency of services, businesses and authorities that are part of the city system and that contribute to the livability of the urban environment. Furthermore, digital technology facilitates participatory urban planning, making people active agents of city's transformations (Granier, 2016).

Another recent aspect of digitalization in urban areas is the digital twin model that can be considered an innovative model of urban planning combining innovations in digital technology with urban operational mechanisms and intelligent control platforms (Allam & Jones, 2021; Fistola & Rastelli, 2021). The physical city is recreated in the digital space, allowing for simulating the effects of phenomena and transformations and, thus, providing feasible solutions for urban upgrading.

In summary, the promotion of digitalization can generate added value on multiple levels, such as economy, mobility, environment, governance, safety, competitiveness and, in broad terms, quality of life of citizens. Specifically, the desirable results of this promotion concern:

- the promotion of technological solutions to improve the services offered to businesses at the urban level and simplify administrative procedures for the development of new business initiatives;
- the promotion of transformation to attract digital nomads;
- the improvement of the relationship between the public administration and citizens throughout more efficient and rapid means of private/public dialogue, both for facilitating decision-making and for simplifying the actions of private actors;
- the digitalization of existing services to support citizens and economic actors;
- the rationalization of the technological infrastructure to guarantee interoperability and accessibility to ICT services;
- the use of technological and digital resources to strengthen the mobility system and the existing urban networks, (optical fibers, broadband, water network, etc.) making them more sustainable and efficient;

- the realization of urban planning tools easily interpretable and interchangeable, as well as, the promotion of digitalization in governance processes;
- the improvement of ecosystem services throughout innovation and digitalization of such services, e.g. temperature or energy monitoring systems for public buildings, sensors to reduce network dispersion, innovative lightening systems, monitoring systems for waste collection, and so on;
- the monitoring of pollution and air quality through the improvement and digitalization of existent services;
- the increase of urban safety through the diffuse use of surveillance systems, monitoring systems of road safety, early-warning systems linked to the specific risks insisting on the territory, and so on;
- the sharing of demographic and spatial data useful for decision-making in business strategies and investments;
- the digitalization of the touristic services offered by the city.

2. Digitalization in the NGEU program and the Italian Recovery Plan

As mentioned, the Covid-19 pandemic forced countries and territories to reimagine and revamp their development pathway, giving a further boost to digitalization. In Europe, the Next Generation EU program aims at making European countries greener and more resilient, and, inherently, more digital (European Commission, 2021).

A significant portion of NGEU funding has been allocated to sustain digital transition, throughout innovations that are able to enhance citizens' welfare and economic preparedness. For what concerns the case of Italy, the digitalization sector has been included among the fields of investment of the Italian NRRP (Governo Italiano, 2021), covering a total budget of €48 billion, absorbing about 27% of the total amount of resources (Openpolis, 2021). The proposed strategies are structured along 2 main axes: (i) digital infrastructure and ultra-broadband connectivity; (ii) the digitalization of the public administrations.

Particularly, the Mission 1- M1 "Digitalization, innovation, competitiveness, culture and tourism" includes investments for a total budget of € 40.29 billion, distributed among 3 components which aim to relaunch the competitiveness of Italy by enhancing the connectivity, the digital performance, and the innovation of several economic sectors. This mission is structured in different components, some of which deal with the digital transition in urban environment. Firstly, the Component M1C1 of the plan delas with innovation, digitalization and security of public administrations, providing a total budget of €10 billion. Secondly, the component M1C2 deals with the digitalization, innovation, and competitiveness of the production system, allocating €27.47 billion. The third component (M1C3) is "Tourism and Culture 4.0" and promotes interventions to renew the touristic and cultural sectors, through the use of, inter alia, digital technology, by allocating € 6.08 billion. From the available documentation it is not possible to understand how the resources will be distributed in the different territories. The available data about the regional distribution of funding concern ultrafast connections, whose allocation has been affected by the differences in the availability of adequate domestic connections emerged during the pandemic. The regions that benefit most are Calabria, Puglia and Sardegna.

Investment	Resources (€ billion)
Plan "Italia 1 giga"	3.8
Plan "Italia 5g"	2.02
School system connection	0.261
Healthcare system connection	1.80
Cloud migration of Public Administrations	1.00
Services and digital citizenship	2.01

Tab.1 the investments for digitalization in the National Plan for Recovery and Resilience (Source: Openpolis https://www.openpolis.it/i-nostri-open-data-per-il-monitoraggio-del-pnrr/)

In conclusion, although the territorial dimension is not predominant in the Italian NRRP, digitalization is being one of the main components of territorial competitiveness for Italy, and cities, as main competitors in the international market, should adapt to the prominent digital evolvement. The development of smart, innovative and sustainable models of growth is one of the main challenges that our cities are called upon to face in the coming years. The investments of NRRP in the digital sector should be managed by policy-makers with a renovated attention to territories and, in particular, urban areas that, thanks to their characteristics and resources can sustain the digitalization itself. In this regard, the plan includes some measures that deal with the digitalization of public entities and services. Digitalization at the policy-level should be accompanied by integrated actions at the urban and metropolitan scale in different sectors (economic, social environmental, and so on) considering both private and public initiatives. In the following tables, there are some of the proposed measures within the framework of the NRRP, that are basically linked to the territorial scale.

Digitalization, Innovation and Cyber-Security of PAs

In this table, some of the main investments of the component M1C1, referred to mission M1, are reported, including both reforms and measures. One of the investments provided by this component is at the national scale and aims to develop a National Digital Data Platform to ensure the interoperability of public data, thus allowing also local institutions, at the city level, to provide safe services in a faster and more effective way and dialogue with national data systems. The funding is accessible by Central public administrations, Metropolitan Areas, Regions, Provinces, and the budget is €556 million. Another important measure of the mission M1C1 is the construction for the Single Digital Gateway, with an investment of €90 million. It tries to respond to the increased mobility needs of European citizens and businesses, being an incentive to modernize public administration and to develop e-government strategies to improve relations with users. A portion of funding is dedicated to the creation of a digital system for production and construction activities, to ensure machine-to-machine communication between the ICT systems of different municipalities. €813 million are destined to improve the citizens experiences of public digital services by defining and promoting the adoption of proven and reusable models; on the other side, €80 million are dedicated to the improvement of accessibility of digital public services through the dissemination of shared tools among Regions, Metropolitan Areas, and Municipalities. The mission provides funding also for the strengthening of the Public Administration website against cyber threats, such as fraud, blackmail, and terrorist attacks and all the risks posed by cybercrime.

MaaS – Mobility as a Service

This investment promotes the adoption of the model "Mobility as a Service" (MaaS) involving Regions and Metropolitan areas, with the Department of Digital Transformation as main implementing body. This model is based on a global concept of mobility, that provides the integration of multiple services of private and public transport thanks to a digital channel. The cities that have been selected as leaders of the project are Milan, Naples and Rome, along with the later occurred Bari, Florence and Turin, with a total budget of €56.9 million. Through the implementation of digital platforms, which combine various functionalities and guarantee different travel alternatives, the project aims at supporting users in planning, booking and paying mobility services according to their needs, in a faster and more effective modality. The platform will cover different modes of transport, such as public transport, car sharing, bike sharing, and taxis. It includes three lines of intervention:

- applying the model to territories: laboratories will test MaaS services through the introduction of digital platforms, new business models, data sharing and interaction between different subjects offering mobility services, assessing the impact on the environment and the socio-economic context;
- creating an open platform ("Data Sharing and Service Repository Facilities - DS&SRF"): this technological infrastructure will be built to ensure effective interaction between multiple operators in the sector and to establish a single national access point to the set of transport and mobility data. The platform will also enable a range of services including enabling the choice of possible travel options and facilitating booking and payment;
- enhancing the digital dimension of public transport for the dissemination of MaaS in selected territories by enabling digital payment services, user information systems and travel booking services.

Therefore, the first phase will finance experimentation in technologically advanced metropolitan cities. In this phase, it will be essential to identify territories with different characteristics to make them testing laboratories where to test the services themselves and the interaction between the various subjects that can offer mobility services.
An effective MaaS service can become an indispensable tool for driving the city towards more sustainable transport modes, a better organization of services, a more effective management of urban space, and improvements in urban planning choices.

"Mobility as a Service for Italy" will lead to the growth and improvement of the transport sector, to offer users an increasingly simplified and accessible experience, and providing alternative modes of transport to the private car through innovation. Public policies will be able to achieve significant results in terms of the homogeneity of the service offered to citizens, economic development for involved businesses, and benefits for the community and the environment. This would have horizontal benefits on competitiveness of territories where these services will be activated. All in all, it can generate benefits not only for users and the public sector but also for the digital economy companies active in the field of transport, thanks to the openness to innovation.

Digital strategies for cultural heritage

The investment M1C3 aims at filling the digital gap of cultural subjects and at supporting local entities in the conservation of heritage, museums, libraries, and so on. This line of action is structured in multiples sub-investment regarding: i) cultural services; ii) the development of R&D sector within the field of cultural heritage; iii) the scientific empowerment of data systems regarding cultural heritage; iv) the improvement of the accessibility to digital cultural services; v) the reduction of inefficiency and costs of management throughout the rationalization of informative systems; vi) the simplification of the relationship between public subjects, citizens and firms.

References

Aldegheishem, A. (2019). Success factors of smart cities: a systematic review of literature from 2000-2018. *TeMA-Journal of Land Use, Mobility and Environment, 12*(1), 53-64. https://doi.org/10.6092/1970-9870/5893

Allam, Z., & Jones, D. S. (2021). Future (post-COVID) digital, smart and sustainable cities in the wake of 6G: Digital twins, immersive realities and new urban economies*. Land use policy*, 101, 105201. https://doi.org/10.1016/j.landusepol.2020.105201

Bailey, D., Crescenzi, R., Roller, E., Anguelovski, I., Datta, A., & Harrison, J. (2021). Regions in COVID-19 recovery. *Regional Studies, 55*(12), 1955-1965. https://doi.org/10.1080/00343404.2021.2003768

Batty, M., Axhausen, K. W., Giannotti, F., Pozdnoukhov, A., Bazzani, A., Wachowicz, M., ... & Portugali, Y. (2012). Smart cities of the future. *The European Physical Journal Special Topics*, 214, 481-518.

Caglioni, M. (2023). Il divenire della disciplina urbanistica: il contributo di Matteo Caglioni. *TeMA-Journal of Land Use, Mobility and Environment*, 181-187. https://doi.org/10.6093/1970-9870/9743

Dana, L. P., Salamzadeh, A., Hadizadeh, M., Heydari, G., & Shamsoddin, S. (2022). Urban entrepreneurship and sustainable businesses in smart cities: Exploring the role of digital technologies. *Sustainable Technology and Entrepreneurship, 1*(2), 100016. https://doi.org/10.1016/j.stae.2022.100016

Dipartimento per la trasformazione digitale (2023). Le misure del PNRR. Su PA digitale 2026 il dettaglio delle opportunità del PNRR dedicate alla digitalizzazione della Pubblica Amministrazione: fondi allocati, beneficiari e modalità di accesso alle misure. Retrieved from: https://innovazione.gov.it/progetti/

European Commission (2021). NextGenerationEU. Retrieved from: https://ec.europa.eu/info/strategy/recovery-plan-europe

Fernandes, S. (2021). Which way to cope with COVID-19 challenges? Contributions of the IoT for smart city projects. *Big Data and Cognitive Computing, 5*(2), 26. https://doi.org/10.3390/bdcc5020026

Fistola, R., & Rastelli, A. (2021). Envisaging urban changes for the smart city: The live city information modeling (LCIM). In *Innovation in Urban and Regional Planning: Proceedings of the 11th INPUT Conference-Volume 1* (pp. 161-169). Cham: Springer International Publishing.

Gargiulo C., Guida N., & Sgambati S. (2022). NextGenerationEU in major Italian cities. *TeMA - Journal of Land Use, Mobility and Environment, 15* (2), 287-305. https://doi.org/10.6093/1970-9870/9260

Governo Italiano (2021). Italia domani. Piano Nazionale di Ripresa e Resilienza. Retrieved from: https://italiadomani.gov.it/en/home.html

Granier, B., & Kudo, H. (2016). How are citizens involved in smart cities? Analysing citizen participation in Japanese``Smart Communities''. *Information Polity, 21*(1), 61-76.

Guida, C. (2021). Ecological transition: innovation in cities. *TeMA-Journal of Land Use, Mobility and Environment, 14*(3), 493-500. https://doi.org/10.6093/1970-9870/8304

Halegoua, G. (2020). Smart cities. MIT press.

Kim, H. M., Sabri, S., & Kent, A. (2021). Smart cities as a platform for technological and social innovation in productivity, sustainability, and livability: A conceptual framework. In *Smart Cities for Technological and Social Innovation* (pp. 9-28). Academic Press.

Lai, S., Leone, F., & Zoppi, C. (2020). Covid-19 and spatial planning: a few issues concerning public policy. *TeMA*, (Special Issue: Covid-19 vs City-20), 231-246. https://dx.doi.org/10.6092/1970-9870/6846

Malecki, E. J. (2002). Hard and soft networks for urban competitiveness. *Urban studies, 39*(5-6), 929-945. https://doi.org/10.1080/00420980220128381

Openpolis (2021). I nostri opendata per il monitoraggio del PNRR. Retrieved from: https://www.openpolis.it/i-nostri-open-data-per-il-monitoraggio-del-pnrr/

Raspe, O., & Van Oort, F. (2006). The knowledge economy and urban economic growth. *European Planning Studies, 14*(9), 1209-1234. https://doi.org/10.1080/09654310600933322

Yigitcanlar, T., Velibeyoglu, K., & Martinez-Fernandez, C. (2008). Rising knowledge cities: the role of urban knowledge precincts. *Journal of knowledge management, 12*(5), 8-20. https://doi.org/10.1108/13673270810902902

Author's profile

Sabrina Sgambati

She is an engineer, Ph.D. student in Civil Systems Engineering at Department of Civil, Architectural and Environmental Engineering of University of Naples Federico II. Currently, her Ph.D. research concerns the topic of urban competitiveness.

Tonia Stiuso

She is a master's degree student in Building Engineering-Architecture at the Department of Civil, Architectural and Environmental Engineering of the University of Naples Federico II.