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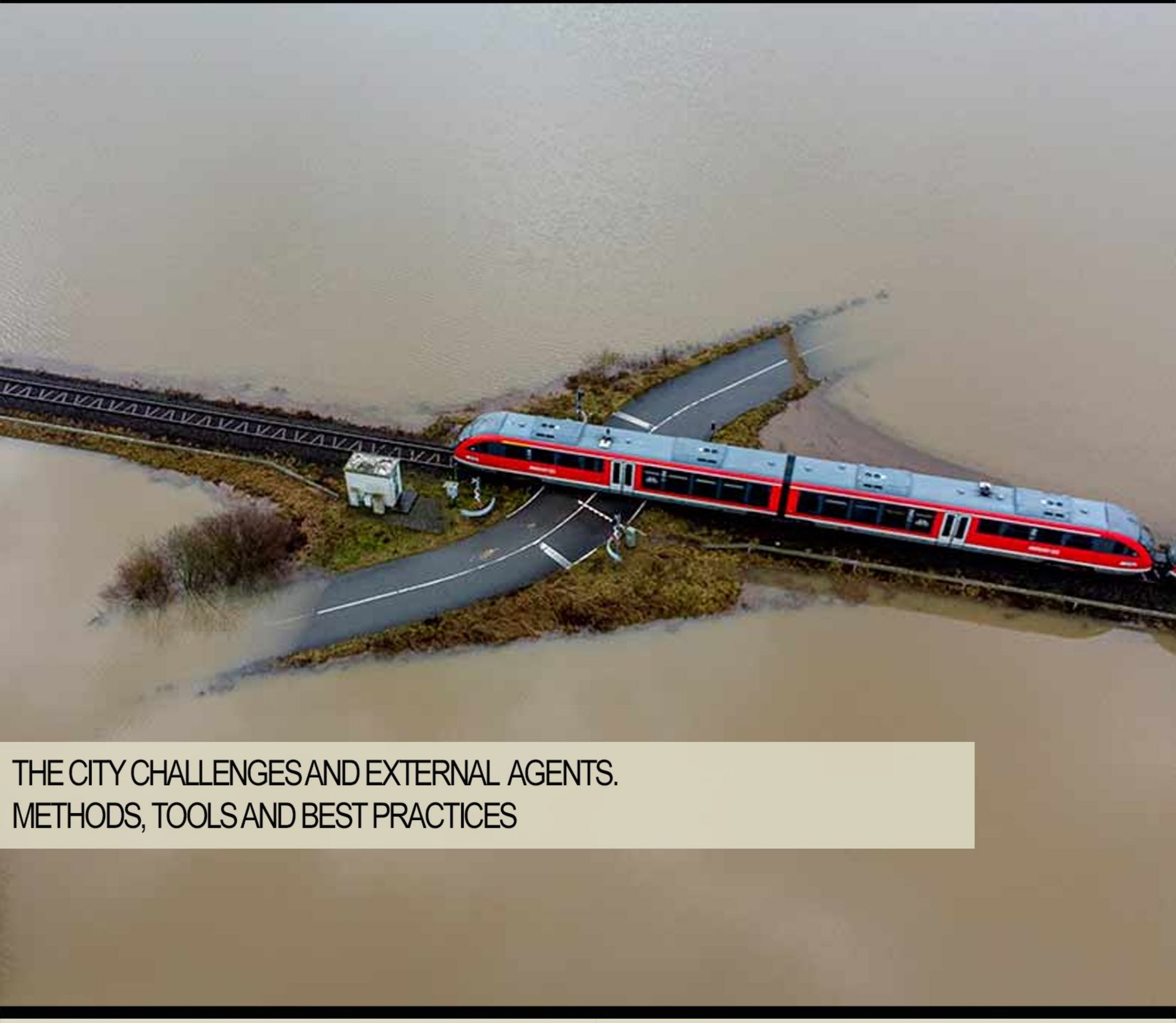

THE CITY CHALLENGES AND EXTERNAL AGENTS. METHODS, TOOLS AND BEST PRACTICES

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The cover image is a train passes a rail road crossing that is surrounded by flooding caused by rain and melting snow in Nidderau near Frankfurt, Germany, Wednesday, Feb. 3, 2021. (AP Photo/Michael Probst)

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EDITORIAL PREFACE: TEMA JOURNAL OF LAND USE MOBILITY AND ENVIRONMENT 2(2021)

The city challenges and external agents. Methods, tools and best practices

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Cities need to modify and/or adapt their urban form, the distribution and location of services and learn how to handle the increasing complexity to face the most pressing challenges of this century. On these topics and the ones born during the last year, the scientific community is working in order to minimize adverse effects on the environment, social and economic issues and people's health.

The three issues of the 14th volume will collect articles concerning with the effects of climate change, the ageing of the population, the reduction of energy consumptions from fossil fuels, immigration flows from disadvantaged regions, innovation technology, the optimization of land use and the impacts, in the short and long period, with innovative methods, tools, techniques and practices.

For this Issue, the section "Focus" contains two contributes. The first article of the section is titled "Towards the Metropolitan City of Venice climate-proof. Multilevel approach in broad area governance", by Giovanni Litt, Filippo Magni and Giovanni Carraretto (IUAV, Italy). This paper, starting from the specific case of the Metropolitan City of Venice, reconstructs the possibilities that a governing body of an intermediate territory such as Metropolitan City can activate to support the climate transition and the sustainability of its territory. Also, it proposes a methodology, activated by the Metropolitan City of Venice, to support the process of Metropolitan Cities in leading the territorial transition.

The second article, titled "Impact of city district borders and ecosystem edges correlation application of Green and Blue Infrastructure – Case study the city of Prague" by Jenan Hussein, May Salama, Peter Kumble, Henry. W.A. Hanson IV (Czech University, Czech Republic). The article discusses a way to understand the correlation between green and blue natural elements and territorial edges also by considering the Territorial System of Ecological Stability (TSES) procedure, with a special focus on the city of Prague. The study proposes a method useful to understand the nature of the relation and future vision for developing the land use of the city by considering the two main concepts of protection and connectivity. These concepts have to be considered as joint factors that work together to generate a multifunctional system of green and blue infrastructure.

Three papers address the section "LUME" (Land Use, Mobility and Environment). The first, titled "Territorial disparities in Tuscan industrial assets: a model to assess agglomeration and exposure patterns" by Diego Altafini, Valerio Cutini (University of Pisa, Italy). The paper aims to advance in the development of spatial-economic models suitable to highlight the spatial distribution and territorial disparities within industrial agglomerates on urban and regional systems. For this purpose, the proposed model assesses a condition defined as territorial exposure, evaluated through the Tuscany regional structure analysis.

The second article, titled "Quantitative estimation of the effect of urbanization on landscapes using Corine Land Cover data" by Gizem Dinç, Atila Gül (Süleyman Demirel University, Turkey). The purpose of this study is to determine the impact of human effects on future land cover changes in Turkey using CLC data. Considering the current and future urbanization effects, planning studies should be performed consider Turkeys' three largest cities, which are under pressure in terms of land use with dense population.

The last paper of the section, titled "Quantifying the urban built environment for travel behaviour studies" by Ndidi Felix Nkeki, Monday Ohi Asikhia (University of Benin, Nigeria). The study proposes a quantification

of the built environment analysis for the Benin metropolitan region (BMR), a large African-sized urban area using several spatial indicators disaggregated to the neighbourhood-level.
The section "Covid-19 vs City-20" collects three papers. The first, titled "Covid-19 pandemic and urban mobility in Milan. Wi-Fi sensors and location-based data" by Andrea Gorrini, Federico Messa, Giulia Ceccarelli, Rawad Choubassi (Systematica Srl, Italy). The paper analyses a sample of aggregated traffic data collected from 55 Wi-Fi Access Points in Milan. Data were collected over 7 months (January to July 2020), allowing for a study on the impact of the Covid-19 pandemic on urban mobility. Data analysis was based on merging: time series analysis of traffic data; spatial analysis of land and mobility characteristics. Results showed the effectiveness of Wi-Fi location data to monitor long-term traffic trends and identify the mobility profiles of urban areas.
The second, titled "Former military sites and post-Covid-19 city in Italy. May their reuse mitigate the pandemic impacts?" is proposed by Federico Camerin (Universidad de Valladolid, Spain) and it deepens the topic of the former military settlements. For the author they constitute an opportunity for developing inclusive and green cities through a good governance, especially after the 2020 pandemic outbreak, also if the first findings are not hopeful.
The last paper of the section, titled "Investigation of the effects of Urban Density on Pandemic" by Yelda Mert (Iskenderun Technical University, Turkey). The paper highlights the effects of urban density on the spread of Covid-19 infection are evaluated in this study through the sample case of İskenderun district in Hatay (Turkey). As the result of the examination, it was understood that the rate of increase and the density of cases in regions with high housing density was higher than that of regions with lower densities.
From this issue, TeMA journal proposes a new section that aims at drawing the attention of the international scientific community to papers that, despite the passing of time, still present elements of significative scientific interest – insights, anticipations and reflections – enough to deserve careful read back. The first paper - published in Italian in 1993 with the title "Caos e caos: la città come fenomeno complesso" as a contribution in the volume "Per il XXI secolo – una enciclopedia e un progetto" (For the XXI century – an encyclopedia and a project) – is published again in this new section of TeMA Journal, Evergreen, in its literal English translation with the addition of new images.
The new Review Notes section propose four insights on the themes of the TeMA Journal. The first research "Submission Title: Ecological Transition: what's next?" is by Carmen Guida and David Ania Ayiine-Etigo. This contribution aims at defining the definition and intervention domain of ecological transition. This contribution proposes a further insight into the complex ecological transition, with a focus to U.S. and European cities. Cities have faced a worldwide health and economic crisis due to the outbreak of a new coronavirus in 2019 and now, with progressive and massive vaccination and never experienced financial tools, a new era seems to start: significant financial resources, plenty of room for economic maneuvers may turn the ongoing pandemic into an opportunity, for the following years, to build more sustainable societies and environments. Within this scenario, urban areas play an essential role. According to shared and universal goals to achieve a more sustainable model of society and economy, how ecological transition is run by policymakers, stakeholders and citizens strongly depends on cities' backgrounds and structures.
The second research "Resilience as an urban strategy: The role of green interventions in recovery plans" is by Federica Gaglione and Jorge Ugan. The contribution examines the set of reforms of the Recovery and Resilience Plans, concerning the green revolution, the ecological transition and climate policy. In particular, the review focuses on Italy and Germany, highlighting how the green interventions envisaged within them improve the urban strategies to be implemented with respect to the great challenges that the different territorial contexts have to face such as climate change, energy efficiency in accordance while also respecting of the principles of environmental sustainability.
The third research "Toward greener and pandemic-proof cities? Policy responses to Covid-19 outbreak in four global cities" by Gennaro Angiello. The third research "Toward greener and pandemic-proof cities? Policy responses to Covid-19 outbreak in four global cities" is by Gennaro Angiello. The section provides an

overview of the policies and initiatives undertaken by four major global cities in response to the Covid-19 outbreak: New York City (US), Beijing (CN), Paris (FR) and Singapore (SG). Based on this overview, a cross-city analysis is employed to derive a taxonomy of urban policy measures. The article concludes with a discussion on the effectiveness of such measures in providing answers to epidemic threats in urban areas while, at the same time, improving the sustainability and resilience of urban communities.

The last research " Environmental, social and economic sustainability in urban areas: a cool materials' perspective" is by Stefano Franco and Federica Rosso. The note tackles the topic of cool materials for urban areas, as a mitigation strategy to counteract climate-change related issues. The most recent developments about cool materials show that they are relevant tools that can boost environmental, social and economic sustainability in urban areas.

TeMA
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Call for Paper

TeMA vol. 14 (2021) The city challenges and external agents. Methods, tools and best practices

Cities need to modify and/or adapt their urban form, the distribution and location of services and learn how to handle the increasing complexity to face the most pressing challenges of this century. On these topics and the ones born during the last year, the scientific community is working in order to minimise negative effects on the environment, social and economic issues and people's health.

For these reasons, the three issues of the 14th volume will collect articles concerning the six topics addressed in 2020 and also a seventh concerning the effects on the urban areas related to the spread Covid-19 pandemic.

In particular, TeMA Journal intends to propose articles that deal the effects of climate change, the ageing of the population, the reduction of energy consumption from fossil fuels, immigration flows from disadvantaged regions, innovation technology, the optimisation of land use and the impacts, in the short and long period, connected to the Covid-19 pandemic, with innovative methods, tools, techniques and practices.

For this reason, authors interested in submitting manuscripts addressing the issues may consider the following deadlines:

• Third issue: 10th September 2021.

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Metropolitan Cities supporting local adaptation processes. The case of the Metropolitan City of Venice

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Abstract

Cities have a fundamental role in the adaptation and mitigation process to climate change. Even though cities will be the main subject of climate change impacts, they can propose solutions and build alternative scenarios. The difficulties that municipalities may encounter in their adaptation processes concern the lack of planning skills, technical knowledge, and human resources. To face these challenges Italian Metropolitan Cities can play a fundamental role in helping municipalities to plan and coordinate their efforts. The process in the Venetian territory has lasted many years and it has led to the awareness that local adaptation policies need to be addressed with broader support. The Metropolitan City of Venice has constructed a methodology for the planning of climatic adaptation. This methodology has been developed thanks to various plans and projects. These projects acted to increase the coordination between bodies, to define a broad area vision, to help municipalities to implement local actions. The role played by CMVe intends to direct public policies towards adaptation and mitigation in a structural way and with broad area governance. The process activated could be replicable in other Italian Metropolitan Cities in the approach and the result even if adapted to local needs.

Keywords

Climate-proof planning; Metropolitan city; Broad area governance; Climate change.

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1. Introduction

Municipalities have, both in Italy and in Europe, fundamental importance in planning the process of adaptation and mitigation to climate change (CC) (Gaudioso et al., 2014). The Covenant of Mayors (CoM) is the main initiative that engages municipalities in the fight against CC (Pablo-Romero et al., 2018). The Covenant identifies cities as the key institutions for achieving the objectives set in the commitment to climate and energy towards a sustainable future. Starting from 2008, on the initiative of the European Commission, the Covenant has been addressing cities and city networks towards climate change projects in a coordinated manner. The CoM was set up to achieve the European target of a 40% reduction in carbon dioxide emissions by 2030 and to adopt a joint approach to mitigation and adaptation actions.

In 2050, 67.2% of the Earth's inhabitants are expected to live in the city (United Nations, Department of Economic and Social Affairs, Population Division, 2019). Cities and their activities are responsible for about 75% of global CO_2 emissions (REN21 Secretariat, 2021). Even though cities are and will be the subject of the main impacts of climate change, they can propose solutions and build alternative scenarios (Gaudioso et al., 2014). The urban dimension can facilitate the adoption of innovative and virtuous, sharing and cooperation practices (Urban Agenda for the EU, 2016; Musco & Zanchini, 2014). This also because of the density of population, the concentration of services and infrastructure, the socio-cultural context, the ability to innovate and prefigure behaviors and spaces.

These qualities help to adapt to challenges, political and civic participation in democratic life, social interrelation, the cultural and academic ferment (Mercalli, 2011; Musco et al., 2020). The difficulties that municipalities may encounter in their processes of adaptation to climate change concern the lack of planning skills, technical knowledge, and human resources (Magni et al., 2020a). These obstacles are related either to the size of the municipality or to its financial and technical capacities. Moreover, the municipalities belonging to the CoM also report operational limits (Adami et al., 2020). Despite being guaranteed administrative and promotional assistance by the Office of the Covenant of Mayors (Como), these support instruments have not always been sufficient to produce concrete results. Members of the Sustainable Energy Action Plan (SEAP) have not always led to positive responses regarding the commitment of administrations to the environmental challenge.

In Italy, 4736 Municipalities signed the pact, but the resulting Action Plans are only 3304 (69.76% of those expected) and the results monitored are only 1022 (only 21.58%)[1].To face these challenges, Regions and, most of all, Italian Metropolitan Cities (MC) can play a fundamental role (Boggero, 2016) in helping municipalities to plan, coordinate and evaluate their efforts (Piperata, 2018; Marson, 2006). In particular, the MC can have a key role in supporting the process of adaptation to the CC of both Municipalities and Groups of Municipalities (GoM). Operating on an intermediate level of planning and land management, MC can be fundamental in the strategy of a large area (Musco et al., 2018). This technical approach can overcome the gaps between institutional knowledge, technical knowledge, coordination between actors, and resource management.

This paper, starting from the specific case of the Metropolitan City of Venice (CMVe), reconstructs the possibilities that a governing body of an intermediate territory such as MC can activate to support the climate transition and the sustainability of its territory. These possibilities will be analyzed starting from the analysis of the critical issues that slow down the process of climate transition. It will be proposed a methodology, activated by CMVe, to support the process of MCs in leading the territorial transition.

[1] www.pattodeisindaci.eu

1.1 Italian Metropolitan Cities towards mainstreaming of adaptation to climate change

The MCs in Italy were born on April 8, 2014[2], to replace the provinces as large entities in the Italian Constitution. In Italy, the MCs are 15: Bari, Bologna, Cagliari, Catania, Florence, Genoa, Messina, Milan, Naples, Palermo, Reggio Calabria, Rome, Turin, Venice. Each of these has different qualities to be MC. The transition from Province to MC (Crivello & Staricco, 2017) added other key functions to provincial functions (such as provincial spatial planning coordination, protection, and enhancement of the environment, planning of transport services, collection, and processing of data for technical and administrative assistance to local authorities). In detail, in territorial-environmental-climate, the Metropolitan City:

- adopts (and annually updates) a three-year strategic plan of the metropolitan territory which constitutes an act of guidance for the institution and the exercise of the functions of municipalities;
- deals with general spatial planning by setting constraints and objectives to the activity and exercise of the functions of the municipalities included in the metropolitan territory;
- structures coordinated systems of management of public services;
- deals with mobility and practicability, also ensuring the compatibility and coherence of urban planning in the metropolitan area;
- promotes and coordinates economic and social development;
- promotes and coordinates systems of computerization and digitization in the metropolitan area.

The competencies of the MCs – as shown in Fig.1 – can have direct interrelations with the effects and causes of climate change (Molinaro, 2019). These are numerous, both in terms of adaptation and mitigation, and it is for this reason that the choice of encouraging mainstreaming of adaptation and mitigation in MCs and emphasizing their role of coordination and facilitation of adaptation processes at the municipal level is today particularly strategic. Mainstreaming adaptation plays a key role in supporting governance processes, proposing integration of spatial development dynamics (Magni et al., 2020b) so that adaptation to climate change and mitigation can become sustainable and applicable on a large scale, incorporating them into the political apparatus of local governments and so becoming mainstream (Bockel, 2009).

In addition, MC can be a central body in the process of transition toward climate-proof territories. A renewed and necessary attention must support greater awareness of climate problems in local transformations to reduce the ecological footprint of cities in the future policies of urban metropolitan cities in Italy and Europe. The role of MC in this process can be fundamental: for the possibilities of mainstreaming within their governance instruments and for the multilevel process of mainstreaming (Rauken et al., 2014). This process can be done by encouraging the implementation of the vertical process in the hierarchy of the Government of the Territory between over-ordered entities – regional, national, European – and Municipalities (Magni et al., 2020c).

2. Materials and method

Internationally agreed methodologies have led the United Nations Framework Convention on Climate Change (UNFCCC) to the development of a theoretical adaptation framework (UNFCCC, 2008a; UNFCCC, 2008b; Keskitalo, 2010; Fritzsche et al., 2014; Romero Lankao & Zwickel, 2014) as a practical and specific guide to support structured decision-making bodies in several stages that governments, both local, regional and national can undertake. These strong theoretical bases indicate several passages. These passages do not necessarily have a strict order, some may occur in parallel with others. In all cases, the steps should be viewed as a cycle (Jabareen, 2013).

[2] Law n. 56 of April 7, 2014. Disposizioni sulle città metropolitane, sulle province, sulle unioni e fusioni di comuni. (14G00069) (GU n.81 del 07-04-2014). https://www.gazzettaufficiale.it/eli/id/2014/4/7/14G00069/sg

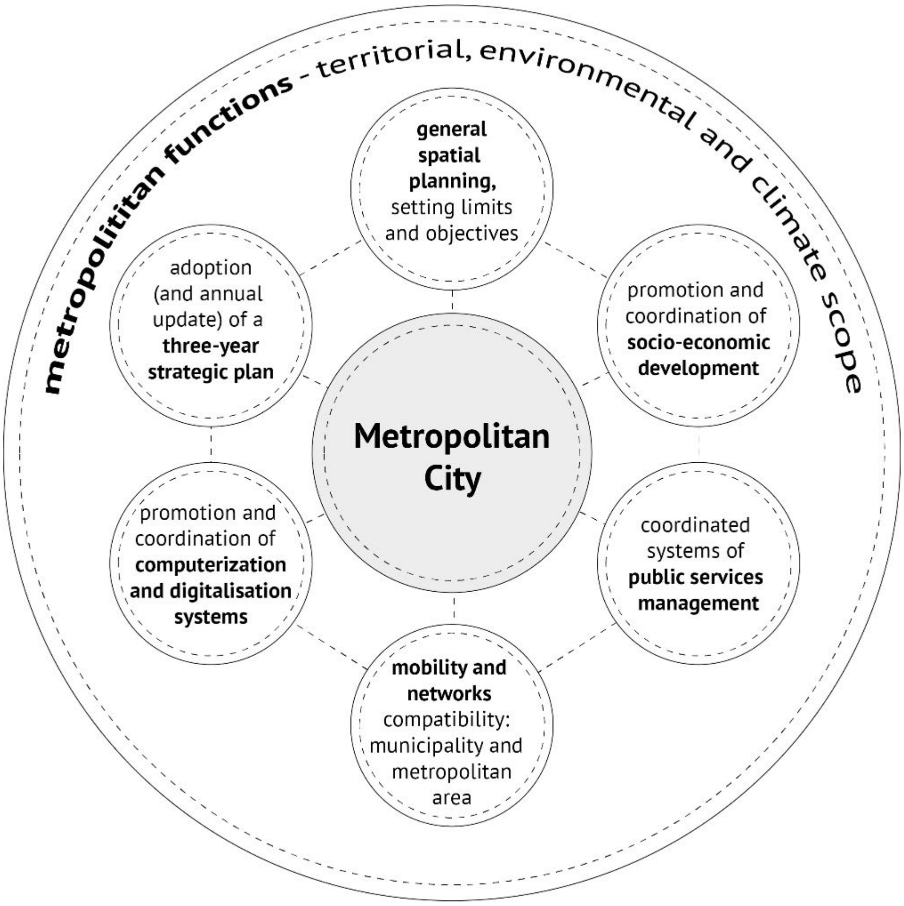

Fig. 1 The functions of the Metropolitan Cities

The macro-steps are (Magni et al, 2020a):

- building a knowledge base for adaptation;
- assess the macro and micro impacts of climate change;
- assess vulnerability and its capacity to adapt;
- to identify possible adaptation options (design of adaptation measures);
- the implementation of the measures;
- monitoring and evaluation of effectiveness.

Municipalities often find it difficult to build their climate change adaptation pathways. These difficulties are due to three main gaps (Musco et al., 2020):

- the lack of a coherent and up-to-date policy and knowledge framework;
- policies of adaptation and mitigation only municipal, when instead of the impacts of climate change often involve a wider territorial context than the municipal, so the answers to these problems should be planned on an equally large scale.
- sectoral and non-global solution approach: adaptation and mitigation are relegated to specific plans and not able to dialogue with cogent planning.

This paper shows how CMVe has supported municipalities in the climate transition process by working to fill these three gaps and how the same process could fit in the other MCs (Fig.2).

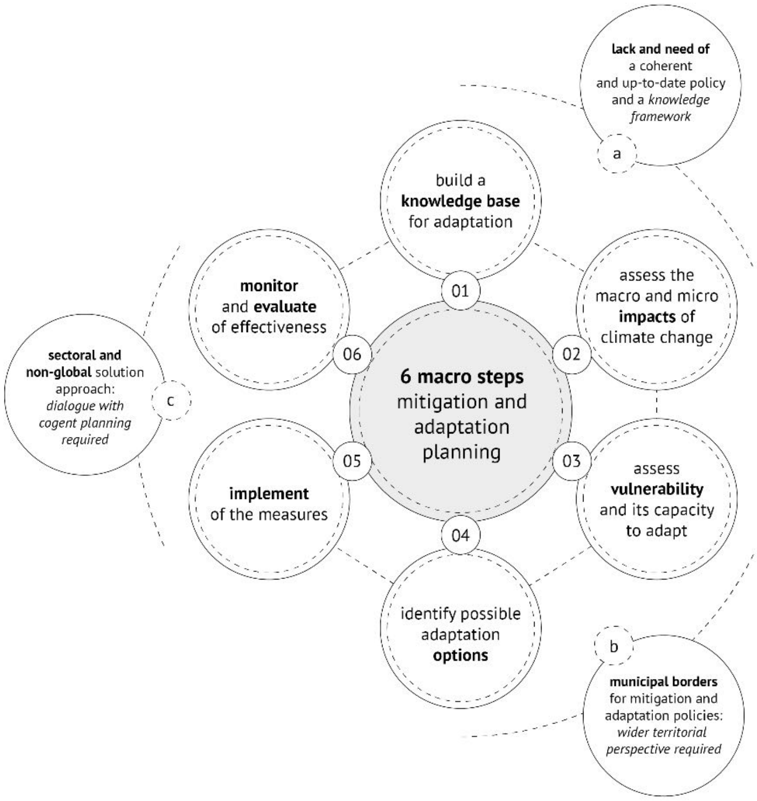

Fig.2 Link between steps and gaps

2.1 Mitigation and adaptation in the Venetian area: the evolution of processes between Province and Metropolitan City

The Metropolitan City of Venice, which replaces the Province of Venice, has always worked on sustainability and CC, both in terms of mitigation and, in more recent times, in terms of adaptation. This effort is dictated by well-known territorial needs (Magni, 2019). The geomorphological (Sistema Nazionale per la Protezione dell'Ambiente, 2019) and hydraulic condition of the Venice Lagoon and the surrounding territories has always been critical: a fragile balance between environment and man-made settlement (Guerzoni & Tagliapietra, 2006; Maragno et al., 2021). For the previous reasons, the spatial configuration is extremely vulnerable to the impacts of climate change. The report of the European Environment Agency (2016) and the most recent climate scenarios for Italy (CMCC, 2021)[3], confirm a critical picture, characterized by the intensification of phenomena of urban flooding, floods, tides, and high waters, heat waves, etc.

The first step of the path towards sustainability – started by the second half of the last decade by the Province of Venice to promote a more sustainable and attentive to the peculiarities of the territory model of development – was the publication in 2008 of the Territorial Plan of Provincial Coordination[4] (PTCP) which introduced the obligation for municipalities to acquire a Municipal Water Plan[5]. The Province has defined the guidelines for the elaboration and has contributed directly to the financing of their preparation, constantly monitoring their development. To date, all 44 municipalities have adopted, or are in the process of adopting, their hydraulic management tool).

3 www.cmcc.it/it/scenari-climatici-per-litalia
4 The PTCP is the instrument of urban and territorial planning through which the Province exercises and coordinates its action of government of the territory, outlining its objectives and fundamental elements of planning.
5 Including land reclamation agencies, private owners of agricultural funds, integrated water supply agencies, etc.

In September 2010, the awareness acquired in the field of sustainability and climate led the Province to adhere, as a coordination and support structure, to the Covenant of Mayors. The Province of Venice has considered the "Covenant of Mayors and its potential effects extremely positive and for this reason, has decided to provide support to the municipalities to accompany them in the path of accession and assumption of commitments arising from the signing". Then, it has launched "a program of accompanying and support to assist municipalities in the path of the Covenant of Mayors, promoting a stable and constant system of territorial coordination, aimed primarily at the preparation of Sustainable Energy Action Plans at the municipal level, seeking opportunities and related financial resources and promoting the Pact" (Venice Province, 2011).
As a matter of fact, the Province undertook to accompany the Municipalities in joining the Covenant of Mayors and to assist them in the implementation of commitments, providing the scientific-technical support necessary to prepare emission balances, SEAP, and creating stable coordination between the signatories of the pact and the Province of Venice. This support has made it possible to carry out monitoring plans, based on substantial cognitive analyses. The Province has been responsible for researching and proposing financial support, providing technical support for the organization of public events, and following the implementation of the action plans and monitoring of the activities carried out by the municipalities. Finally, it has facilitated the networking of experiences and the connection with the services of the European Commission. On the other hand, the municipalities have shared the accompanying program for the Covenant of Mayors with the Province, providing information on the developments of the SEAP and their implementation. The individual municipalities have also helped to identify and implement energy planning paths. They have also contributed to spread and communicate to citizens the contents of the Covenant of Mayors, in synergy with the Province. The Covenant of Mayors was oriented to the reduction of greenhouse gas emissions. Since the beginning the Province has tried to guide municipalities towards adaptation, aiming at the construction and adoption of specific actions. This awareness has not yielded the expected results, as adaptation actions were only introduced by a minority of the submitted SEAPs. The causes of this lack of integration have been identified in the unawareness of the urgency of adaptation actions to CC, in the absence of a simple methodological framework, a comprehensive analysis of the vulnerabilities of the territory, and in the approach strongly oriented to the mitigation of the same Covenant of Mayors. Throughout 2012, the coordination and support activities for municipalities have been reflected in: the definition of guidelines for the implementation of SEAP at the local level; the establishment of a single database for the management of all the information necessary for the definition of emission inventories (BEI) and action plans of municipalities; the training for municipal technicians for the definition of the consumption of municipal structures and the use of the single database; the determination of the basic inventory of emissions for macro sectors for all municipalities of the Province.
The process in the Venetian territory continued with the project SEAP_Alps[6], which allowed the path of adaptation of the new CMVe to derive indications of governance. The methodological approach of this experiment has shown that the cognitive process conducted throughout the theoretical research phase has itself become an act of social adaptation (Lewin, 1946), when municipal technicians, policy-makers, citizens, and other local stakeholders were involved. The project has constructed a common methodology between the partners for the management of the process of planning previewed from the initiative Covenant of Mayors (energy analysis, scenario development, identification of objectives and actions, monitoring of the implementation of plans), integrating it with the concept of adaptation to climate change. The research-action phase started with the adaptation of the construction methodology of a SEAP to the local regulatory environment and then moved to a moment of accompanying and support with continuous training of the partners and local authorities involved. Mentoring has been conducted in a training way, using the

6 www.seap-alps.eu/

methodology and the tools associated with it. The outcome of this path started in 2014 laid the foundations for the construction and implementation of new generation SEAP and a simplified upgrade of those already adopted.

Thanks to the activities developed within the project LIFE Master Adapt[7], CMVe was able to develop and adopt tools to facilitate the optimization of the relationships between levels of planning, to increase and coordinate municipal planning capacity and facilitate public-private collaboration. In addition to these activities, the process of mainstreaming for the design and implementation of adaptation strategies has been developed through coordination between the different levels of government of the territory (State, Regions and Local Authorities) and horizontal coordination between different policies (territorial, landscape, agricultural, environmental, civil protection, etc.). The LIFE Master Adapt project has allowed starting an innovative and detailed climate analysis and a vulnerability assessment at the metropolitan level, aimed at identifying impacts, risks, and vulnerabilities (Maragno, 2017), climate change for key CMVe sectors.

Based on the analysis and evaluation of national and international adaptation practices, targets for supra-local adaptation have been defined, following a vertical and horizontal mainstreaming process, standardizing and aligning adaptation policies at different levels. Technical processes and dialogue with the territories have allowed the development of an effective method for the integration and governance of shared adaptation objectives. This process has allowed defining a strategy of adaptation, and the measures identified, at the intermediate administrative level: both for specific groups of municipalities and the entire Metropolitan City of Venice. The LIFE Master Adapt project has been crucial in the long programming process of the CMVe described. It has allowed the creation of a system of information and skills sedimented over the years, building a common knowledge base and an inventory of vulnerabilities and risks related to climate change through the implementation of the methodologies developed. Particularly, a common knowledge base has been provided and the operational guidelines and common objectives have been defined with a transcalar logic to allow the municipalities of the CMVe to program independently or on the network. Without this support, individual municipalities would hardly be able to engage in the climate challenge and integration with the tools of spatial planning.

Placed the priorities of climate adaptation within the broader framework of metropolitan environmental policies thanks to Seap_alps, with the European project LIFE Veneto Adapt, CMVe wanted to improve, at the multi-scale level (from regional to local), the capacity to respond to climate change, especially those related to hydrogeological risk. The initiatives proposed by the project have been developed since 2017 within the vast area of central Veneto, involving different levels of government of the territory, from the metropolitan one of the City of Venice to the local one of the cities of other provincial capital cities such as Padua, Vicenza, and Treviso, up to the micro-scale one, such as the Union of Municipalities of the Middle Brenta.

This has led CMVe Municipalities to implement actions relating to adaptation directly in existing Seaps or the transition from SEAP to Sustainable Energy and Climate Action Plan (SECAP) towards the reduction of emissions of at least 40% to 2030.

If LIFE Master Adapt and LIFE Veneto Adapt have provided the strategic bases to guide the work in the Metropolitan City of Venice, the next step has been entrusted to two projects still in the development phase: the Interreg SECAP and the Desk project.

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[7] The project, coordinated by Regione Sardegna, with the support of a partnership composed of Ambiente Italia, Università IUAV di Venezia, Fondazione Lombardia per l'Ambiente, Regione Lombardia Coordinamento Agende 21 Locali Italiane, ISPRA, Università degli Studi di Sassari - (https://masteradapt.eu/), aimed to provide a common methodology to support Regions (Region of Sardinia, Region of Lombardy), Metropolitan Cities (CM of Venice, CM of Cagliari) and Groups of Municipalities (Metropolitana del Nord Sardegna, Unione dei Comuni del Nord Salento and Aggregatizione di Città a Nord di Milano), to identify the main vulnerabilities to climate change, the priorities of intervention and, specifically, to develop strategies for the governance of adaptation.

The first one, the Interreg Italy-Slovenia SECAP - Support for Energy and Climate Adaptation Policies[8], has the objective of encouraging sustainable development of the territory by promoting strategies for low carbon emissions creating relevant adaptation and mitigation measures thanks to the transition of the SEAP to the SECAP for the municipalities of CMVe. The project will promote sustainable development models of the Covenant of Mayors with improved quality of life and resilience to climate change. Thanks to the creation of an inventory of strategies, measures and projects to increase resilience, practical support to the municipalities in the partner area will be provided for the implementation of sustainable energy and climate adaptation policies, to improve energy planning by municipalities, focusing on energy saving, renewable energy, reducing CO_2 emissions.

The project Desk - Consultation, participation and Decision support system to Support territorial Knowledge[9], finally, in collaboration between the Metropolitan Cities of Venice (leader), Milan, Genoa, and the Province of Taranto, supported by the Territorial Cohesion Agency and funded by the PON "Governance and Institutional Capacity Programme 2014-2020", aims to build smart, sustainable and inclusive territories. The project, starting from the best practice of CMVe, will allow to computerize and digitize the knowledge tools of the territory. A set of web services will allow sharing in real-time geo-referenced information and aggregate innovation services on a supra-municipal scale. Thus various stakeholders will actively participate in the construction of territorial support indicators to the management, contributing to the definition of in-depth thematic analyses.

In the programmatic chronology of CMVe (and, before, of the Province), the contents and goals of the projects described are part of a path focused on sustainable development and resilience. This path began with environmental protection plans (Water Plans and SEAPs), followed by energy sustainability projects and mitigation of the causes of the greenhouse effect, up to the most recent integration of adaptation policies to climate change. The synergic experiences gained in recent years, between local administrations and the local authority, with the technical-scientific support of universities and other research centers, indicate one of the possible ways, replicable in other contexts, for local adaptation. To achieve these results, it was essential to:

- increase awareness of territorial vulnerabilities to the CC in every sector of public administration to understand the potential effects;
- reorganize public structures, making widespread and uniform use of Information and Communications Technology - ICT tools;
- draft of appropriate technical guidelines to facilitate knowledge sharing;
- define a unique vocabulary for the study and application of the most innovative climate-proof processes, which can be traced back to the virtuous cycle of analysis of needs, planning of interventions, measuring the effects of the processes implemented, calibration of new interventions;
- develop a land approach that is sensitive to evidence of climate change;
- extend the comparison and complexity of the CC discussion to other areas of broad area planning, such as land consumption, mobility, energy, health, and safety.

The path described so far shows how local contexts are currently more likely to undertake a path of adaptation, where higher support bodies such as the Metropolitan Cities can provide a framework to support the development of adaptation capabilities and the exchange of information about existing good practices. (Musco et al., 2015; Musco and Magni, 2014). With the support and the coordination of an over-ordered entity, cities – both in-network and in autonomy – demonstrated greater commitment and effectiveness in producing decarbonized and climate-proofed development strategies.

[8] www.ita-slo.eu/it/secap
[9] www.progettodesk.it

3. Results

The results obtained from the described path are many and differentiated by specific thematic and scientific areas. Concerning spatial planning for adaptation to climate change, in addition to specific legacies of individual projects, the most relevant results of the path of the Metropolitan City of Venice, as shown in Fig.3, can be summarized in:

- development of a common knowledge framework and identification of impacts and assessment of territorial vulnerabilities;
- active support to the process that led to the definition of metropolitan adaptation objectives and strategies;
- integration of adaptation actions into local plans and programs.

These results are fundamental for having equipped the CMVe with tools to address the metropolitan-integrated strategic vision. The construction of a well-defined and common methodology in the metropolitan area has allowed and will allow, to move from a planning "per projects" to a " per processes" (Musco et al, 2019), increasing the capacity of adaptation, administrative resilience, decision-making, and operational processes, building a system capable of facing change in a virtuous and innovative way.

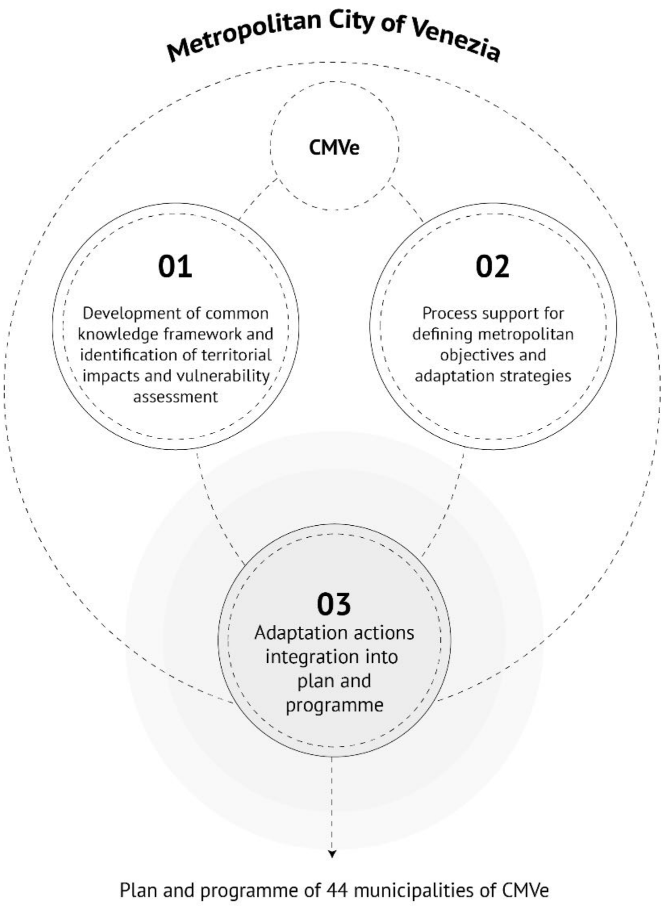

Fig.3 Results of the adaptation planning process of CMVe

3.1 Development of the common metropolitan knowledge framework: identification of impacts and assessment of territorial vulnerabilities

Adaptation has the primary need to know in-depth the study areas and the impacts they are subject to, to cope with specific impacts resulting from CC. The definition of the framework for CMVe has been implemented with the definition of the impacts of climate change, understood as the threats felt in the specific territory, the

outcome of the relationship between climate, urban fabric, and urban functions. Climate change impacts selected through the participatory process for the CMVe are urban flooding and the urban heat island.
The analysis phase for the assessment of vulnerability to urban flooding and urban heat islands (Shmelev, 2019) was based on a quantitative-qualitative of surface runoff of rainwater, soil permeability, temperatures, and vegetation indices. The analysis showed how and to what extent soil sealing negatively affects the area's hydraulic performance and perceived urban temperatures. The elaboration has been useful to construct an updated cognitive picture of the whole metropolitan territory, to orient the policies and the strategies of development to avoid the exceed specific critical thresholds. The results obtained indicate those areas in which the priority is to intervene with blue, green, and grey solutions to adapt to the territory. The aforementioned process is summarized in Fig.4.

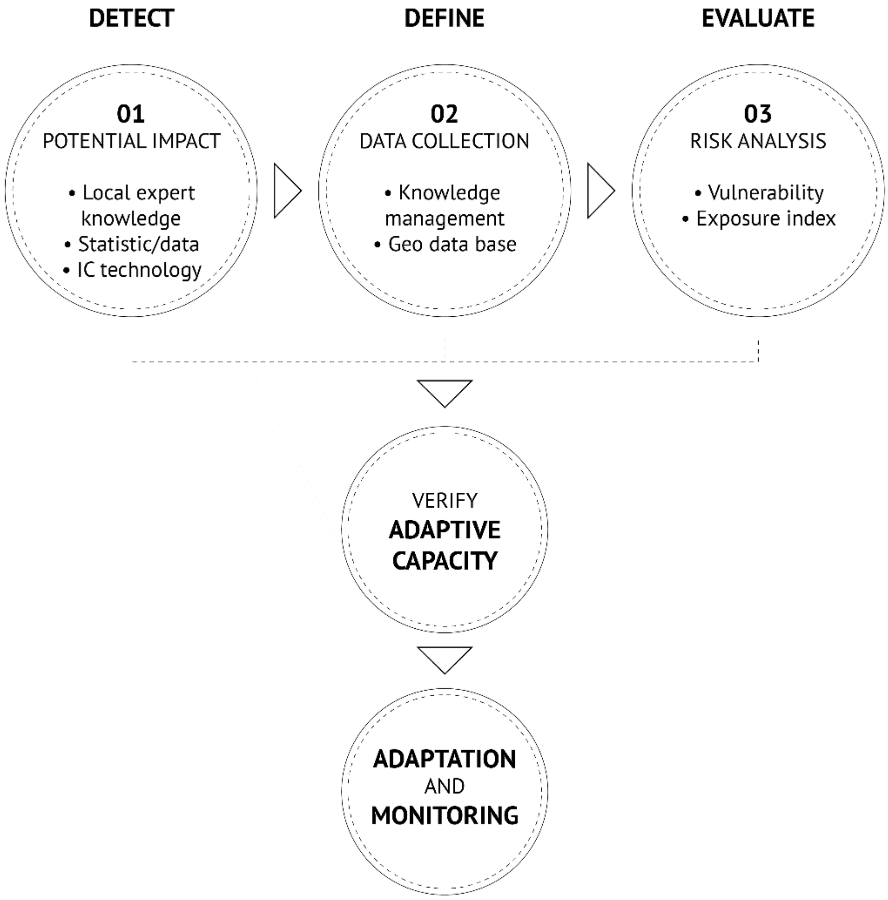

Fig.4 The phases of knowledge framework building

All the information obtained and systematized, together with the information already in the possession of the Municipalities and the CMVe, have created new information levels. These new levels gave rise to the Decision Support Tool[10] (DST). The DST, built in its initial version within the pilot area of the LIFE Master Adapt project and adopted and improved by CMVe with the DESK project, is now available to policymakers and municipal technicians. The results have enabled local adaptation processes to be supported through this new CMVe Territorial Information System (SIT). The Decision Support Tool (DST) is a research site where every municipality can investigate its territory to define its vulnerability and geolocation characteristics. In this way, municipalities are supported for the strategic, political, and practical decisions: which actions to implement, what priority, in which specific area of their territory (Fig.5).

[10] www.desk.cittametropolitana.ve.it:8088/superset/dashboard/10/

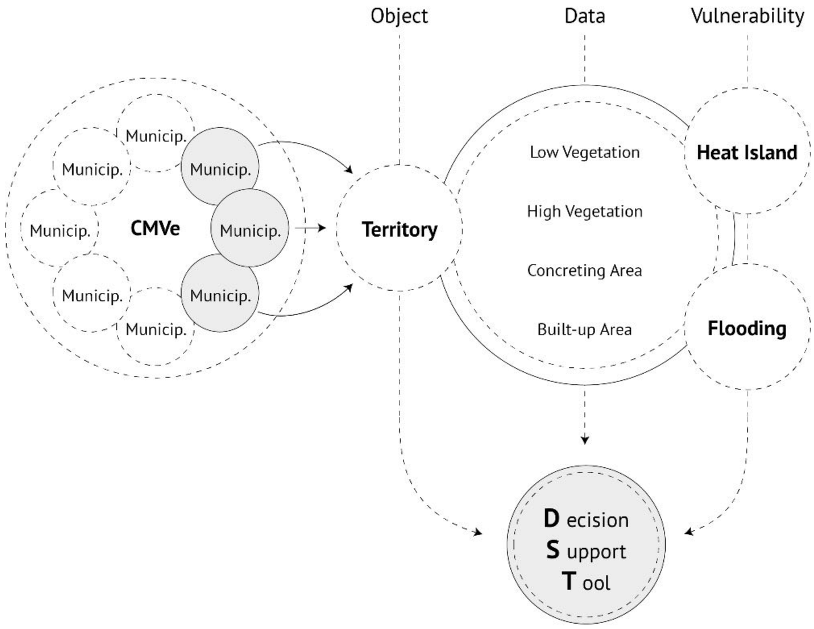

Fig.5 Decision Support Tool (DST) applied to the territories of CMVe

3.2 Support to the process that led to the definition of metropolitan adaptation goals and strategies

By referring to LIFE Master Adapt as a key part of a process that has been underway for more than a decade in CMVe, the two impacts of climate change described above – urban heat island and run-off – have been considered for the definition of adaptation goals and strategies. The technical work of scientific analysis of vulnerabilities was accompanied by an evaluation process of a participatory nature, through workshops, public meetings, and questionnaires entrusted to the Municipalities of the CMVe. The activities were carried out to assess perceptions and investigate what has already been achieved in the Venetian territory in terms of adaptation to climate change.

This phase allowed the participation and multi-level involvement of stakeholders, horizontally between the operating sectors of the Metropolitan City of Venice and vertically with the Municipalities of the CMVe. The dissemination and preliminary communication of the intentions of the process has been an important part in building trust between the citizen and the administration, between perception and effort of the metropolitan administration to make territory, networks, buildings, and communities, mostly climate-proof. The success of the adaptation process also depends on the level of awareness about the effects of CCs in the technical apparatus, in the political bodies, between stakeholders, and the population. Following the elaboration and sharing of the knowledge framework, a vision has been defined to build the orientation process. The definition of the vision has followed a method for the development of goals of adaptation that is articulated in four logical passages:

- understanding of goals or general purposes of adaptation;
- defining an overall vision for land development in climate change conditions;
- identification of general and specific objectives;
- proposal of possible options for achieving these objectives.

The goals, defined through the participatory process (Tab.1) were determined for the two impacts chosen: urban heat waves and urban floods.

Impacts	Sectors	Focus Area	Goals
Urban Heat Waves	Human health	– Increased health risks related to heatwaves	– Improving knowledge of all possible effects of extreme weather events on the population and monitoring their development – Adapting health infrastructure and strengthening emergency management systems – Adequately disseminate the information acquired to the population and develop effective awareness-raising campaigns
	Built environment	– Potential damage to plant structures in urban environments	– Updating urban green planning models and techniques – Increasing knowledge of urban greenery to improve heritage management in a situation of thermal stress – Raising public awareness of efficient management of private green assets – Revision of urban management tools
	Energy	– Increase in energy consumption by cooling buildings	– Updating urban green design models and techniques – Increasing the urban green heritage to boost the provision of urban ecosystem services – Raising public awareness of appropriate behavior in situations of high thermal stress
Urban Run-off	Built environment	– Increasing knowledge of the territory, in particular of areas subject to possible flooding – Updating urban planning and design models and techniques – Raising public awareness of areas vulnerable to flooding – Promoting integrated coordination in hydraulic risk management between the different territorial policies – Greater damage to infrastructure, disruption of public services, danger to the population	– Increasing knowledge of the territory, in particular of areas subject to possible flooding – Updating urban planning and design models and techniques – Raising public awareness of areas vulnerable to flooding – Promoting integrated coordination in hydraulic risk management between the different territorial policies

Tab.1 Goals and Options for Heat Waves and Urban Flooding for CMVe

3.3 Support for the integration of adaptation actions into municipal plans and programs

On the one hand, the actions in the existing instruments of territorial governance (voluntary and/or mandatory) have been modified with an adaptive perspective; on the other hand, new adaptation actions have been inserted. Metropolitan City planning is already very structured by tools and plans that already contain adaptation and mitigation actions. The CMVe Municipalities were offered a questionnaire to verify, within their territorial policies, the presence or absence of adaptation actions (Table 2), to avoid the frustration of what already produced in the territories by public bodies or other actors (waste cycle, water, and wastewater management, mobility, reclamation agencies, ATO, etc.).

This is a very important basis for proper integration/construction of adaptation actions into existing or newly drafted plans and programs.

N	Question
01	Are you aware of what area potentially affected by climate change is currently covered by adaptation measures?
02	If so, what is the surface?
03	Are adaptation measures planned or will be implemented at the end of the project?
04	If so, what area will be affected by these adaptation measures?
05	Are adaptation measures planned or will be implemented five years after the end of the project?
06	If so, what area will be affected by these adaptation measures?
07	Are you aware of particularly vulnerable areas in your area of expertise?
08	If so, what is the surface area of these particularly vulnerable areas?
09	Do you anticipate that at the end of the project the particularly vulnerable areas will disappear?
10	If so, by how much?
11	Do you anticipate that five years after the end of the project, particularly vulnerable areas will change?
12	If so, by how much?

Tab.2 Structure of the survey submitted to the municipalities of the CMVe

For this specific phase, the role of CMVe has been fundamental over the years for having provided technical guidelines that facilitate knowledge sharing and a unique vocabulary for the study and application of the most innovative climate-proof processes. A large body such as CMVe has, in this case, helped to rethink the organization and policies of individual municipalities bringing them progressively towards the interdisciplinary and systemic approach that modern problems require, triggering the virtuous cycle of analysis of needs, planning of interventions, measuring the effects of the processes implemented and possible calibration of new interventions.

The situation of the SEAP and SECAP reported in Fig.6 is indicative of what the CMVe is doing in the environment, climate, and adaptation, both on a large scale (metropolitan), both at a local scale, through actions to support individual municipalities and local authorities.

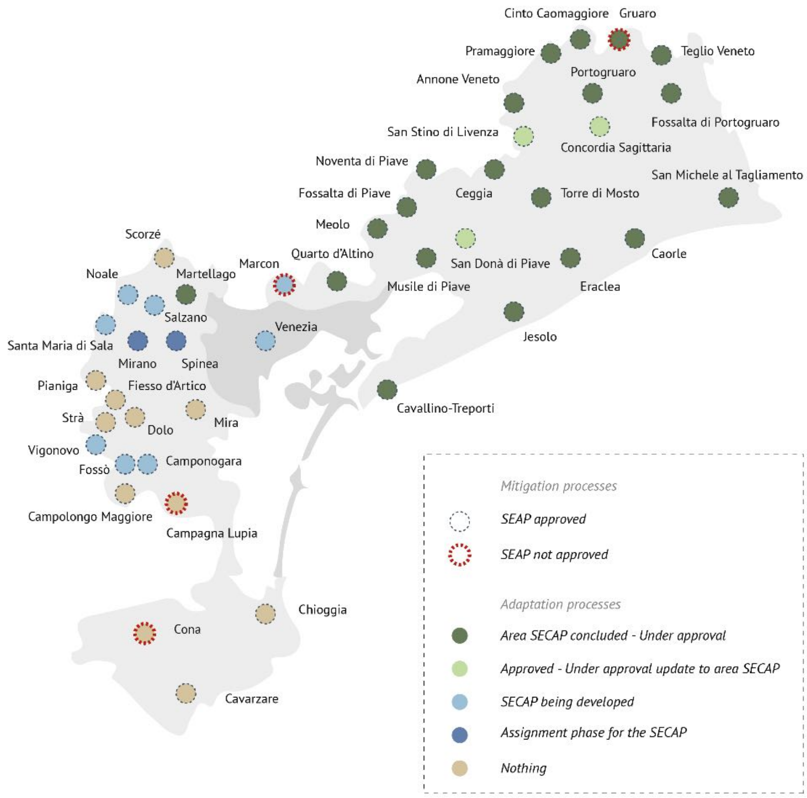

Fig.6 Situation of the SEAPs and the SECAPs in the CMVe

CMVe is also supporting some local and supra-local projects and plans – in addition to the definition of SECAPs – thanks to the methodology described and carried on. The results obtained up to 2021 are shown in Tab.3.

	Action		**Municipality**
Year	**Project**	**Plan**	
2018	Venezia2021: scientific research program for a "regulated" lagoon		Cavallino-Treporti, Chioggia, Dolo, Eraclea, Jesolo, Marcon, Mira, Musile Di Piave, San Donà Di Piave, Venezia
2020	AdriaClim		City of Venice
2020	STREAM		
2019	Hyperion		
2020		Adaptation Plan (ongoing)	
2019	SAVEMEDCOASTS - 2		
2017	I-STORMS		
2016	GreenerSites		
2020	Metropolitan Sustainable Urban Mobility Plan – PUMS (ongoing)		All the Municipalities of the CMVe
2019		Metropolitan Strategic Plan with references to territorial resilience	
Ongoing	Capillar interventions of the Consorzio di Bonifica Acque Risorgive for ordinary management of extreme weather events		

Tab.3 Other projects and plans in the CMVe

Obviously, the City of Venice has been able to start more projects than other municipalities, but many projects (Metropolitan Sustainable Urban Mobility Plan – PUMS, Metropolitan Strategic Plan, Venezia2021) have been started at the metropolitan level or jointly between more municipalities thanks to the intermediation of the CMVe.

4. Discussion

The processes of adaptation need to have an in-depth knowledge of the territories to become shared, effective and efficient and to cope with the specific impacts resulting from CCs (Maragno, 2018; Bezzi et al., 2015). Studying territorial specificities and making them known (Miranda Sara, & Baud, 2014) to policymakers and technical offices is the first step in knowing how to make an informed decision and which actions are the most important. Since the late 1990s, the need to address the dynamics of CC in cities has been recognized at the institutional, academic, and operational levels in urban management practices (Musco, 2008).

It is also demonstrated that an overall vision is fundamental to overcome economic and technical difficulties that municipalities often encounter in initiating processes of adaptation (Ministero dell'Ambiente e della Tutela del Territorio e del Mare, 2014; Ministero dell'Ambiente e della Tutela del Territorio e del Mare, 2017). These operations usually involve different administrations and bodies at the same time. Difficulties may arise for the different roles they can have, for the transcalarity of the actions, for the convergence of needs of more municipalities on a specific theme, and, not least, because the effects of climate change exceed administrative boundaries. Therefore, acting in a coordinated way is as efficient a choice in saving time, resources, and means as it is effective in achieving the goal.

The presence and support of an intermediary body such as MC are crucial for municipalities to facilitate the process at every stage. Indeed, it is found that the main causes of the poor implementation of adaptation

actions at the local level are the lack of awareness of the urgency of adaptation actions to CCs, the absence of a methodological framework, and the lack of analysis of the vulnerabilities of the territory.
The MC, as an intermediary between the regional and local levels, have the opportunity to acquire a leading role, no longer that of a body supporting the Covenant of Mayors, but rather that of guarantors of responsibilities and skills adequate to respond to large-scale problems going beyond the usual dichotomy between strong (rich) and weak municipality (lacking in financial and technical resources).
CMVe's adaptation process has adopted these principles, committing itself from the beginning to support the planning of wide areas. For this reason, it was necessary to increase the levels of knowledge available by making interoperable spatial information on the geomorphological and climatic specificities of the place, as well as on the adaptation practices already initiated by local communities. The process in the Venetian territory has lasted many years and has led to the awareness that climate impacts need to be addressed with a broader perspective (Magni, 2019). Also, it has emerged that the MC can be the most suitable administrative level for information and knowledge support; technical support, and scientific support. Due to this, the CMVe has constructed a method of approach to the planning of the climatic adaptation on a wide area thanks to the various plans that made the MC address the problem of the union and the coordination of strategies and actions to level metropolitan, supporting individual municipalities in defining a broad vision and common lines.
As shown in Fig.7, CMVe acted to (specifics results are shown in Fig.8):

- support municipalities in the processes of integration of technical knowledge into the technical apparatus and among political decision-makers. This happened thanks to the support in having Covenant of Mayors and thanks to the projects LIFE Master Adapt, LIFE Veneto Adapt, Desk and to the PTC;
- support the establishment of a free and shared metropolitan knowledge framework (DSTs and vulnerability and risk maps). This happened thanks to SEAP_ALPS, LIFE Master Adapt, Interreg Italy-Slovenia SECAP;
- to accompany with a participatory process in the definition of the vision matrix/goals/action that has allowed shared reasoning on a large scale, thanks to LIFE Master Adapt;
- organize actors and stakeholders in a strong and metropolitan way, thanks to LIFE Master Adapt and LIFE Veneto Adapt.

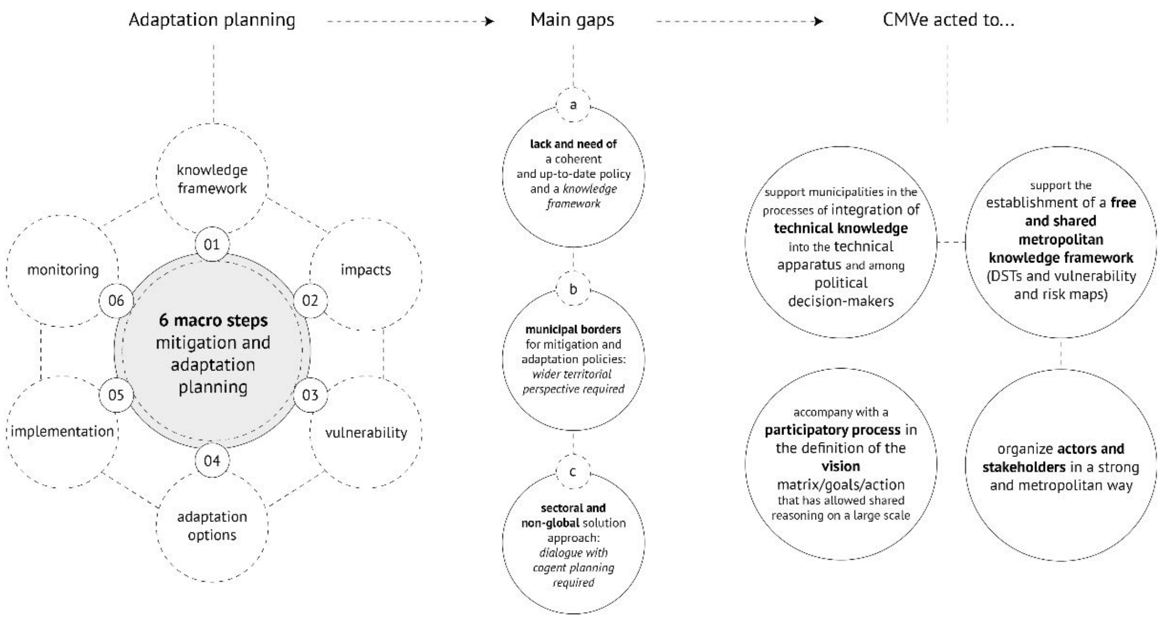

Fig.7 Connection between methodological steps, gaps, and actions in CMVe

As shown in Fig.8, the adaptation processes implemented in the CMVe have been carried out also thanks to external funding – the EU LIFE program, the special resources of the Provveditorato public works, Interreg Italy-Slovenia, Italy-Croatia CBC Programme – which CMVe has been able to direct and manage for all its 44 municipalities.

As the CMVe did, the other Italian MCs should be able to channel in specific projects and implementation in the various Municipalities/Aggregations of Municipalities concerned according to territorial needs. Also, MCs could have the opportunity, thanks to their structure and expertise, to take on the role of representativeness in raising European or national funds, coordinating projects, allocating financial resources and energy, and facilitating the work of connecting the municipal, regional and European levels. MC could also direct the process of integration of adaptation to climate change in tools and processes "ordinary" planning and territorial planning.

The narrated path can be replicable in other MC in the approach and in the result, but not necessarily in the process. Adaptation and climate transition processes, unlike mitigation processes, must be site-specific. Therefore, each MC could start a path differentiated according to starting conditions (Burton & Dredge, 2007), to the available cognitive and economic resources, to the relations between operational planning levels (Laukkonen et al., 2009; Satterthwaite, 2007).

5. Conclusions

As demonstrated above, to integrate adaptation measures into local urban agendas and in the management of cities, it is necessary a reorganization of public structures.

This should happen to make the use of ICT tools widespread and uniform, technical guidelines to facilitate the sharing of knowledge, a unique vocabulary for the study, and application of the most innovative climate-proof processes.

It would also be essential to rethink the organization of individual public administrations and gradually move them towards the interdisciplinary and systemic approach that modern problems require to guarantee the success of such an administrative practice. Another fundamental aspect is that of the now necessary obligatory nature of adaptation and mitigation practices.

The MC can access funds and economic sources through European and National partnerships that would be difficult to find and carry forward for individual municipalities, especially small and medium-sized. Compared to other types of administrative aggregations, the MCs have an autonomous form and a well-structured legal framework that can address policies of the wide area on the issues of climate change. This innovative process took place, for example, in the Venetian metropolitan area with the Territorial Plan of Provincial Coordination, which, starting from a will of the CMVe, has become a virtuous and compelling element of adaptation for each of the municipalities of the MC.

The role played by CMVe over the years intending to direct public policies towards adaptation and mitigation in an increasingly structural way has been of considerable importance and has the value of being replicable in other Italian MC. As the DESK project provided a common approach among MC of Italy for data management, it would be interesting to replicate the approach between MC in the governance of climate-proof planning to move towards homogeneity in the approach to emerging issues regarding the Territorial Government.

The CMVe has been able to develop the described process also thanks to the large sum of funds deriving from European and other financings. In the absence of these, the process can be more difficult. The MC can however engage themselves to take action to find these financings and to modify their administrative structures to facilitate the process of territorial adaptation.

To implement with greater effectiveness and efficiency some innovations within the metropolitan administrative structure, the government could focus on:

- the creation of a team dedicated to climate change: coordination that meets periodically to update and organize the work; a team that deals structurally, within the public administration, the topic; a person who, with the assistance of representatives of other sectors, coordinate work on the subject;
- the definition of a real Metropolitan Strategy for Adaptation able to organize in a single document the goals that the entire vast area poses. Adaptation has a very wide and long-term potential that can be found in a Document and in a formal process in which it is channeled to have greater authority and continuity that formalizes and defines goals and adaptation actions. This can certainly help the effectiveness of mainstreaming and address the salient issues on which the Metropolitan City must work in collaboration with stakeholders and administrative structures, both within the Metropolitan City and the Municipalities belonging. A Metropolitan City endowed in all its local administrative declination of such climate-proof government tool addressed by a single methodological hat would allow the spread with greater speed and effectiveness of sensitivity towards an integrated approach of mitigation and adaptation.
- be aware that many important plans to tackle CC with adaptation or mitigation measures are in the hands of municipalities, which must be appropriately encouraged to do so. The MC has many limits in improving this.

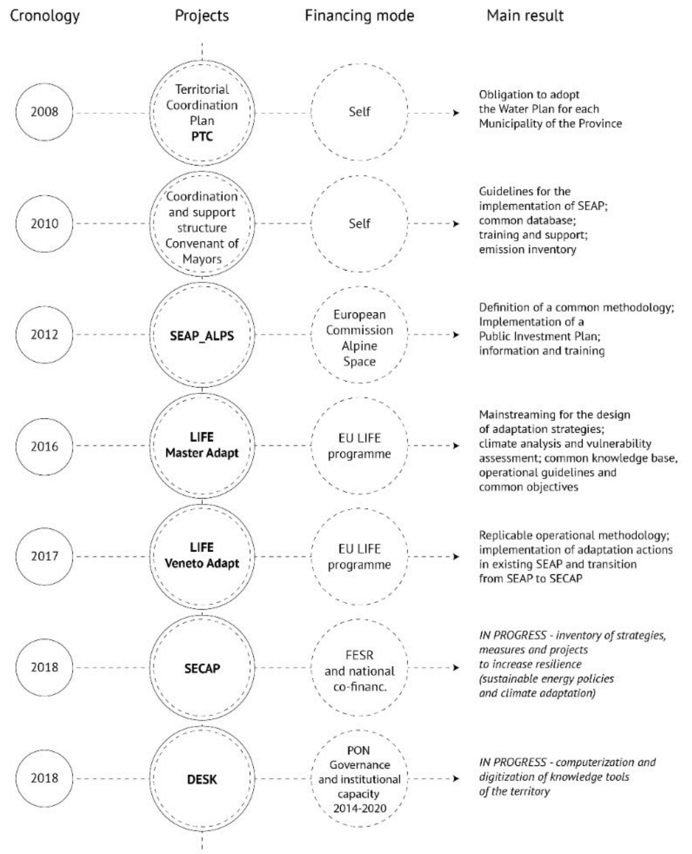

Fig.8 Projects and programs of adaptation planning in the CMVe related with main results

The difficulties of the municipalities in systematically addressing the impacts of climate change and a certain uncertainty in the definition of the direction that has the MCs in Italy can find, in the climate transition project, a renewed mutually positive alliance. The path told happened in the CMVe shows that, despite the numerous difficulties of both municipalities and MCs, the presence and support of a large area local authority can play an indispensable role in supporting climate change and territorial resilience.

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Image Sources

All figures are elaborated by Giovanni Carraretto.

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Territorial disparities in Tuscan industrial assets: a model to assess agglomeration and exposure patterns

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Abstract
Industrial agglomerates are considered *drivers* of urban development. This reiterative process of industrial growth, nevertheless, tends to increase regional territorial disparities, an asymmetrical development pattern that can lead to productive spaces' underuse or abandonment. Although numerous economics studies about industrial distribution and territorial disparities were so far conceived, those are based on dated spatial methodologies. These consider space as an abstract background, hence, leaving unexplored several spatial relations between production, infrastructural networks and industrial agglomerates organization. Novel models ought to consider real attributes of space, being crucial to economic recovery in times of territorial constrains; with this in consideration, the paper objective is to construct and discuss a spatial-economic model tailored to assess territorial disparities in industrial agglomerates distribution and the condition here defined as *territorial exposure*. *Exposure,* represented by a composite spatial index, denotes disparities in territorial endowments, identified as factors of sensitivity or support to firms placed within industrial agglomerates, spatial conditions that can affect their capabilities to react to periods of economic recession and their post-crisis recovery. The model analyses Tuscany Region's industrial structure and depicts territorial disparities in a GIS-based environment. The spatial knowledge produced can aid regional initiatives for economic recovery directed to Tuscan industries.

Keywords
Territorial disparities; Territorial exposure; Industrial agglomerates; Urban and regional planning; Tuscany.

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1. Introduction

Urban settlements have industrial spaces as one of their fundamental substructures. It is inside these places of production that the values destined to sustain and reproduce urban economies, commercial exchanges, and to support other economic activities are created (Lefèbrve, 1974). On this assumption, it is logical to associate industrial activities' dynamism to the processes of growth and decline of other urban functions, such as residential areas or shopping complexes production, in a manner that defines the industrial agglomerates as the real and proper drivers of modern urban development (Lefèbrve, 1974 and 1996). In this sense, industrial activities' location within territories possesses a recursive role regarding built-infrastructures organization: the industrial activities will be located near important market nodes (cities) and their development will have an influence on the successive industrial agglomerates' growth, as well in further public policies of investment in urban infrastructure, in a circular and reiterative relationship. Even though desired from a developmental point of view, these relations tend to also to increase territorial disparities. These asymmetrical regional development patterns can lead to a condition of underuse or abandonment of potentially productive spaces, which result in the urban environments' *exposition* to grave socio-economic pressures (Smith, 2008), such as unemployment and populational decrease.

This interdependence between spatial localization and production was quite discussed since the seminal works on territorial economics were published during the 1920's, both assessing regional (Weber, 1929; Nijikamp, 1986) and urban (Alonso, 1964; Mills, 1987) contexts. Nevertheless, economics' analytical efforts have been, since then, restricted to comparative evaluations of location within macro-territorial scales, above all, focused on microeconomic repercussions, in terms of productive returns and growth, interpreted as derived from economic activities' *geography* at urban – with bid-rent theory (Cheshire and Mills, 1999) – and regional scales – through spatial equilibrium, input-output and agglomeration analysis (Henderson & Thisse, 2004; Duranton et al., 2015a, 2015b). These formalistic analyses predominance and the historical detachment amid economic and territorial studies after the 1970's conduced to a limited development of spatial analyses capable to describe with sufficient detail how disparities in territorial endowments (built-spaces characteristics) affect economic activities – as space is often interpreted in economics as an *abstracted* background. The *abstracted* spatial representation can be identified as one of the issues for the evident discontinuities in spatial knowledge and models' progress in the Urban and Regional Economics field, as classical principles and theories of location developed during the 1920's (Capello, 2015), as well as comparative territorial models with limited spatial detail – such as locational quotients *(shift-share* models) (Fracasso et al. , 2018; Bellandi et al., 2019) – are still revered, being used on most economic-based territorial analysis. Hence, economics' reluctance in the adoption of novel instruments and computational methods that assess space with a greater level of detail, as those developed for use in Geography, Urban and Regional Planning and Territorial Engineering and Risk Assessment (Francini et al., 2020; Di Ludovico et al., 2021), has left several spatial-economic relations among production systems, the spatial configuration of infrastructural networks, and the organization of industrial agglomerates fundamentally unexplored.

In this aspect, innovative models capable to assess the complex behaviours and the disparities within industrial territories placed on urban-regional settings are dependent of a transformation in how economics understand space and interpret spatial knowledge. This achieves an unprecedented relevance, as surpassing the analysis limitations of Urban and Regional Economics' spatial models is fundamental to the successful outcome of post-crisis economic recovery policies, above all, following territorial constrains due to lockdowns and the serious recession period decurrent of the Covid-19 pandemic (Campagna, 2020). With these issues in consideration, this paper objective is to advance in the development of spatial-economic models, suitable to highlight the spatial distribution and territorial disparities within industrial agglomerates on urban and regional systems. For this purpose, the proposed model assesses a condition defined as *territorial exposure*, evaluated through analysis of the Tuscany regional structure. The conceived concept of *exposure* – determined by a parametric index – denotes how the territories' built-spaces support the industrial agglomerates and highlights disparate territorial endowments, that are identified as factors of spatial sensitivity to the firms and may affect their capabilities to interact and react to periods of economic recession and their post-crisis recovery. The spatial knowledge produced can aid the regional initiatives for economic recovery directed to Tuscan industries.

2. Datasets and Methods

The data extraction processes, and the datasets used in the evaluation of Tuscan territorial disparities are described in the section 2.1. To be suitable for spatial-based correlations, these datasets are organized into a GIS suite (QGIS, 2020). Several geoprocessing steps are needed to perform data treatments needed to assess the industry territorial patterns through *Macroarea* and Configurational Analyses; those are outlined, together with the parameters used for the *Territorial Exposure Index (TEi)* construction, in the methods section (2.2).

2.1 Datasets organization

Spatial information on the industrial assets used in the *Macroarea* Analysis construction, to assess the territorial size, and dynamics of industrial placement, is extracted from the Tuscan Region Built-Structures dataset *(Edificato 2k,10k 1988-2013)* (Regione Toscana, 2019a). This database outlies the location of all built-structures throughout the territory, represented by volumetric units (polygons), categorized according to their main urban function. The information contained on the dataset is multiscale, meaning that it is assembled from different Technical Charts (scales 2k and 10k), and periodic, thus collected over a time-period comprised between 1988 and 2013. For this analysis purpose, only volumetric units that are categorized under "Industrial" *(Industriale)* or "Technological Plant" *(Impianto Tecnologico)*, and that are listed as "active" in the 2013 period, are considered as industrial assets, which are exported from the main dataset.

The road-infrastructure dataset employed in the Configurational Analysis, that model road-circulation network movement dynamics, derives from the Tuscan Region Road Graph *(Grafo Stradario della Toscana)* (Regione Toscana, 2019b), a Road-Centre Line (RCL) graph map that represents the entire regional road-infrastructure. Road-elements were further generalized through QGIS integrated Douglas-Peucker algorithm (QGIS, 2020; Altafini & Cutini, 2020), to diminish the total number of vertices and reduce the extensive network modelling time-lapses for Space Syntax' Angular Analysis (Turner, 2001). Angular Analyses are able to assess different kinds of network parameters, related to urban-regional centralities hierarchies, therefore, are able to estimate several movement dynamics within the road-infrastructure system, through Normalized Angular Integration - NAIN *(mathematical closeness centrality)* and Normalized Angular Choice - NACH *(mathematical betweenness centrality)* configurational measures (Hillier et al., 2012). For this analysis purposes, only the latter measure is considered. Since *betweenness centrality* counts, for all origin-destination pairs, the number of times each road-element is traversed when travelling through the overall shortest path towards all potential destinations (Turner, 2001), the NACH measure is capable to depict the *preferential routes* hierarchies used in regional transport connections, important factor to be considered regarding industrial activities placement.

2.2 Methods for evaluating territorial disparities

Several steps of geoprocessing are required to assess industrial assets' distribution and territorial disparities. While each step can be considered as an independent territorial analysis, since it addresses a particular spatial factor, two collective assessments can be summarized: the *Macroarea* Analysis, that, based on industrial assets' placement, considers the industrial *macroareas*' size, degree of industrialization and agglomeration patterns within a certain part of the territory; and the Configurational Analysis, that highlights the regional-wide preferential transport routes of the road-circulation network. The parameters/indicators of these analysis are combined, and result in the Territorial Exposure Index (TEi) – which evaluates the spatial patterns and differences in endowments that can lead to economic unsoundness from a territorial standpoint. The Territorial Exposure Index (TEi) is constructed through the attribution of scores for parameters determined through the *Macroarea* and Configurational Analyses, that individuate the following variables, described in Equation 1: the *macroareas* size (Si) and the agglomeration index degree (Ai), given by the industrial assets' positional analysis; and the road-configuration parameter (Ri), that is established through correlations between *betweenness centralities* values and the industrial assets, and depict their nearness to *preferential routes.*

$$TE_i = S_i + A_i + R_i \qquad (1)$$

As an initial step to construct the *Macroarea* Analysis, an industrial spaces' dataset is created from the industrial assets' volumetric units to establish the spatial linkages among industrial assets placed in the same on in near plots of land. The procedure draws a 30m buffer radius – equivalent to the plot plus the street area – for each volumetric unit, then dissolved into continuous areas. The result, a sole spatial unit (Fig.1a), is submitted to a negative buffer, that reduces the excess areas created through the positive buffer into the original industrial assets' dimensions, while maintaining the area boundaries and contiguities established by the buffer (Fig.1b). The industrial spaces are then individualized, through the conversion into single parts from the sole territorial unit, that are then categorized according to their area size (Tab.1, Figg.1a; 1b; 2).

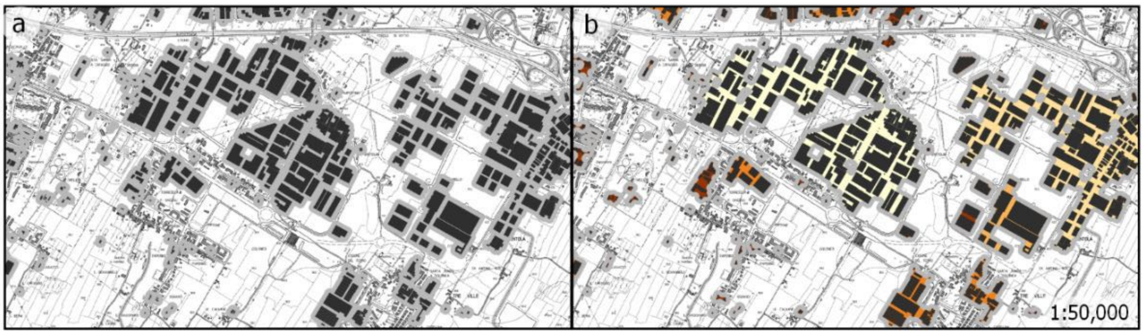

Fig.1 Industrial spaces creation from industrial assets: positive (a) and negative (b) buffer results, with area categorization

Classification	Industrial Assets Count	Industrial Spaces Count	Total Area [km²]	Buffer radius [m]	Buffered surface [km²]
Maximal (>= 0.6 km²)	2,118	4	4.73	100	9.44
Large (>= 0.2 - < 0.6 km²)	6,914	38	11.98	200	47.29
Medium (>= 0.075 - < 0.2 km²)	9,062	128	15.33	300	131.71
Small (>= 0.02 - < 0.075 km²)	16,780	623	23.34	400	591.33
Minimal (< 0.02 km²)	45,319	14,901	27.60	500	12,741.37
Total	80,193	15,694	82.98	-	13,521.14

Tab.1 Tuscany industrial spaces classification regarding count, total area, relative multi-distance buffer and total surface after buffer

Industrial spaces are considered as base features to draw multi-distance buffers from each of the single parts (Fig 2). This differentiation in radius is enacted to reflect general characteristics of a particular industrial space regarding internal and external displacement tendencies towards regional transport routes. Larger industrial spaces tend to require a greater internal displacement to reach regional *preferential routes* – hence a smaller buffer radius, while smaller spaces tend to require greater external displacements – thus a greater radius.

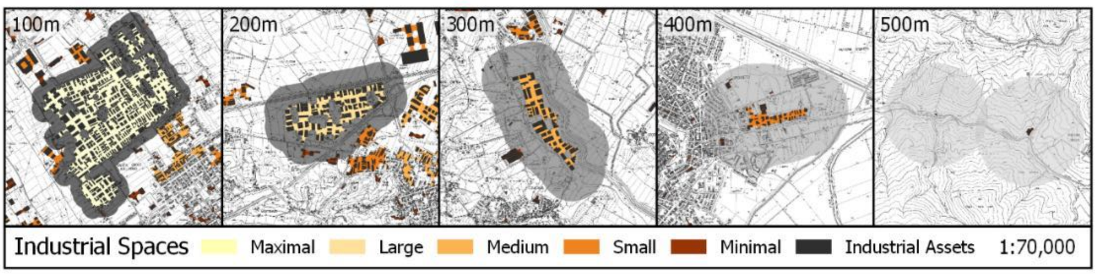

Fig.2 Examples of categorized industrial spaces with their respective buffer distances applied

Areas created through the multi-distance buffer are dissolved to form continuous *macroareas*, that are divided into single parts based on their contiguities, and categorized according to: size, industrial spaces (contiguous spaces) and industrial assets (structures) counts (Fig.3a, Tab.2). *Macroareas* are conceptualized to establish a visual representation of Tuscan industrial assets' territorial cohesion and distribution, their industrialization patterns (industrialization degree), and to highlight the displacement reach of the collective industrial spaces. The ratio between the number of individual industrial spaces and the number of industrial assets located within a *macroarea* yields an agglomeration index (Fig.3b, Tab.3), that illustrate industrial assets' overall degree of agglomeration and depicts the industrial spaces' usage (average industrial assets' density). This index performs a supportive role to the macroareas spatialization that, nevertheless able to depict the territorial dimensions of industrialization, is unsuited to address the proximity conditions among industrial assets within a same territory. The *macroareas*' size (Si) (overall cohesion and industrialization) and the agglomeration index (Ai) are used as parameters to define the economic activities spatial patterns considered for the Territorial Exposure Index (TEi).

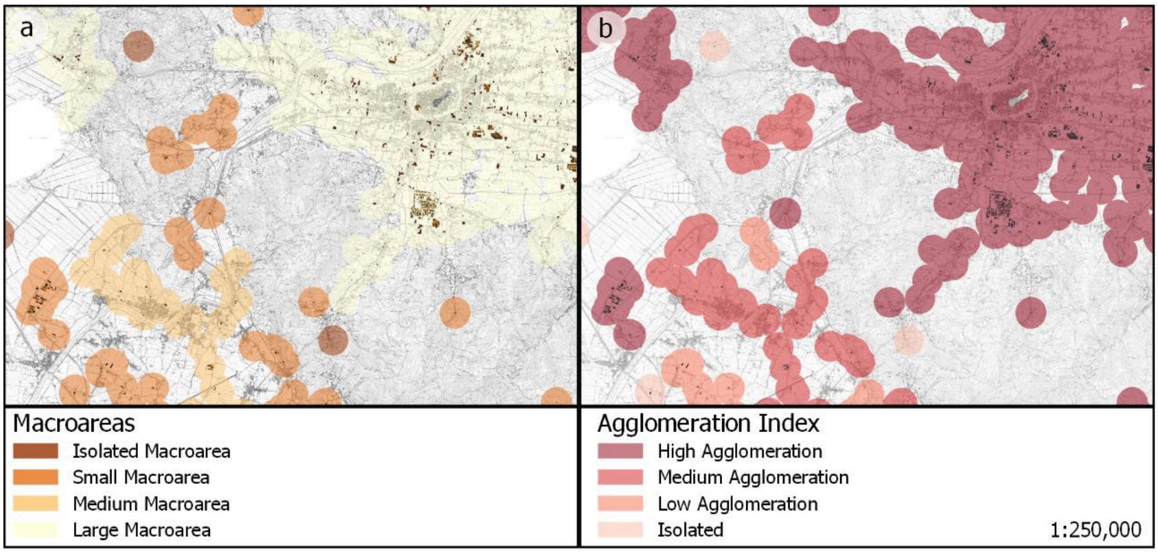

Fig.3 Comparison between Macroareas (a) and Agglomeration Index (b)

Classification - Size	Industrial Assets Count	Industrial Spaces Count	Area Range [km²]	Macroareas Count
Isolated Macroarea	1	1	< 5.00	435
Small Macroarea	> 1	> 1	< 5.00	862
Medium Macroarea	> 1	> 1	>= 5.00 – < 100.00	87
Large Macroarea	> 1	> 1	>= 100.00	3

Tab.2 Macroareas size classification according to industrial spaces count, industrial assets count and area value ranges

Classification - Degree	Agglomeration Index Range	Macroareas Count
Isolated	1.000	591
Low Agglomeration	> 1.000 – >= 0.750	49
Medium Agglomeration	< 0.750 – >= 0.250	578
High Agglomeration	< 0.250	169

Tab.3 Agglomeration Degree classification, according to agglomeration indexes value ranges

Configurational analysis provides another parameter used in the Territorial Exposure Index (TEi) construction, yet it can stand as an independent analysis as well, as it addresses the road-infrastructure system dynamics. Normalized Angular Choice (NACH) is a *betweenness centrality*-based network measure that establishes and depicts the road-elements' hierarchies based on their probability of usage as a through-movement route (Fig.4a). In this aspect, core centralities, represented by the NACH highest values, highlight the *preferential routes'* structure that constitutes the main linkage-paths between different areas within the regional road system. To establish spatial correlation among the *macroareas* and the *preferential routes*, and assess the industrial assets nearness to them, betweenness centralities values are restricted in the visualisation to their core centralities, equivalent to NACH values that range from 1.00 to 1.47 (top 20% road-elements) (Fig.4b).

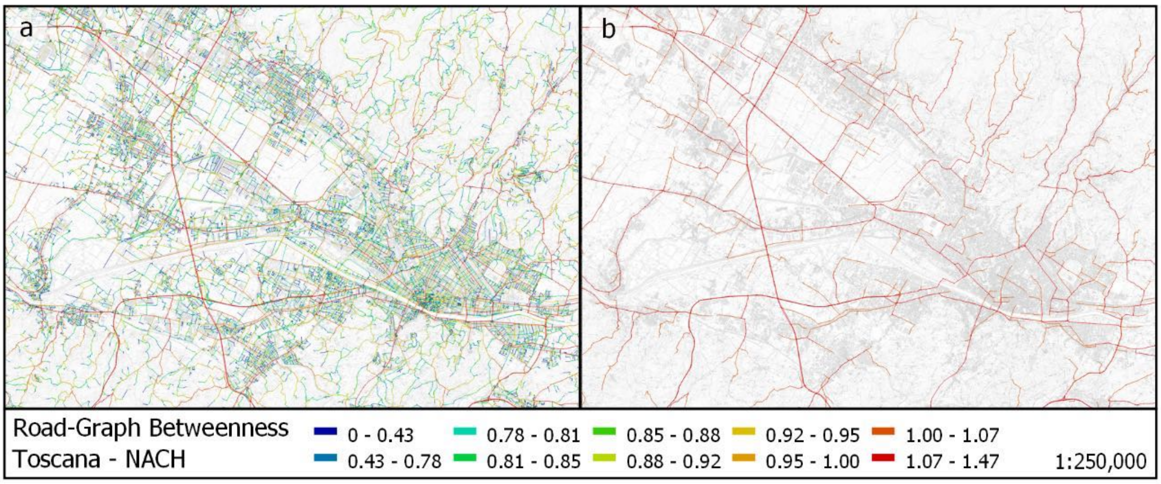

Fig.4 Road-circulation network betweenness centralities' hierarchies (a) and restrcted *preferential routes* structures (b)

Spatial correlations occur when a road-element within the specified value range (1.00 to 1.47) intersects at any point with a *macroarea*. Therefore, this relation means that the cohesive territorial extent in question – and the industrial spaces and assets within it – is near enough to a road-element that, considered the overall displacement predisposition, represented by the *macroarea* reach, provides access to a main transport axis *(preferential route)*, hence, to the remainder of the regional road-circulation network. The road-configuration parameter (Ri) is established as a Boolean variable in the TEi, being interpreted as a *true* or *false* given the presence or absence of correlation.

The partial parameters of *macroareas* size (Si), agglomeration index (Ai) and road-configuration (Ri) compose the Territorial Exposition Index (TEi), in accordance with the relation previously defined in Equation 1. The TEi is defined through the simple sum of the partial parameters scores, that are attributed according to the degree of territorial support provided by each parameter subcategorization. TEi values sums range from minus three to five and will correspond to a defined degree of exposure. Negative values obtained as results from this sum are defaulted to zero, therefore, categorized in the *very high* class of territorial exposure; values in which the sum is over four are instead included in the *very low* class of territorial exposure (Tab.4, Fig.5).

Parameter	Scores	Macroarea Count	Industrial Assets	I.A. (%)
Macroareas Size Parameter – Si				
Isolated Macroarea	-1	435	435	0.54
Small Macroarea	0	862	9,043	11.28
Medium Macroarea	1	87	23,389	29.17
Large Macroarea	2	3	47,326	59.02
Agglomeration Degree Parameter – Ai				
Isolated	-1	591	838	1.04
Low Agglomeration	0	49	353	0.44
Medium Agglomeration	1	578	8,331	10.39
High Agglomeration	2	169	70,671	88.13
Road-Configuration Parameter – Ri				
No Spatial Correlation with a Preferential Route	-1	59	111	0.14
Spatial Correlation with a Preferential Route	1	1328	80,082	99.86

Tab.4 Territorial Exposure Index parameters scores and count for each variable

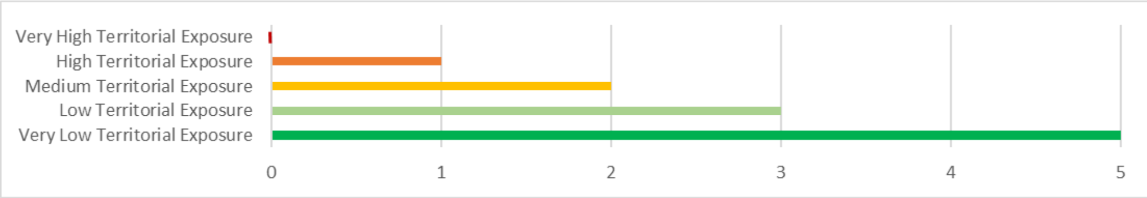

Fig.5 Territorial Exposure Index scores color graph and respective degree of exposure

The index establishes the degree of territorial exposure for each *macroarea*. The *exposure* concept is defined as the amount of support that the territorial context – the built-structures' cohesion, their agglomeration, and the nearness to the road-infrastructure's *preferential routes* – provides to the industrial activities operation. Hence, the parameters are tailored to consider how industrialized the territory is *(macroareas'* s cohesiveness and size), and how and how close in organization the industrial assets are to each other (their degree of agglomeration) – aspects that contribute to facilitate local interindustry relations; as well as their access to other industrial agglomerates (road-infrastructure correlation) that allows movement of people and production. In this regard, differences in territorial exposure indicate what are the disparities in the territorial framework, in terms of infrastructure, organization and overall cohesiveness. These endowments can, if present, contribute to industrial dynamism and resilience, by providing better conditions for industries to interact and compete; and, if absent, lead to these spaces underuse or outright activity abandonment under economic recession conditions, due to the insufficient support from the territories or other local productive agglomerates within the region, that in a situation of restriction of supply – or movement of goods and people – may hinder industrial function.

3. Results and Discussion

Although a partial outcome from the collective spatial analysis that results in the territorial exposure evaluation, the industrial *macroareas* spatialization reveal clear territorial disparities in the Tuscan industrialization that, to some extent, mirrors the Italian north-south dualism (Fig.6).

Septentrional Tuscany locates all three large *macroareas*, cohesive spaces of industrial presence, that on their own encompass 59.02% (47,326) of the total regional industrial assets – structures dedicated to production. Traced a divide in central Tuscany, and considered the remainder of medium, small and isolated *macroareas,* 83.41% (66,891) of the industrial assets are placed in northern Tuscany, hence, by far, being its most industrialized territory. These spaces of production tend to decrease in overall size, cohesiveness and quantity towards central and meridional Tuscany, a circumstance that outlines the sparse industrial presence in the south, where small and isolated *macroareas,* that comprise, respectively, 11.28% (9,043) and 0.54% (435) of the total regional industrial assets are prevalent. Such sparse industrial distribution characterizes the *Maremma* area, within the Grosseto province, and illustrates the remarkable disparities in industrialization amid northern and southern Tuscany. Albeit several medium *macroareas* are present in the around the city of Grosseto, and in punctual locations throughout the *Maremma* area, this territory is mostly comprised of small and isolated industrial *macroareas* that correspond to only 1.72% (1,359) of the total regional industrial assets. Likewise, it is distinguishable that the *preferential routes* network become few and far between in southmost *Maremma*, especially when compared to the interconnected central and northern Tuscany road-infrastructure (Fig.6), a territorial feature that contributes to the increase of these areas' exposure, since communication and access to the larger industrial areas is hindered.

Medium *macroareas* encompass 29.17% (23,389) of the total regional industrial assets. Despite a prevalence in septentrional Tuscany, their presence within central Tuscany is rather significant around the *preferential* routes that extend towards the south, that marks the transition in the Tuscan patterns of industrial distribution – and territorial disparities. Important industrialized spaces are set in the central Tuscany; an example are the productive territories placed in *Valdichiana*, area located in-between the *Arezzo* and *Siena* provinces, that exhibit a compact group of medium *macroareas*. Collectively, these incorporate 20.98% (4,908) of the total industrial assets within medium *macroareas*, and 6.12% of the total regional assets, hence, having greater industrial presence than other important individual medium sized productive areas, such as those located in-between the *Pisa-Livorno* area in septentrional Tuscany, or in the *Chianti* area, that extends across the *Firenze* and *Siena* provinces in central Tuscany (Fig.6).

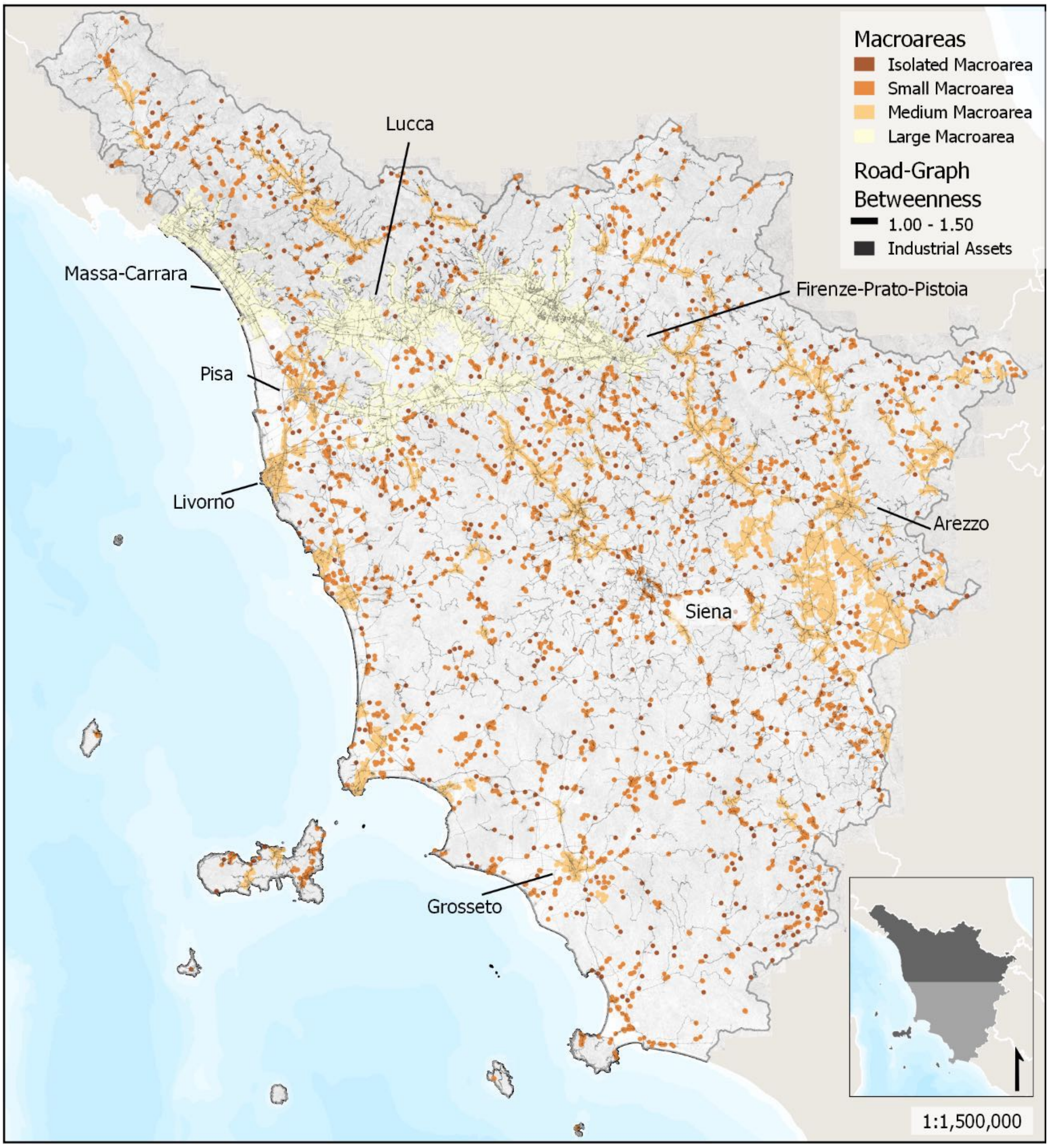

Fig.6 Macroareas placement and *preferential routes* distribution across the Tuscan territory

Regardless of their condition as the most industrialized cohesive spaces in Tuscany, the large macroareas still conserve several territorial disparities when compared to each other (Fig.7) Located along the *Versilia* coast, the smallest of these *macroareas* comprises the *Lucca* province littoral towns, that locate small sized industrial assets; and extends towards the cities of *Massa* and *Carrara*, where the larger industrial spaces are set (Fig.7a). Notwithstanding its considerable dimension (226.4km²) – over a third of the largest sized macroarea – the *Versilia* possesses only 16,69% (7,901) of total industrial assets (47,326) located within large *macroareas*. This distinctive feature can be explained through the observation of its industrial spaces' average size and distribution. In this *macroarea*, the industrial structures are smaller, therefore, their dissolution in single areas

results in reduced industrial spaces with larger buffer reaches; their displacement, however, is interleaved along the highways that cross the *Versilia coast*, which results a rather contiguous productive agglomerate.
In contrast to the *Versilia* productive space, the largest macroarea (588.37km²) – henceforth denominated as *Valdarno* – extends throughout the Arno River Area (*Valdarno*) and the *Lucca* and *Pistoia* plains, therefore comprising several urban settlements between *Lucca*, *Pisa, Pistoia* and *Firenze* provinces (Fig.7b). The *Valdarno* macroarea contains 36.89% (17,428) of the total industrial assets within the large *macroareas*, which corresponds to 21.73% of all industrial assets within Tuscany (80,193). The larger industrial spaces are sited in-between the *Pisa* metropolitan area and the *Empoli* urban area – in close relation to the Fi-Pi-Li, a main highways that connects *Firenze, Pisa* and *Livorno*; while the *Lucca-Pistoia* area has a more diffuse industrial distribution, marked by smaller industrial assets, also in close position to the road-infrastructure. In this aspect, even if the industrial placement logic is quite similar to the one found in the *Versilia* macroarea, with industrial spaces located near the regional road-circulation network *preferential routes*, there is a noticeable difference in the industrial assets' quantity, overall industrial spaces' size and agglomerative patterns, which lead to a larger industrial cohesive agglomerate.

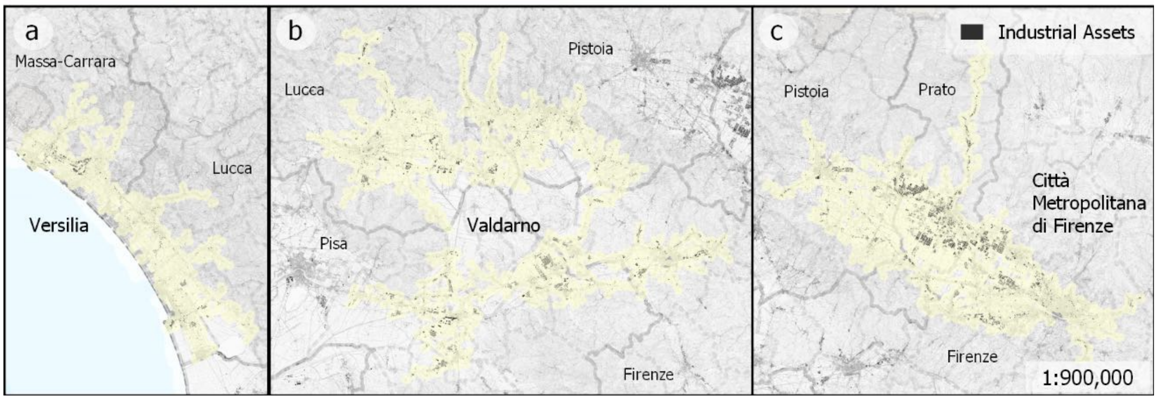

Fig.7 Large Macroareas of *Versilia* (a), *Valdarno* (b) and *Città Metropolitana di Firenze* (c)

The *Città Metropolitana di Firenze* (Florence Metropolitan City) *macroarea* (Fig. 7c) possess a territorial extent of 438.92km² and, although smaller than the *Valdarno macroarea*, it consists in the most industrialized space within Tuscany. This cohesive industrial agglomerate spans throughout the provinces of *Firenze, Prato* and *Pistoia* (Fig. 7c) and encompasses 46.48% (21,997) of the total industrial assets within large *macroareas*, being equivalent to 27.43% of the total regional assets. Most of these assets, however, are not located within the main provincial urban centres – that have a sparse industrial presence – but instead are placed on industrial districts on metropolitan area boundaries. Such distinctive spatial organization results in significant differences when the industrial spaces within the *Città Metropolitana di Firenze macroarea* are considered, especially when compared to the ones present in *Versilia* (Fig.7a) and *Valdarno* (Fig.7b) *macroareas*. Given the compact nature of the industrial assets' distribution within this territorial extent – with a noticeable concentration in-between *Firenze* and *Prato* provinces – the industrial spaces tend to have a greater number of industrial assets established within them, while maintaining average sizes. This results in a higher agglomeration degree due to the presence of more productive-oriented structures in each industrial space.
Agglomeration is a crucial variable in the territorial exposure assessment. The average density of industrial assets within an industrial space can give indicatives about the industry size, as well as the amount of economic support that is provided by interindustry relations among nearby firms, factor that contributes to local industrial aggregates dynamism. Agglomeration analysis has a supportive role to the *macroareas* spatialization that, nevertheless able to depict the territorial dimensions of industrialization, is unsuited to address the proximity conditions among industrial assets within a same territory. From a regional perspective, what emerges from this analysis is, once again, the dualism – albeit in this case, less prominent – amid northern and southern

Tuscany (Fig.8), as territorial disparities in agglomeration still follow patterns similar to those verified through *macroareas* spatialization.

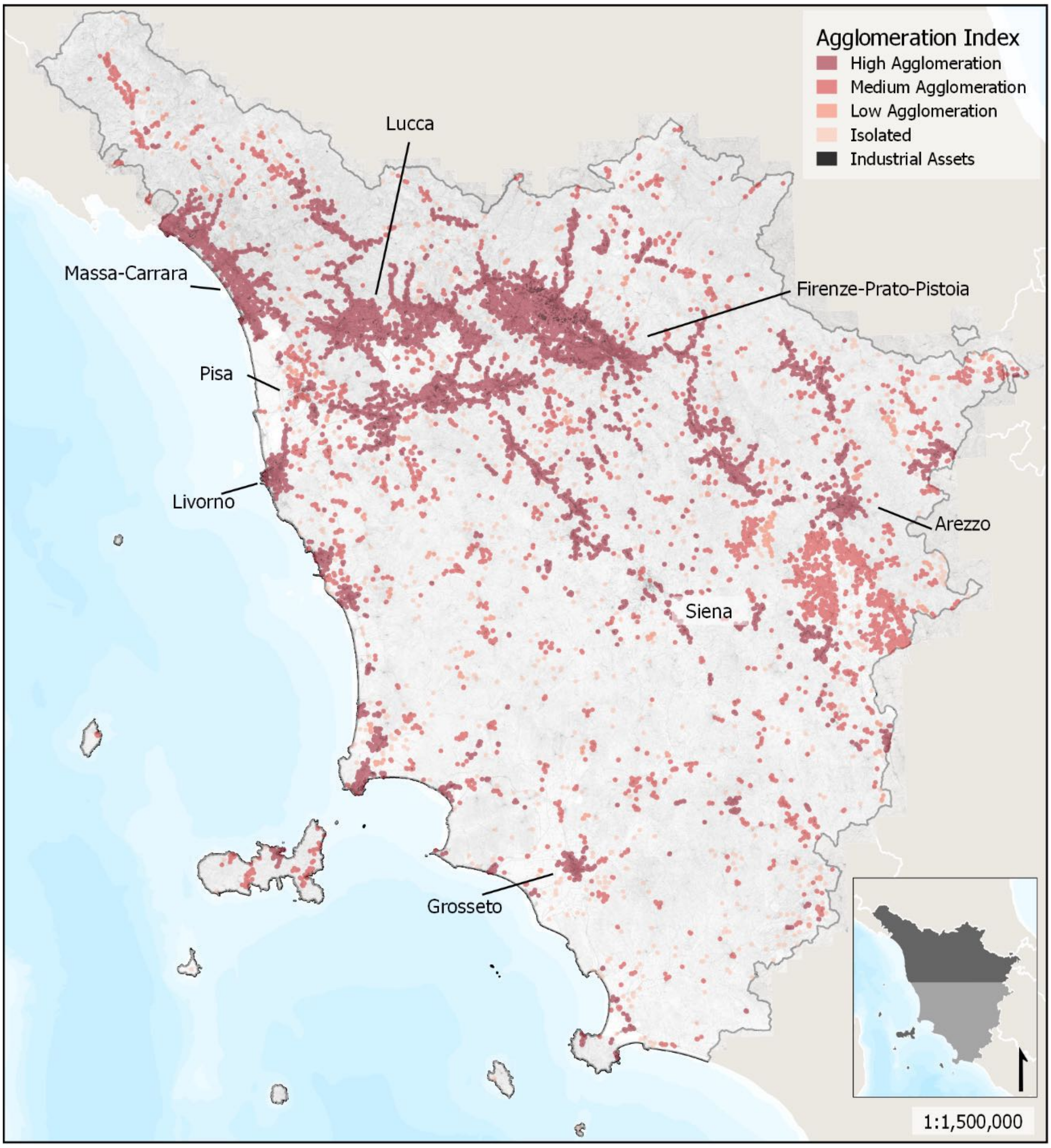

Fig.8 Industrial assets agglomeration degree across the Tuscan territory. Source: *Regione Toscana - Edificato 2k,10k 1988-2013*

Despite a certain equilibrium in distribution, septentrional Tuscany amass most of the *macroareas* (55.96% - 113 of 202) classified within the high agglomeration range. This condition, however, is not particular to the large or medium cohesive production spaces, that encompass only 23.89% (27) of this total, but is prevalent on small *macroareas*, which amount to 76.11% (86) of the northern-based *macroareas* within the high range (Fig.8). Overall agglomeration tends to decrease beyond central and towards meridional Tuscany, where areas with medium to low agglomeration indexes are predominant (. These areas, comprised by small and medium *macroareas*, are located near *preferential routes* that cross the Tuscany hinterlands, and adhere to the size logic verified in the previous analysis, as isolated *macroareas* – that exhibit no agglomeration – become more prevalent in the septentrional and central hinterlands, in addition to meridional Tuscany (Fig.8).

Comparison of absolute values for agglomeration reveals that, although large *macroareas* possess high values (over 0.80), medium and small *macroareas* are those that exhibit the highest agglomeration indexes (over 0.90). Further examinations reveal that the cause for this discrepancy is the presence of sparsely distributed industrial spaces in the larger *macroareas*, with few or single industrial assets within them – a remarkable trait of the *Versilia* macroarea (Fig.9a) – that diminishes otherwise high overall industrial assets' densities. Some medium *macroareas* exhibit similar patterns, as observed in the groups of *macroareas* placed in the *Valdichiana* (Fig.9b). In this context, small and medium *macroareas* in northern – but, above all, in central Tuscany – that structured by few, compact and densely occupied industrial spaces, are those that possess the highest degrees of agglomeration. Instances where this patten can be verified are in the production spaces in-between the *Valdelsa* (Elsa River Valley) and the *Chianti* productive areas (Fig.9c), as well as in small *macroareas* placed in close relation to road-circulation network *preferential routes* (Fig.8).

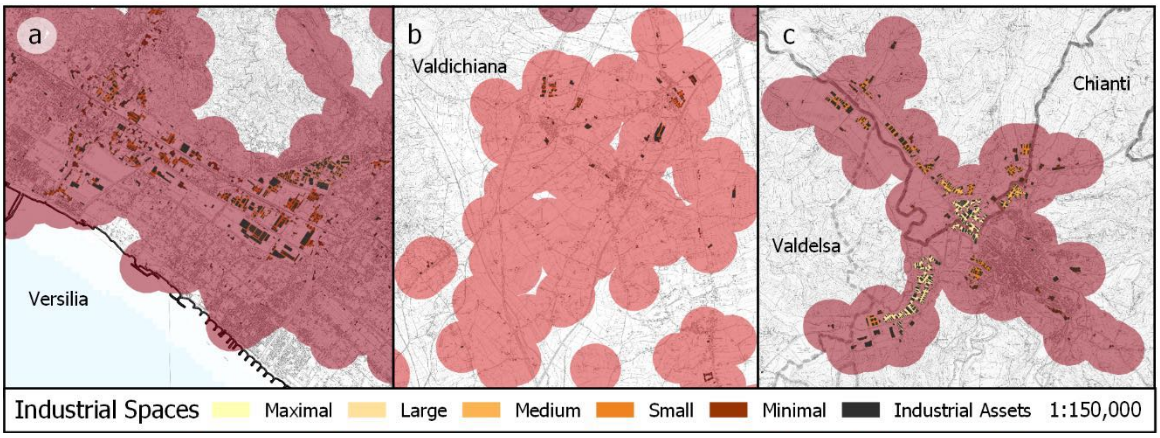

Fig.9 High agglomeration in the *Valdelsa* (a), *Chianti* (b) and *Valdichiana* (c) macroareas

Furthermore, the examination of absolute values for agglomeration reveals that *macroareas* located within the immediate boundaries of large urban centres often exhibit higher agglomeration values, in comparison with the *macroareas* that compose the city area – a peculiarity quite noticeable in the *Pisa* metropolitan area (Fig.10) – but also in other urban areas such as *Grosseto* and *Arezzo* provinces (Fig.8). Beyond those boundaries, agglomeration values are prone to decrease towards the hinterland areas, as industrial assets become sparse.

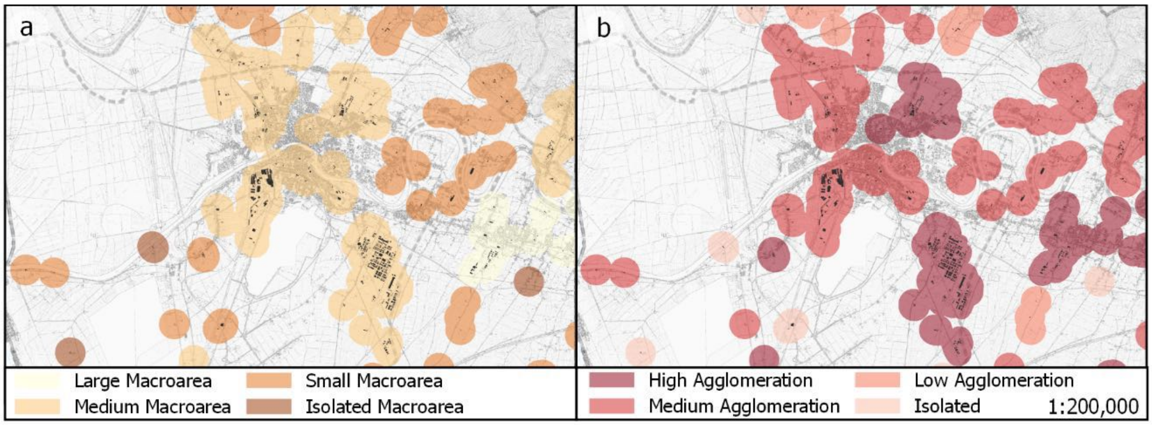

Fig.10 Comparison between macroareas size (a) and agglomeration analysis (b) for the Pisa area

The Territorial Exposure Index (TEi) construction and spatialization reveals that the disparities in exposure lie beyond the distinguishable north-south divide, highlighted in the previous analysis as a characteristic that represents the transition in *macroareas'* size and industrial agglomeration (Fig.6; Fig.8). From a regional standpoint, the condition of territorial exposure can be associated to specific local differences in the territorial endowments that exist amongst *macroareas* placed in proximity to urban centres and *preferential routes* and those located in the hinterlands, which have sparse concentration of industrial structures, as well as less infrastructural support (Fig. 11). In this context, it becomes evident that the agglomeration degrees have a significant influence over regional exposure patterns and consist in the main differentiation factor for variations in TEi values within *low, moderate, and high* index ranges, above all, among medium and small *macroareas.* Hence, industrial agglomerates that would otherwise possess analogous characteristics, given their similar *macroarea* size, degree of industrialization and nearness to *preferential routes*, unveil important disparities when industrial assets' agglomeration is considered (Fig.6; Fig.11).

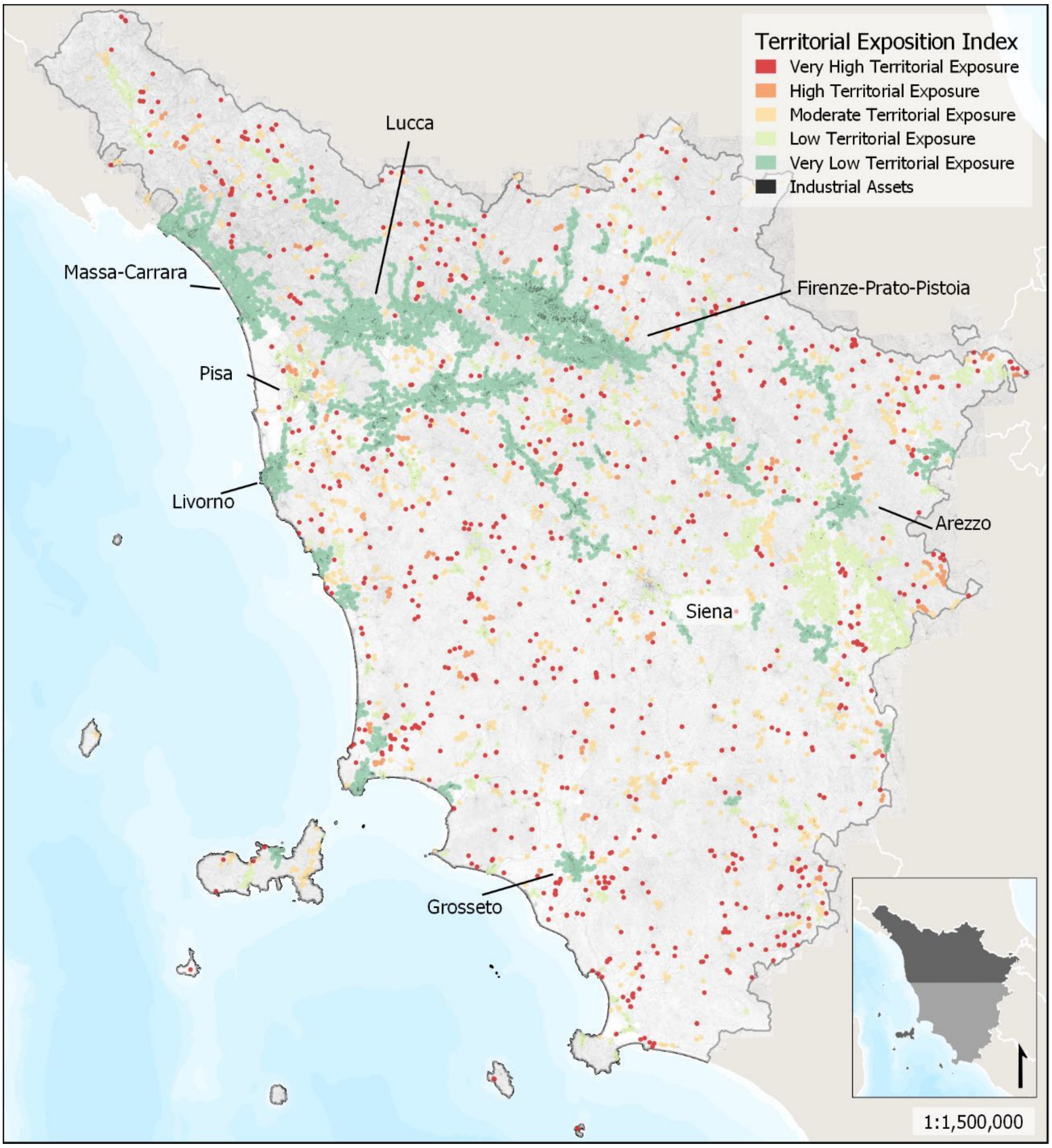

Fig.11 Territorial exposure degree and territorial disparities across the Tuscan territory

Notwithstanding an evident prevalence of industrial agglomerates possessing *low* and *very low* territorial exposure in septentrional Tuscany (Fig.11), space that comprehends, respectively, 52.42% (108 of 206) and 65.85% (27 of 41) of the total *macroareas* within these categories, the increased ranges for territorial exposure possess a rather even spatial distribution. Territorial disparities' analysis observe that Meridional Tuscany encompasses 51.66% (291 of 602) of the *macroareas* in the *very high* range of territorial exposure. When the *high* exposure ranges are considered, it is instead northern Tuscany that locates the majority of the industrial agglomerates, with 59.18% (29 of 49) of the total *macroareas* within this category; a similar proportion, 55.21% (270 of 489), is also verified for the *macroareas* within *moderate* territorial exposure range. While differences between *low*, *moderate and high* exposure are mostly due to different agglomeration degrees, the ones regarding *high* and *very high* ranges can be also attributed to *preferential routes' absence*. In this case,

small *macroareas* that possess medium agglomeration degrees – and would otherwise have a *moderate* degree of exposure if only agglomeration and size were considered, tend to have a higher exposure, due to not being sufficiently near to the main *preferential routes*, thus resulting in a diminished territorial support.
From this perspective, the influences of industrial assets' agglomeration and, to a lesser degree, the nearness to *preferential routes* become quite perceptible. In the example of *Pisa* metropolitan area (Fig.12) it is possible to notice that *macroareas*, that have lower industrial assets' agglomeration, tend to have a higher exposure condition, with degrees' varying according to their size and cohesion (Fig.12a; Fig.12b). However, it is also noticeable that, when this lower agglomeration is associated to an absence of access to the road-infrastructure, the exposure degrees are aggravated (Fig.12b). This restricted accessibility to *preferential routes* leads to a deficient state regarding the connection to nearby industrial agglomerates, a condition that may hinder both interindustry relationships and further industrial expansion of those areas, as industrial placement tendencies have positive correlations with the road-circulation network centralities (Altafini et al., 2021). In this aspect, firms will avoid placement in areas that are *segregated* in terms of infrastructural linkage, consequently leading to the development of greater territorial disparities in long-term.

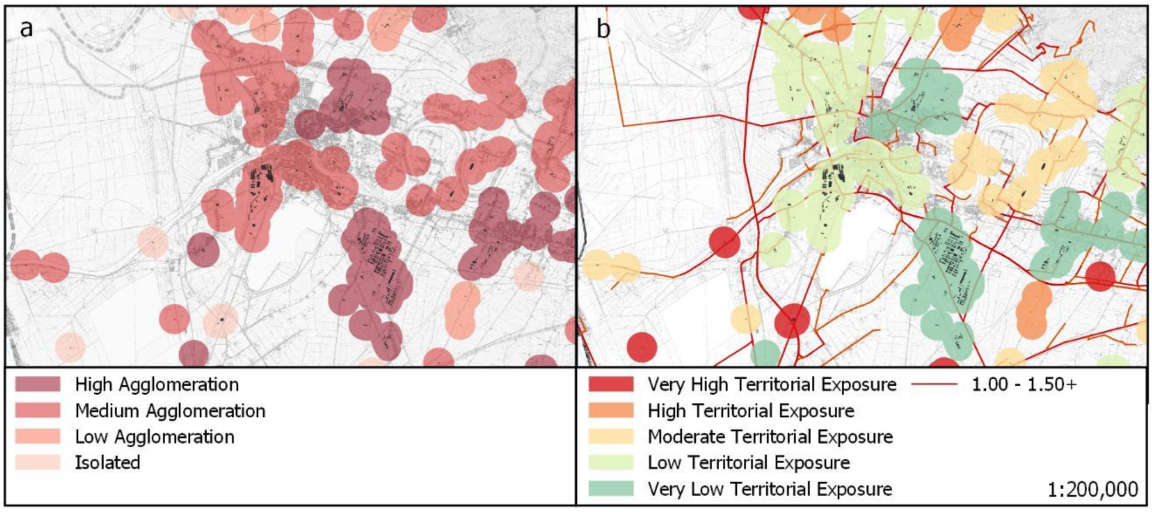

Fig.12 Comparison between agglomeration analysis (a) and territorial exposure index (b) for the Pisa area

In terms of economic dynamism, lower local industrial presence can lead to weaker interindustry relationships; this, when associated to the absence of connection to other industrial agglomerates, contributes to a reduced support network from other local firms placed throughout the region. These could serve as a lifeline in terms of supply and demand for produce, in the advent of an economic recession, stagnation of one industrial sector, or limitations in the global supply chains availability due to territorial restrictions – as the one ensued during 2020 and 2021, during the Covid-19 pandemic. Overall, the territorial exposure condition indicates that the disparities on territorial endowments can compromise certain aspects related to the industrial agglomerates' resilience, therefore, certain areas are in a greater risk of being unproductive under economic constrains, that can ultimately can result in their underuse or abandonment.
With these results in consideration, although it is possible to affirm that meridional Tuscany has fewer industrial agglomerates within lower ranges *(low* and *very low)* of territorial exposure, and that the *very high* degree of exposure is prevalent in the south, since more isolated industrial agglomerates are present, it is erroneous to uphold that the south has an overall higher exposure condition. If absolute numbers of industrial agglomerates within the ranges of *moderate, high* and *very high* are considered, it is northern Tuscany that has a greater total exposure degree (Fig.11). Hence, while the idea of a north-south dualism provides a sufficient overview and explanation, regarding the assessment of territorial disparities in industrialization, the territorial disparities in terms of exposure remain associated to positional differences at local scale, and to a more intricate spatial

logic, that cannot be observed in an abstract space, as the spatial characteristics of certain areas can provide more or less support to economic activities there placed.

4. Conclusion

Urban and regional economics ought to ponder about their *abstracted representation of space.* The recognition and analysis of the different territorial endowments derived from position and road-infrastructure, as well as their influence in regional disparities, are crucial factors for the effectiveness of forthcoming recovery policies. Economic studies, so far, have not taken space and spatial representation into appropriate consideration, as spatial-economic analyses are still in the shadow of applied macro and microeconomics fields, which draw attention away from the vital importance and influence of territorial features in economic efficiency. Changes in this concept in economics are dependent on the adoption of instruments that can represent territories – and the structures and networks within them – with a greater level of detail, such as Geographic Information Systems (GIS), followed by an associated development of models that incorporate economics' variables to real representations of space.

As discussed, the Territorial Exposure Index is conceived with these issues in consideration. Constructed based on the *macroareas* – a cohesive territorial unit – conceptualization, the index evaluates industrial agglomerates' distributional logics, assessing the different territorial endowments – characteristics derived from the built-structures placement – that contribute to a condition of *territorial exposure*. The concept of *exposure* evinces the support that territorial features of cohesiveness, degree of industrialization, agglomeration, and the nearness to regional *preferential routes*; provide to the economic activities there placed, in terms of allowing local and regional interindustry relationships. With this in consideration, the parametric index identifies factors of territorial sensitivity to firms' economic dynamism within an agglomerate, dependent of both position within the territory and relation to the remainder industrial spaces.

In Tuscany, spatial disparities in industrialization are associated to a north-south dualism, where septentrional Tuscany possess a greater number of larger and more cohesive industrial agglomerates, while the meridional Tuscany has a sparser industrial distribution. Still, when the parameters of industrial agglomeration and the nearness to road-infrastructures are considered, it is revealed that this dualism does not accurately reproduces the *exposure* conditions, as the highlighted territorial disparities are instead related to the urban-hinterland divide, or the presence of absence of a sufficient infrastructural support within these settings.

Challenges remain, however, in the further inclusion of economic variables to this analytic framework. Datasets that aid the assessment of industrial agglomerates' economic dynamism, such as sector, firm size, productivity or revenues, are still constrained to spatialization issues, since their survey is made at a firm level, therefore, consisting in a sensitive information about the productive activity, which can possibly lead to its identification. Research costs are also in question, since most of these databases (i.e., *ORBIS/AIDA, Registro Imprese*) are private owned and, given the scale of the analysis – regional – require substantial funds for a comprehensive data acquisition. Issues can be addressed using industrial census data as proxy parameters, at least regarding firm-size. Their adaptation to the *macroareas* concept that provides their representation as a spatial aggregate – similar to how the information is already used in economic models – thus, solving possible privacy concerns. This will allow an in-depth economic assessment and consists in the next step for this model. In this sense, it is possible to consider the Territorial Exposure Index developed until this point as the *spatial component* of a broader index that includes an *economic component* as well.

Nevertheless, even with the limitations, the overall results indicate that the proposed model and framework, based on real spatial representations, can highlight territorial disparities in the industrial agglomerates found throughout a region, as well as demonstrate how the territorial endowments presence and placement have implications on their economic dynamism, given the amount of support for the productive activities. In this regard, the model surpasses, in terms of territorial representation detail, the spatial models commonly used in Urban and Regional Economics studies.

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Image Sources

Fig.1: Regione Toscana (2019a) - Edificato 2k,10k 1988-2013;

Fig.2: Regione Toscana (2019a) - Edificato 2k,10k 1988-2013;

Fig.3: Regione Toscana (2019a) - Edificato 2k,10k 1988-2013;

Fig.4: Regione Toscana (2019b) – Grafo Itnet – Grafo Stradario della Toscana;

Fig.6: Regione Toscana (2019a) - Edificato 2k,10k 1988-2013; Regione Toscana (2019b) – Grafo Itnet – Grafo Stradario della Toscana;

Fig.7: Regione Toscana (2019a) - Edificato 2k,10k 1988-2013;

Fig.8: Regione Toscana (2019a) - Edificato 2k,10k 1988-2013;

Fig.9: Regione Toscana (2019a) - Edificato 2k,10k 1988-2013;

Fig.10: Regione Toscana (2019a) - Edificato 2k,10k 1988-2013;

Fig.11: Regione Toscana (2019a) - Edificato 2k,10k 1988-2013;

Fig.12: Regione Toscana (2019a) - Edificato 2k,10k 1988-2013; Regione Toscana (2019a) – Grafo Itnet – Grafo Stradario della Toscana.

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Estimation of the future land cover using Corine Land Cover data

Estimation of the future land cover

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Abstract

In this study, linear and polynomial regression functions were applied to the Corine Land Cover (CLC) data to quantitatively estimate the future land cover for three different cities of Turkey, Ankara, Istanbul and Izmir. For the related cities, the CLC data sets recorded for every 6 years between the years 2000-2018 were individually obtained from satellite images for monitoring changes in land cover for Turkey. These data allow us to have information about artificial surfaces, agricultural areas, natural and semi-natural areas, wetland and water bodies which have been changed accordingly urbanization process in Turkey. Based on CLC data of 2000, 2006, 2012 and 2018 the areas and widths of artificial surfaces spread in these three cities were determined. Mathematical calculations were made by using the linear and polynomial regression models to understand what the future scenarios would be in order to understand what would happen if these changes continued in the same way. To conclude, revealing the possible scenarios in the future will provide important outputs for land cover and will contribute to the development of urban planning and the creation of sustainable cities.

Keywords

Quantitative estimation; Effect of urbanization; Land cover change; Linear and polynomial functions; Corine land cover data.

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1. Introduction

The city has a dynamic structure that is constantly changing, developing and tending to grow. Economic, technological, political and socio-psychological factors with the mentioned situations cause the cities to spread. Because of sudden effects in these factors, the transform from natural areas to artificial surfaces is called urbanization. Urbanization has a great effect on the change in land cover. Urbanization stimulates land cover changes, determining the contraction of agricultural land, the consolidation of forests and semi natural areas and the expansion of artificial surfaces (Paulsen, 2014; Zitti et al., 2015). Other factors affecting the change in land cover are other human-induced activities (migration, agricultural activities, deforestation, etc.) (Hietala-Koivu, 1999; Nagashima et al., 2002; Çakır et al., 2017) and natural factors (insects, natural phenomena, terrain structure etc.) (Çakır et al., 2017). In addition, urbanization, industrialization and intensive agriculture often cause rapid land cover change, loss of ecological capacity, diversity, natural beauty, and damage to the cultural landscape with and historical value (Bastian et al., 2006; Feranec et al., 2010). Urbanization is driven by population growth and migration, which leads to the physical expansion of existing urban centers (Samson, 2009; Alaci 2010; Satı et al., 2017). Migration not only the structure of the community, but also changes the land cover seriously (Cui & Shi, 2012). When the population data were analyzed, according to the data of 1950, the city population was constituting 30% of the total population. In 2018, this rate exceeded 55% and in 2025 it would reach 60% (World urbanization prospects: the 2007 revision, 2007). In addition, the relations of production which have been constantly changing as a result of the rapid technological developments seen after industrialization also affect land cover.

In short, rapid industrialization and unbalanced population growth and unplanned construction are the factors affecting the land covers. Urban ecosystems are adversely affected from this social process, so land cover changes are easily observable. All these factors also cause major local and global problems (Kim &Baik, 2005; Zhao et al., 2006; Cui & Shi, 2012). These are air and water pollution (Liu & Diamond, 2005; Shao et al., 2006; Cui & Shi, 2012), demand for energy and raw materials (Zhou et al., 2004; González et al., 2005; Cui & Shi, 2012), demand for housing and transportation, traffic congestion (Jago-on et al., 2009; Cui &Shi, 2012), and local climate change (Zhou et al., 2004; González et al., 2005; Cui & Shi, 2012).

In Turkey, the rural population until the 1980s constituted the majority of the general population. Therefore, it is classified as a low urbanized country. However, a large majority of the population in Turkey live in urban centers, according to current data. The urban population in Turkey in 1950 was 5 million, this figure has reached 61 million in 2018. As a result of the continuous increase in the urban population and the decline of the rural population in 2050, it is estimated that 82 million people will live in urban centers (The World's Cities in 2018, 2018). Land covers in Turkey after 1980 has been influenced by political decisions. Put into force the "Metropolitan Application" legislation has led to an artificial increase in population in Turkey's urban centers. These artificial population increases in urban have also affected the land cover change. Considering the land cover changes in Turkey, it is seen that there are many factors such as sudden population increases, migration, inadequate planning approaches and ignoring natural processes during the implementation phase. These risks should be evaluated by experts, planners and designers to develop approaches to minimize natural damage. This situation requires an examination of the land cover change. Therefore, urban policy and decision makers are challenged by the complexity of cities as social, ecological, technical systems (Webb et al., 2018).

In order to understand these systems well, analyzing the past land covers, knowing the future effects of these uses and finally making a decision in the light of these data will significantly contribute to the sustainable planning approach. Also, urban growth generates some opportunities for sustainable planning. There is a need for a true decision-making process in order to shape urban growth with sustainable land use planning. National and international policies with land use provide decision makers the strategic opportunities to get sustainable cities. To the vulnerability of urban areas to the present and future effects of "global warming", non-climatic factors should be also included, whose effects, combined with those of climate change, enhance the final impacts and/or condition the adaptive ability of the population and territory (Zucaro & Morosini, 2018). In the European Union, an average of 117.5 people live in an area of 3 million square kilometers, so the European Union emphasizes the importance of land use planning and management (Environment - land use, 2019). The Association focuses on factors such as air pollution and traffic density that led to greenhouse gases as a result of direct or indirect effects on natural habitats and landscapes, where land covers patterns may have significant effects on environmental conditions.

The European Commission's The ESPON Sustainable Urbanization and land-use Practices in European Regions (SUPER) research project has been set out to create more sustainable land use through a series of qualitative and quantitative surveys based mainly on data processed with analytical and predictive models (Solly et al., 2020). In Turkey, integrated Urban Development Strategy and Action Plan Preparation Project in preliminary studies by the Ministry of Environment and Urbanization was launched (Güler & Turan, 2013). Providing a sustainable spatial development in the settlements and creating an environmentally sensitive living environment in the cities have been within the objectives of the project.

CLC contributes to the knowledge of the land cover and its changes in 24 European countries between 1990 (Feranec et al., 2010) and 2018. In the literature, there are some typical published papers on monitoring land cover changes using Corine land cover data (Yılmaz, 2009; Cieślak et al., 2017). Feranec et al. (2010) did a study on land cover change flows in landscape using CLC data. As land cover is an indivisible part of the landscape, it reflects its states in different stages of changes. Remote Sensing has been an important method for spatial investigations (Yaprak et al., 2017). This is the reason why land cover changes can be considered the correlated information source about processes in the landscape (Feranec et al., 2010).

The purpose of this study is to determine the impact of human effects on future land cover changes in Turkey using CLC data. Considering the current and future urbanization effects, planning studies should be performed take into account Turkeys' three largest cities, which are under pressure in terms of land use with dense population. Therefore, in this study, Ankara, which is capital of Turkey, Istanbul which is one of the world's metropolis city and Izmir which is Turkey's third dense population city were examined. Impacts of human effects on the land cover in the city were evaluated. The future scenarios were obtained as a result of mathematical calculations.

This study proved that the monitor of the impact of human effects on land cover with statistical or mathematical approach gave an opportunity to get the correct planning studies, sustainable land management and predicting the possible harmful human effects on land cover and taking precautions.

2. Location of cities and data collection from maps

2.1 Study area

The studied areas cover the city of Ankara, Istanbul and Izmir in Turkey (see Fig.1). Ankara is located in the Central Anatolia Region of Turkey. The city stretching between 30º 49' - 33º 53' E and 40º 46' - 38º 40' N with a total area of 25,632km² (Province and District Areas, 2020). There are Kirikkale province in the east, Eskisehir province in the west, Bolu and Cankiri provinces in the north and Konya province in the south of Ankara. It is the capital of Turkey and second most populous province with the population of 5639076 (Address Based Population Registration System, 2020). Its altitude is about 890 meters above sea level and it includes 25 districts (Ankara History and Other Information, 2020). In this region, which has a continental climate, winter months are cold and summer months are hot. The hottest month is July-August and the coldest month is January (Cities & Holiday Resorts, 2020). The average annual rainfall is 391.9 mm and temperature is 11.9°C (Cities & Holiday Resorts, 2020). Forest areas constitute 17.1% of the province (Turkey's Forest Assets, 2015). Due to its climate, there are steppe and forest plant communities and 2,389 plant species grow naturally in Ankara (Köroğlu, 2012; Tarıkahya Hacıoğlu et al., 2012).

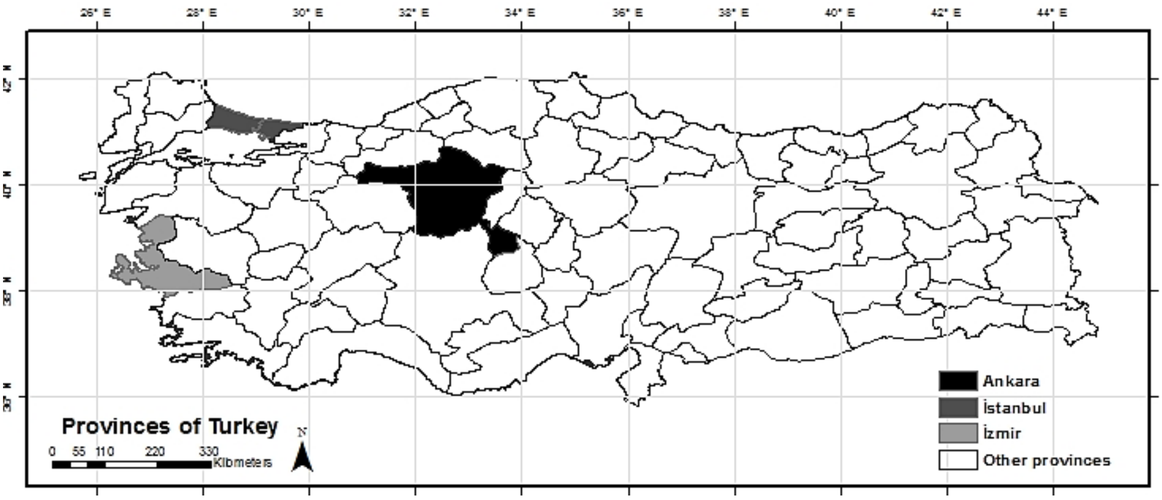

Fig.1 The map of the studied areas

Istanbul located on north-west of Turkey, Istanbul, is a bridge between Asia and European continents. The city stretching between 27º 54' - 29º 55' E and 41º 38' - 40º 48' N with a total area of 5,461km² (Province and District Areas, 2020). There are Kocaeli province in the east, Tekirdag province in the west, Black Sea in the north and Marmara Sea in the south of Istanbul. The lowest altitude in the area is 0, and the highest altitude is 537 m where Aydos hill is located. It includes 39 districts and its total population is 15,519,267 (Address Based Population Registration System, 2020). The area has a temperate climate as it is a transition between the Black Sea and the Mediterranean climate. The average annual precipitation is 677.2mm with the average annual temperature of 14.5°C (Cities & Holiday Resorts, 2020).

Forest areas constitute 43.9% of the province (Turkey's Forest Assets, 2015). In the region, maquis vegetation is dominant. The most important of the forested areas in the region is the Belgrad Forest, 20 km north of the city (Geography, 2020). Izmir is located in the Aegean Region of Turkey. The city stretching between 26º 18' - 28º 30' E and 39º 22' - 37º 51' N with a total area of 11,891km² (Province and District Areas, 2020). There are Manisa province in the east, Aegean Sea in the west, Balikesir province in the north and Aydin province in the south of Izmir. It is the third most populous province with the population of 4367251 (Address Based Population Registration System, 2020). The lowest altitude in the area is 0, and the highest altitude is 2159 m where Bozdaglar Mountain is located (General Information, 2020). It includes 30 districts (General Information, 2020). In Izmir, which is in the Mediterranean climate zone, summers are hot and dry winters are mild and rainy (General Information, 2020).

The average annual rainfall is 711.1 mm and temperature is 17.8°C (Cities & Holiday Resorts, 2020). Forest areas constitute 39.8% of the province (Turkey's Forest Assets, 2015). Izmir is under the influence of the Mediterranean climate in terms of vegetation. There are all types of Mediterranean plants. In areas where forests have disappeared due to overgrazing and fire for centuries, the maqui flora shows itself (About Izmir, 2020).

2.2 Data collection and data analysis

In this research paper, the effect of urbanization on the land cover was studied. In order to estimate the relationship between urbanization and land cover changes. The future information related to land cover change was extracted from actual map information. In preliminary process of the study, the CORINE land cover (CLC) maps at four different years (2000, 2006, 2012 and 2018) were collected from Copernicus land monitoring services. CLC maps are created by using different satellite images. Statistics were produced with the data obtained by interpreting Sentinel-2 and Landsat-8 images. Satellite images have a mid-spatial resolution between 15 and 100 meters, depending on the spectral range. Existing maps were re-created using ArcGis software, as illustrated in Figg. 2, 3 and 4 for Ankara, Istanbul and Izmir, respectively. In the analysis of the effect of urbanization on land cover, CORINE Land cover data were categorized into five different groups, artificial surfaces, agricultural areas, forest and semi-natural areas, wetlands and water bodies.

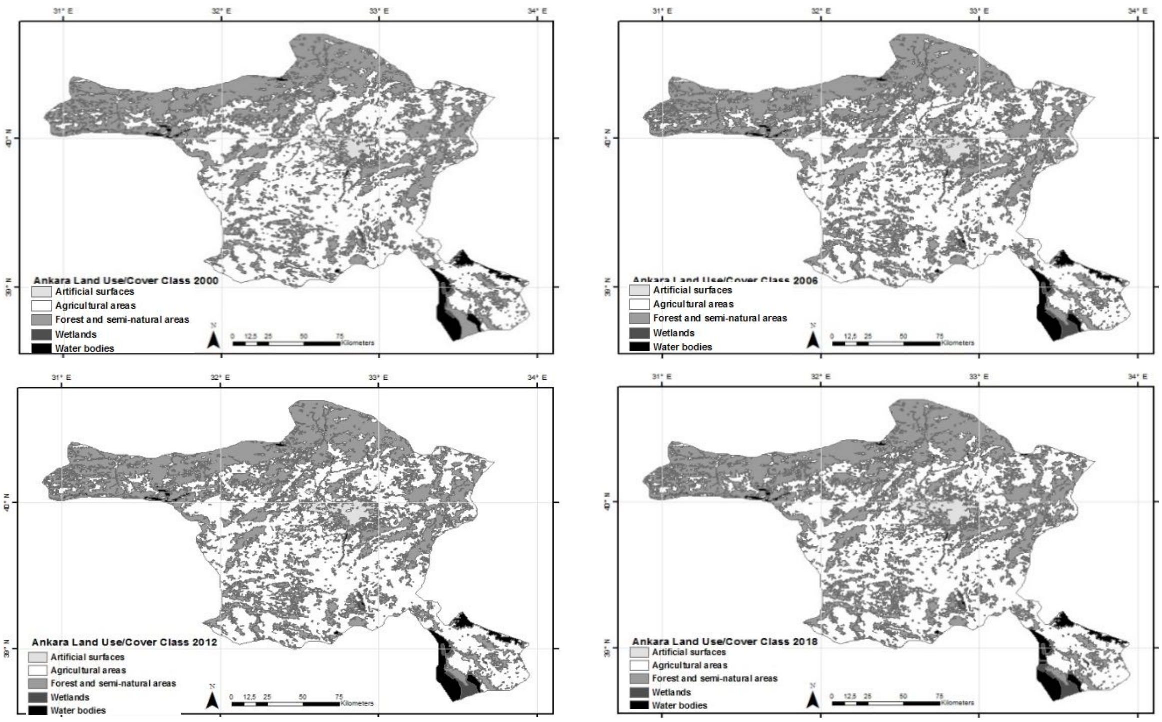

Fig.2 Maps for land cover/ use 2000, 2006, 2012 and 2018 in Ankara

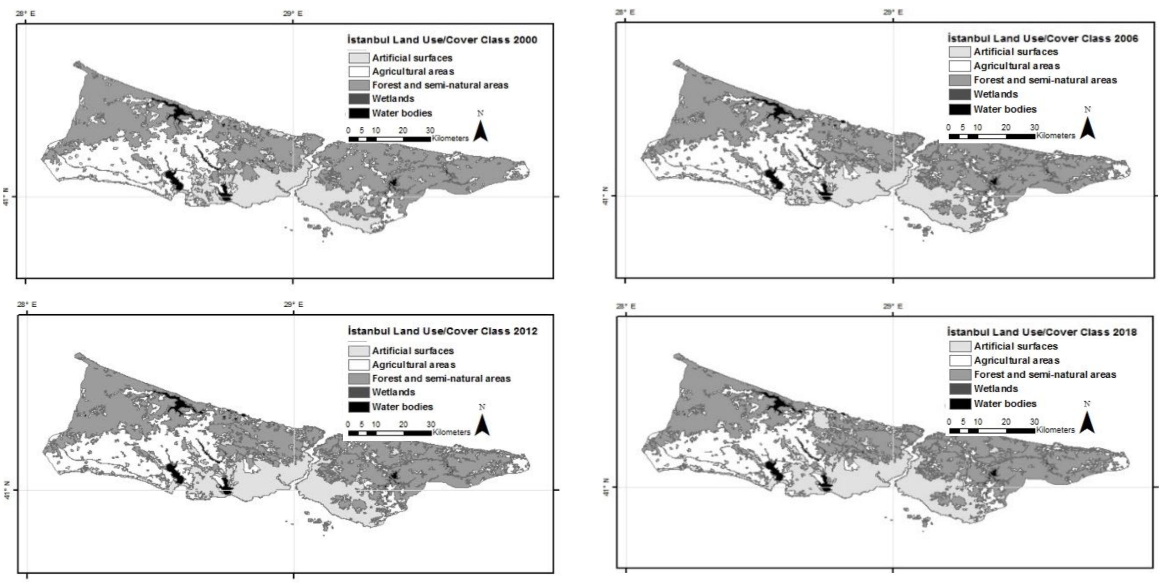

Fig.3 Maps for land cover/ use 2000, 2006, 2008 and 2012 in Istanbul

Then land cover/use areas which correspond to artificial surfaces, agricultural areas, forest and semi natural areas, wetlands and water bodies were computed from maps created for three different cites, Ankara, Istanbul and Izmir. According to the corresponding years, the numerical values of the data for the three cities were listed in Tab.1.

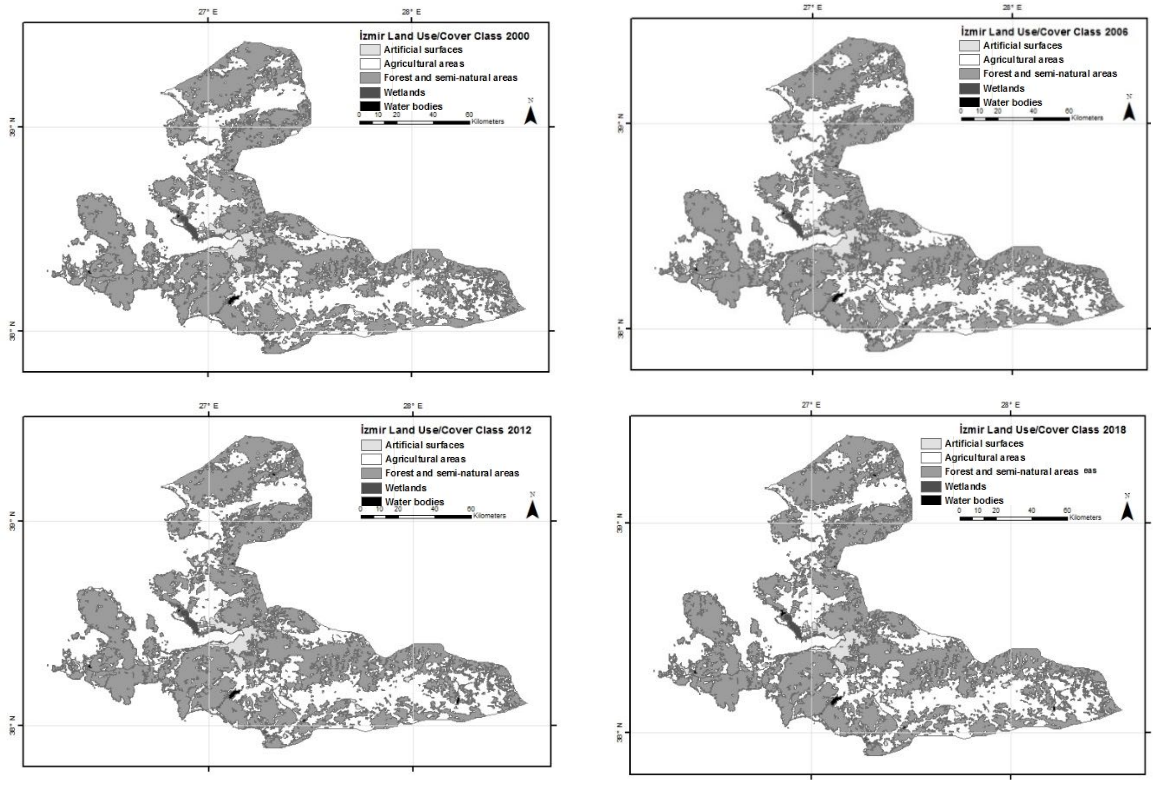

Fig.4 Maps for land cover/ use 2000, 2006, 2008 and 2012 in Izmir

City	Years	Artificial surfaces	Agricultural areas	Forest and semi natural areas	Wetlands	Water bodies
Ankara	2000	75,300	1,492,736	930,602	9,604	64,889
	2006	84,588	1,450,938	949,968	22,674	64,963
	2012	90,818	1,443,932	949,010	22,760	66,612
	2018	102,786	1,432,212	947,207	25,414	65,511
Istanbul	2000	97,505	133,396	231,696	308	13,821
	2006	104,915	139,084	218,160	286	14,280
	2012	108,785	135,578	217,582	286	14,494
	2018	118,690	134,240	209,245	752	13,699
Izmir	2000	52,869	499,659	677,401	6,872	6,655
	2006	61,547	493,232	675,044	6,810	6,822
	2012	64,724	491,537	672,600	6,826	7,768
	2018	67,515	489,875	671,308	6,556	8,199

Tab.1 Computed data of land cover areas in ha for three cities of Turkey

In Tab.1, time (or year) axis (x-axis) and land cover/ use change observation (y-axis) were considered as independent and dependent variables, respectively. From this table, linear and polynomial equations (or functions) for the surfaces of Ankara, Istanbul and Izmir were calculated from the relationship between independent and dependent variables. Linear and polynomial equations and corresponding correlation coefficients for each city were presented in Tab.2. Statistical calculations were performed by using the Microsoft Excel software.

City	Surface	Equation	Correlation coefficient (r)
Ankara	Artificial Surfaces	$y = 147.133x - 2.88x10^6$	0.9858
	Agricultural areas	$y = 208.88x^2 + 824403x + 9.00x10^8$	0.9625
	Forest and semi-natural areas	$y=15.03x^3-90733x^2+2.00x10^8x-1.00x10^{11}$	1.0000
	Wetlands	$y=12x^3-72396x^2+1.00x10^8x–1.00x10^{11}$	1.0000
	Water bodies	$y =-3.3372x^3+20105x^2-4.00x10^7x+3.00x10^{10}$	1.0000
Istanbul	Artificial Surfaces	$y = 1123,8x – 2.00x10^6$	0.9867
	Agricultural areas	$y = 8.767x^3-52887x^2+1.00x10^8x - 7.00x10^{10}$	1.0000
	Forest and semi-natural areas	$y = -15.985x^3 + 96380x^2 – 2.00x10^8x + 1.00x10^{11}$	1.0000
	Wetlands	$y = 0.3426x^3-2061.4x^2 + 4.00x10^6x-3.00x10^9$	1.0000
	Water bodies	$y = -0.5895x^3+3544.2x^2-7.00x10^6x+5.00x10^9$	1.0000
Izmir	Artificial Surfaces	$y = 785.25x -1.52x10^6$	0.9578
	Agricultural areas	$y = -3.6258x^3 + 21886x^2 – 4.00x10^7x + 3.00x10^{10}$	1.0000
	Forest and semi-natural areas	$y = -345,32x + 1.00x10^6$	0.9917
	Wetlands	$y = -0.2809x^3+1691.3x^2\ \ 3.00x10^6x + 2.00x10^9$	1.0000
	Water bodies	$y = 93,004x - 179485$	0.9690

Tab.2 Linear and polynomial equations obtained by the mathematical relationship between independent and dependent variables for Ankara, Izmir and Istanbul

As it can be seen from Tab.2, linear and polynomial (or non-linear) relationships between independent (time or year) and dependent (land cover change) variables with high correlation coefficient was observed. By using the equations illustrated in Tab.2 for the investigated surfaces and for each city, the quantitative prediction of land cover value of artificial surfaces, agricultural areas, forest and semi natural areas, wetlands and water bodies in 2024 for the related cities were obtained by using the extrapolation process. Mathematical results of extrapolation procedure were indicated in Figg. 5, 6 and 7.

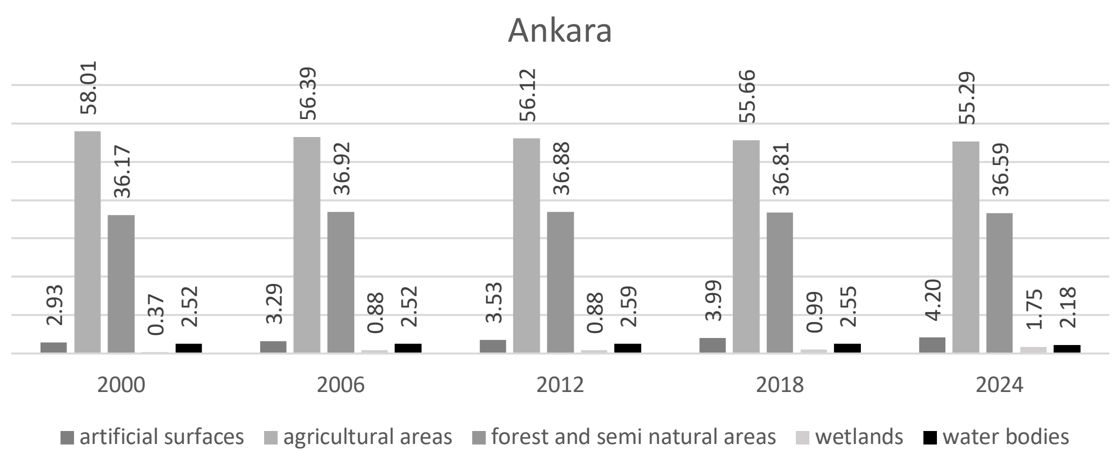

Fig.5 Results related to Ankara obtained from the prediction of land cover percentage changes in 2024 by applying extrapolation process

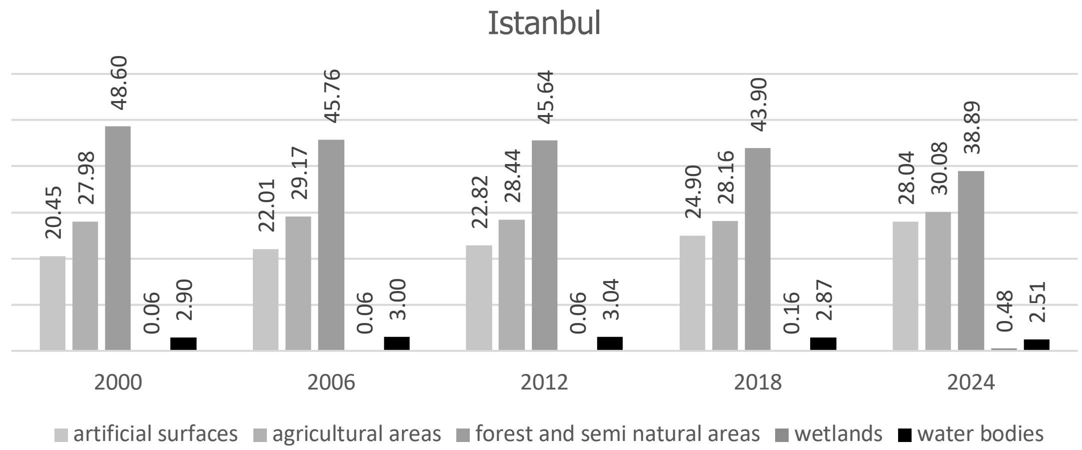

Fig.6 Results related to Istanbul obtained from the prediction of land cover percentage changes in 2024 by applying extrapolation process

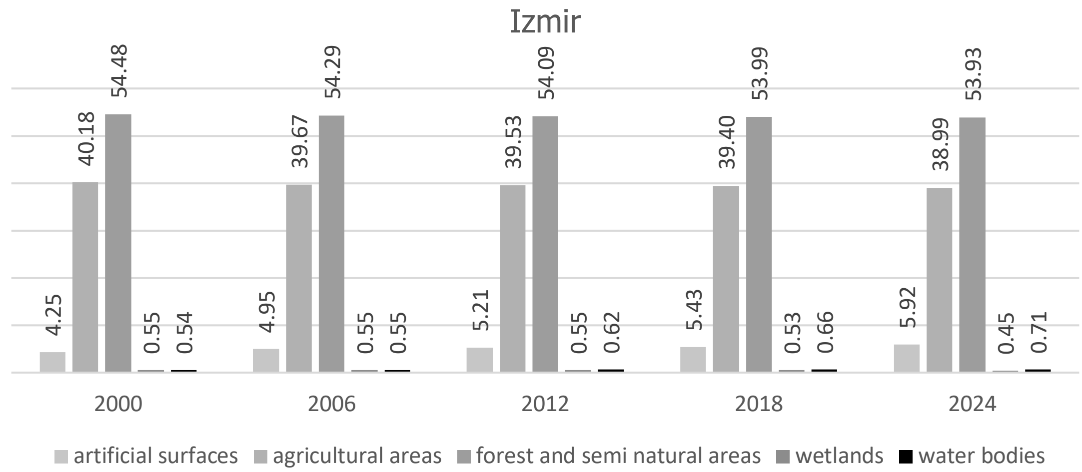

Fig.7 Results related to Izmir obtained from the prediction of land cover percentage changes in 2024 by applying extrapolation process

3. Results and discussion

As it can be seen in Tab.2, in Ankara, Istanbul and Izmir, a linear increase was observed for the values of artificial surfaces against the years 2000, 2006, 2012 and 2018. In the same way, forest and semi-natural areas and water bodies have showed a linear change in Izmir. On the contrary, the polynomial (or non-linear) relationship between the independent variables, years and the dependent variables agricultural areas, forest and semi-natural areas, wetlands and water bodies for Ankara and Istanbul were reported from the related equations in Tab.2. In Izmir, agricultural areas and wetlands showed a polynomial change (see Tab.2). From the linear and polynomial equations given in Tab.2, the numerical values of the investigated surfaces in 2024 were predicted by using the extrapolation process. The results of the landscape change predictions were given in Figg. 5, 6 and 7 as seen in Fig.5 artificial surfaces are expected to increase in Ankara, Izmir and Istanbul in 2024. It has been calculated that artificial surfaces in Ankara will increase by 1.9% compared to 2000. This figure reveals that there was a rapid construction within the specified dates in Ankara. It is estimated that there will be a 2.72% decrease in agricultural areas in the specified date range in Ankara. The increase in artificial surfaces in Ankara will cause a significant decrease in agricultural areas. In parallel with the results of this study, Bayar and Karabacak (2017) state that there is a relationship between the decrease in agricultural areas and the increase in residential areas in Ankara. The disappearance of natural and semi-natural areas in Istanbul reveals that the natural structure has been damaged significantly and measures should be taken against this risk in the future. It is estimated that the natural and semi-natural areas of Istanbul will decrease by 9.91% from 2000 to 2024. Algancı (2018) states that when the land cover change characteristics of Istanbul are examined, the large-scale artificial surface increase especially in the last five years are important. It is stated that a large part of the change in artificial surfaces in Istanbul is caused by the 3rd Airport, Yavuz Sultan Selim Bridge and the connection roads that provide access to these areas (Algancı, 2018). Karaali (2020), in her study examining the changes of land cover, states that between 1990 and 2019, artificial surfaces in Izmir have undergone a visible change. There is an increase in artificial surfaces with the increase of the population due to reasons such as industrial activities, education and migration (Karaali, 2020). In this study, it has been observed that there will be a 1.67% areal increase in artificial surfaces from 2000 to 2024 in Izmir. On the other hand, it was revealed as a result of calculations that there will be a decrease in forests and semi-natural areas in Istanbul and Izmir in 2024. Another situation in our predictions, while artificial surfaces increased in Istanbul and Izmir in 2024, forests and semi-natural areas decreased. In addition, a series of important land cover changes are expected to occur in 2024. For example, wetlands in Istanbul are expected to increase rapidly from 752 hectares in 2018 to 2128 hectares in 2024. This means a 0.08% surface increase in wetlands. As described above, mathematically or statistically monitoring the CORINE Land cover data obtained in a certain period using linear and polynomial models provided the opportunity to visualize the effect of urbanization on the land cover. In practice, the quantitative prediction of artificial surfaces, agricultural areas, forest and semi-natural areas, wetlands and water body for the analyzed cites, Istanbul, Ankara and Izmir enabled to take measures against the major changes or to prevent the destruction of natural and semi-natural areas. From the results obtained, it would be possible to modify a healthy direction of wrong planning decisions for urban sprawl in the future.

Exploring the rules and relations which are effective in changing lands into urban area and also the estimating the trend of city development in the future through credible and efficient methods have received significant attention in urban researches (Soltani & Karimzadeh, 2013). There are many studies in the literature that make predictions for medium-term physical growth based on past trends. Such models remain an essential part of efforts to determine the global consequences of human activities; untested predictions, based on the best science available, are still better than proceeding blindly (Rastetter, 1996; Miller et al., 2021). In order to include economic, demographic and political decisions in extrapolation models, the importance of these studies needs to be emphasized and developed. The greater availability of data in recent years also allows for models that incorporate shorter transition periods, potentially leading to more accurate estimation (Iacono et al., 2015). In addition, extrapolation models may also have value in identifying data needs and knowledge gaps and in describing the potential consequences of alternative management actions (He & Mladenoff, 1999). In many cases, the products of extrapolation are amenable to testing, and there is much to be gained by doing so (Miller et al., 2021).

4. Conclusions

Urban planning is the most relevant decision-making process affecting urban land covers. To support planners in enhancing sustainable urban land use planning, there is a need to understand how human impacts may affect urban land cover. In this paper, the mathematical extrapolation procedures based on linear and polynomial regression models obtained from the relationship between the related dependent and independent variables revealed the effect of human on land covers in the analyzed provinces in Turkey. Another contribution of this applied methodology is that it provides strong evidence regarding the future effects of past land cover changes.

Within the studied areas, possible land cover changes in 2024 have been presented. Evaluating these data combined with national population data and policies can have a complementary effect in terms of environmental monitoring. Moreover, information on changes in landscapes will makes an invaluable contribution to appropriate decision-making, which is essential to wise use of the resources and sustainable development (Alphan, 2003). This study showed that agricultural areas, forests and semi-natural areas were at risk with the creation of artificial surfaces for the investigated cities, Istanbul, Ankara and Izmir. In this context, observing the land cover under risk is of great importance in terms of establishing a correct urbanization understanding, protecting the natural structure and not losing biodiversity. In the coming years, we concluded that observing the landscape changes in Ankara, Istanbul, Izmir, and putting forward a controlled urbanization policy and planning approach would be effective in preventing natural areas and biological destruction and sustainable land management.

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Quantifying the urban built environment: a neighbourhood-scale analysis

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Abstract
The quantification of the built environment has been approached from two major perspectives-regional-scale and neighbourhood-scale. Few studies have attempted to quantify the built environment from the neighbourhood-scale and none of these studies attempted to examine the interactions that exist between the respective built environment indicators and the spatial variation of such interaction which may help under the emerging travel-related prototypical neighbourhoods. Two types of datasets were used in the study and these are neighbourhood-based field surveys and data extracted from a satellite image. These were used to compute indicators which were in turn used to measure the built environment of Benin metropolitan region. The interaction between the indicators revealed that the quantification of the built environment categorised the region into 3 distinct prototypical neighbourhoods-pedestrian-oriented zones, transit-oriented zone, and car-oriented zone.

Keywords
Built environment; Travel behaviour; Land-use; Entropy; Neighbourhood-scale.

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1. Introduction

The built environment (BE) describes the anthropogenic related spatial and physical entities of an urban landscape characterised by the land-use patterns, neighbourhood design and urban morphology. The BE has been argued in the literature (Schwanen & Mokhtarian, 2005) to be a fundamental factor in the study of travel behaviour (TB). The drive to understanding this link has continued to provoke attention from diverse disciplines because the findings in most of the existing literature show a pronounced level of inconsistency (Yang et al., 2019). For example, a handful of literature has revealed that increased urban area density, proximity to certain linear infrastructure and land-use diversity are the three main components of the BE that influence TB since they are associated with smaller shares for the private car and a larger proportion of travel by public mode and cycling/walking (Limtanakool et al., 2006; Schwanen et al., 2004; Frank & Pivo, 1994; Newman & Kenworthy, 1989; Dargay & Hanly, 2004). Other studies have reported that cities with compact density are associated with a longer travel length (Norland & Thomas, 2007). Yet, other studies have suggested that the relationship between the BE and TB is mostly equivocal because there are no direct effects (Kockelman, 1997; Limanond & Niemeier, 2004; Miller & Ibrahim, 1998; Pickrell, 1999; Badoe & Miller, 2000).

The major reason for the mixed findings may be tied to the selected variables, methods and scale of measuring the BE indicators. The majority of the existing literature tends to quantify the BE from a larger grain/macro-scale perspective (Yang & Zhou, 2020; Tsai, 2005; Nari & Zhang, 2018). Fewer studies have quantified the BE using a neighbourhood or finer/micro-scale analysis (Lee & Moudon, 2006; Guzman et al., 2020) and they paid no attention to the neighbourhood types that may emerge from the integration of the BE indicators and how such spatial units are defined from travel-based modal split perspective. Also, the complexity of the BE requires the consideration of several other dimensions (beyond density, diversity and design) holistically to offer an all-inclusive and robust measure that includes all aspects of the BE of the city under study. The identified gaps were addressed by this study thereby presenting a significant contribution to global literature on urban studies.

This study is necessary because each neighbourhood may likely present distinct characteristics that may impact travel activities differently. The BE has been measured at two major scales-local-neighbourhood and metropolitan-wide (Comendador et al., 2014). In contemporary literature, several interrelated spatial indicators have been used to quantify the BE. Prominent among these are density, diversity and design (Cervero & Kockelman, 1997; Lee & Moudon, 2006). Quantifying BE within the scale of the neighbourhood may reveal heterogeneous urban landscape patterns within the metropolitan region. It is expected that the result would promote understanding and aid further analysis regarding the interactions of the BE indicators within each neighbourhood. The major objectives of this study are to quantify the BE of the Benin metropolitan region (BMR), a large African-sized urban area (a case study from a developing region) using several spatial indicators disaggregated to the neighbourhood-level which is the scale of analysis. Also, the interactions of these indicators within the neighbourhoods were analysed. It is expected that each spatial unit would show not only the associated but also the strongest BE component that characterises such neighbourhood. This may help to understand how each spatial unit would possibly influence TB. Such findings will guide the decisions of urban planners and transport analyst on the appropriate land-use policies and transport planning strategies that may drive urban sustainability.

2. Literature Review

2.1 Measures of the built environment

The quantification and spatial characterisation of the urban BE of any metropolitan region are far from been significantly achieved and has presented a challenging scenario regarding fully understanding and achieving a consensus on the BE-TB interaction. This absence of consensus may be linked to both the methodological and theoretical setbacks reflected in efforts to correctly explain BE interactions with other urban activities and its quantification within a specific spatial extent (Gehrke and Clifton, 2016). A plethora of other empirical studies mostly emanating from the US utilizes either sprawl or land-use mix to quantify the BE of cities (Yang & Zhou, 2020; Ewing et al., 2016; Gehrke & Clifton, 2017; Burchell et al., 1998; Cervero & Wu, 1998; Christian et al., 2011; Mavoa et al., 2018).

Some other studies have taken it further by identifying and integrating a series of BE indicators to define the urban physical landscape. Prominent among these are the 3Ds concept consisting of density, diversity and design of urban areas (Cervero & Kockelman, 1997) which investigated the influence of the BE on travel demand. The BE of the San Francisco Bay Area was measured along three chief dimensions-density, diversity and design. Other studies have further extended these indicators by incorporating two additional D indices and routes and these are destination accessibility, distance to transit and travel route (Lee & Moudon, 2006; Ewing et al., 2014; Ewing & Cervero, 2001).

The 5 Ds indices consisting of density, diversity, design, destination accessibility, distance to transit (Ewing & Cervero, 2010; Choi, 2018) and travel route characteristics identified so far in literature tend to capture a substantial number of dimensions that define the BE. However. it is clear in the literature that the route characteristics identified by Lee & Moudon (2006) are captured in the design dimension earlier presented by Cervero & Kockelman (1997). Lee & Moudon (2006) described route index from ratio, length and area perspective-the ratio of a more and less direct route to access the closest urban activities such as schools and shopping stores; the total length of sidewalk with a spatial unit; and lesser grain size of the household block. To achieve a composite and robust measure of BE especially concerning TB understanding, there is a need to include major indicators that may affect all aspects of travel modes such as transit, car and walking/cycling. Some scholars have achieved a high level of indicators selection for quantifying the BE characteristics and its relation to land-use and TB studies but then some of these may have selection bias (Lee & Moudon, 2006) since the selected indicators only included variables that may influence walking mode leaving out other equally significant modes. Nkeki & Asikhia (2019) included urban sprawl indicators to account for the BE effect on car mode choice.

Quantifying the BE using the 5Ds indices (density, design, diversity, distance to transit or some centrality, destination accessibility (Ewing et al., 2014; Choi, 2018) and sprawl (S) as included in Nkeki & Asikhia, (2019) would, without doubt, present a robust, well represented and consolidated measure of any BE. Also, it would help to build a useful framework in global literature that may bring some level of order and consistencies in land-use-TB related studies (Ewing et al., 2014).

2.2 Scales of measuring built environment

Literature has shown that the scale of modelling the effects of the BE on TB continue to play an integral and intriguing role in the consistency of the results (Yang et al., 2019; Handy et al., 2005). By implication, BE needs to be defined at such a scale since travel-land-use interactions take place at such a geographic unit. However, two major scales of modelling BE have been identified in the literature, they include regional or metropolitan-wide level and local or neighbourhood level of analysis. The formal is often based on aggregate methodology by examining features at the macro/holistic level through averaging out all outcomes or measuring large geographic framework such as region, metropolitan area, states, political area, urban city, by sprawl indicator (Yang & Zhou, 2020; Tsai, 2005; Nari & Zhang, 2018). This geographic scale has been seriously criticised for its tendency of introducing bias and may cause ecological fallacy, hence impacting significantly on the results (Ewing et al., 2017). The latter, on the other hand, is based on the disaggregate methodology which analyses data at the micro-level or finer grain spatial unit. It defines the built environment closer to the household location by breaking down outcomes into a smaller geographic framework such as neighbourhood, street block, etc (Lee & Moudon, 2006; Guzman et al., 2020).

2.3 Indicators of the built environment and their implications to travel pattern

The 5Ds and S indicators of quantifying the BE as identified in the existing literature exhibit significant influence on TB. Each may have some level of an implication that may help to characterise the spatial units of interest based on the interaction of these dimensions.

The density dimension had been defined with various variables that ranged from population distribution to urban footprint distribution. Population density as a variable to define the density dimension of the BE is primarily and commonly adopted as the measure of density (Choi, 2018; Ewing et al., 2017; Yang & Zhou, 2020), this is because the data is mostly and readily accessible and very easy to compute. Others adopted residential and employment densities which measures the activity intensity within a spatial unit (Yu & Peng, 2020; Ewing et al., 2014). Yet, others included infrastructural density which measures the intensity of urban infrastructures such as road, rail and paved surfaces (Yu & Peng, 2020; Nari & Zhang, 2018), in these studies, density was used to represent the intensity of people residing interactively within an area. Another measure of density dimension is the urban patch index (Nkeki & Asikhia, 2019; Wang et al., 2020). This is a robust method though not as popular as the population intensity method due to its computational complexity and data scarcity. It measures the intensity and fragmentation of the general urban landscape which consist of population residence, employment spaces and overall activities and infrastructure such as roads, rail, pavement, etc. Also, it shows that true density can influence travel in all directions. However, as shown in literature density exhibit a significant influence on TB (James et al., 2014; Cervero & Kockelman, 1997). For example, higher density encourages walking and other non-motorised travel modes by implication, more compact geographic landscape may lower the automobile usage (Cervero & Kockelman, 1997; Nari & Zhang, 2018; Cho & Rodriguez, 2014; Levinson & Wynn, 1963) and also, shortens the travel distance (Hu & Huapu, 2007).

The diversity dimension simply describes the level of land-use mix in an urban space. The land-use mix is an important variable in urban studies since it promotes understanding of the land-use pattern and its relationship with other interacting activities. It is also used to calculate the magnitude of balance among the land-uses with a defined spatial unit. The diversity dimension has been used for over 2 decades to quantify the BE for TB related studies (Ewing et al., 2014; Nkeki & Asikhia, 2019; Gehrke & Clifton, 2016). In land-use-transport planning, diversity has been shown in previous studies to significantly impact TB. For example, higher land-use mixed areas tend to encourage walking due to the short distance that connects activity locations while lower mixed areas tend to promote longer travel distance and hence encourages motorised travel modes (Guzman et al., 2020; Ewing et al., 2014; Gehrke & Clifton, 2016).

Design dimension typically describes the general patterns of infrastructure that result in a specific spatial arrangement. Design dimension is among the first 3D variables, which is often measured by urban overland linear transport infrastructure, such as road, rail and pedestrian network pattern (Ewing & Cervero, 2010); block size, the density of 4-way intersections, sidewalk density and number of parking space (Nkeki & Asikhia, 2019; Choi, 2018). Design variables have been found to significantly affect travel. For example, literature (Yu & Peng, 2020) has shown that road density may produce more ride-sourcing demand; Ewing et al. (2014) revealed that 4-way road intersections increase walking trips (though there is a mixed reaction in literature as some believe that it may trigger the search of other modes for intermediate-distance travel); yet another study found that smaller block sizes and longer sidewalks along the main streets significantly influences walking (Lee & Moudon, 2006). However, it is believed that a certain urban design pattern promotes certain TB. For example, the presence of sidewalk in a neighbourhood may encourage walking and discourages automobile trips; the high the density of street intersection, the higher the likelihood to walk because higher urban density and activity concentration may emerge; a grid pattern of road network may force block kind of neighbourhood design which encourages people to walk; corridor road design encourages transit dependence (Asikhia & Nkeki, 2013).

The destination accessibility dimension measures the ease of accessing the commuters residence or source/neighbourhood from a certain activity-based location such as the central business district (CBD), shopping centre, etc. In most cases, a neighbourhood's level of accessibility is measured by its distance from the CBD. This is because the shorter the distance of a neighbourhood to a major activity centre, the shorter would the commuters travel, it is expected that this would promote walking and for a neighbourhood with an average distance to an activity centre with a grid design, car usage may be encouraged while in a corridor road design, the probability for transit usage may increase (Asikhia & Nkeki, 2013; Schwanen et al., 2001). The longer the distance of a neighbourhood from an activity centre, the more the likelihood of automobile dependence. The destination accessibility dimension has been quantified with several variables such as regional or local trip attraction activities, the distance between residence and job location.

Distance to transit has been quantified by some variables such as the average of the shortest route between commuters residences or work location and the nearest bus stop/rail station (Ewing et al., 2014; Choi, 2018); transit route density of a neighbourhood (Nkeki & Asikhia, 2019). The closer a neighbourhood is to a transit route or the higher the transit route density, the higher the probability of transit performing more than other modes. This dimension tends to strongly encourage automobile usage and discourages walking, biking and other pedestrian modes. It has been shown to manifest a positive relationship with TB (Yu & Peng, 2020).

Sprawl dimension is often neglected in choosing BE indicators that influence TB. Very few studies have used sprawl to quantify BE (Tsai, 2005; Nkeki & Asikhia, 2019). It may be mistaken for a kind of low-density development. Cities may grow either by increasing density or sprawling (Nkeki, 2016). Whatever the case, sprawl and density influence TB differently. For example, higher density promotes pedestrian modes while a higher level of sprawl encourages automobile usage.

2.4 Summary

The review of existing literature demonstrates that very few or no study has holistically measured the BE using several other dimensions that look beyond density, diversity and design or distance and destination accessibility. Most of the literature either utilized the initially proposed 3Ds or some of the 3Ds and included the later additional 2Ds. It is the view of this study that to conduct a robust quantification of the BE for TB study, all dimensions/indicators should be exhausted. Also, the review shows that no study has attempted to examine the interactions between the BE indicators and how such interactions varies spatially. This study intends to present an all-inclusive and robust quantification of the BE for TB study.

3. Methodology

3.1 Study region

The study area is the BMR which is roughly 506 km^2 in the urbanized area and has over 1.1 million inhabitants. From the census estimate, the region is composed of 248,620 households and an average of 6-7 persons per household (NPC, 2006). It is located between latitudes 6° 16′ to 6° 33′ N and longitudes 5° 31′ to 5° 45′ E (Fig. 1a & b). There are 55 major neighbourhoods characterised by high to low urban density from the CBD. Density reduces with increasing distance from the CBD. Unlike the cities of most advanced countries where building floors reach an average of 10, the region is dominated by single floor buildings making density essentially horizontal. The CBD is a prominent region known for essentially commercial activities and it falls within the King square/core neighbourhood (see map 'b' in Fig.1)

Also, the massive unauthorized land-use conversion occurring in the CBD is unprecedented. However, in this area, commercial activities predominate and rapidly engulfing and replacing other land-uses.

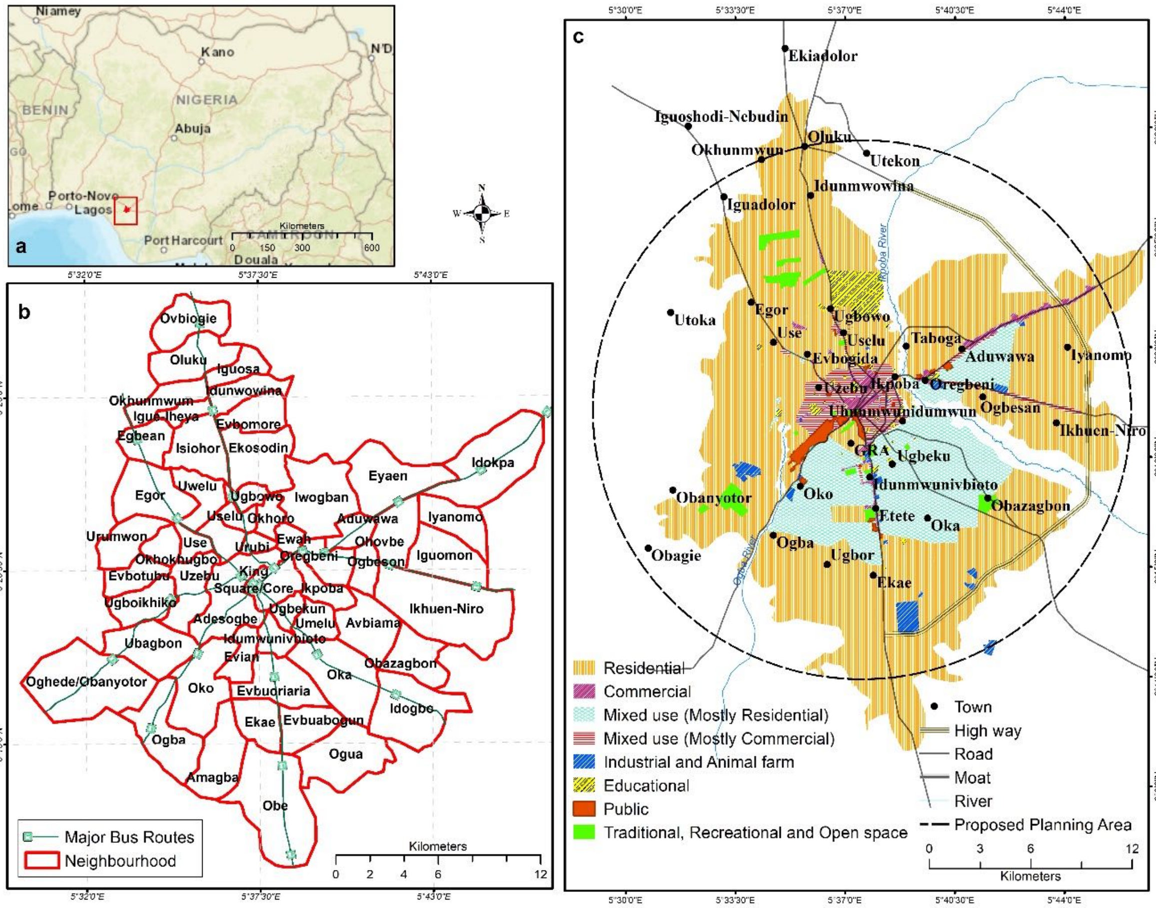

Fig.1 Location of the study area map 'a' is the location of Benin in Nigeria; map 'b' is Benin metropolitan region and the neighbourhoods; map 'c' is land-use of Benin

For example, within the King-Square/Ring-Road axis, tending towards the New-Benin market axis (northeastern part of the region), commercial land-use continuously spread over roughly 1.7 km^2. At the New-Benin market area, commercial land-use formed a cluster covering over 1.2 km^2. Such activities are also found along trunk roads (Fig.1c). Predominantly, residential land-use tends to concentrically envelop the core region and spread towards the outer part of the metropolis, particularly along the trunk roads.

3.2 Data

Two major sources of data were utilized in this study and these datasets were categorized into primary data and secondary data. The first part of the primary datasets was obtained from a comprehensive neighbourhood-based field survey. This involved the identification, recording and capturing of data with a GPS device. The datasets that were extracted from this field survey were implemented to derive such indicators as the availability of sidewalks in the neighbourhood and the number of regular bus routes within the neighbourhood. The second part of the primary data collection comprises the counting of housing (residence) and job (employment, commercial and administrative land-uses). This was done with a 200m x 200m quadrat which covers 40,000 m^2 of urban space. The mean centre points of each of the identified 55 neighbourhood polygons were determined with ArcGIS spatial statistical module. With the mean centre tool, a 200m x 200m quadrat was delineated for each polygon and with the help of the worldview satellite data, the locations on the ground were identified before fieldwork. The number of houses and job locations were captured for the 55 locations from the field. This data was used for diversity analysis.

The secondary datasets were extracted from the high-resolution (2m spatial resolution) worldview image (provided by Digital Globe Foundation) of the entire region. These datasets were used to calculate the urban density and local sprawl indicators.

3.3 Satellite data processing and classification

The satellite data was classified to assess the built-up area of the region. Computing urban density and local sprawl indicators, urban patches were mined from the worldview imagery using GIS and remote sensing procedures. These procedures combined presented a robust empirical methodology prescribed in this study for measuring the BE. This spatial data was used for urban density and local sprawl indexes computation. The overall proposed procedure for the analysis is shown in Fig.2. The image was entered into ENVI version 5.1 for seamless mosaicking since the imagery was acquired in tiles (mosaicking is a photogrammetric algorithm that helps to combine several raster scenes into one while maintaining a uniform spectral characteristic). The single raster scene was re-projected and transformed. The projected coordinate system, with Universal Transverse Mercator (UTM)–Minna UTM zone 31°N was adopted.

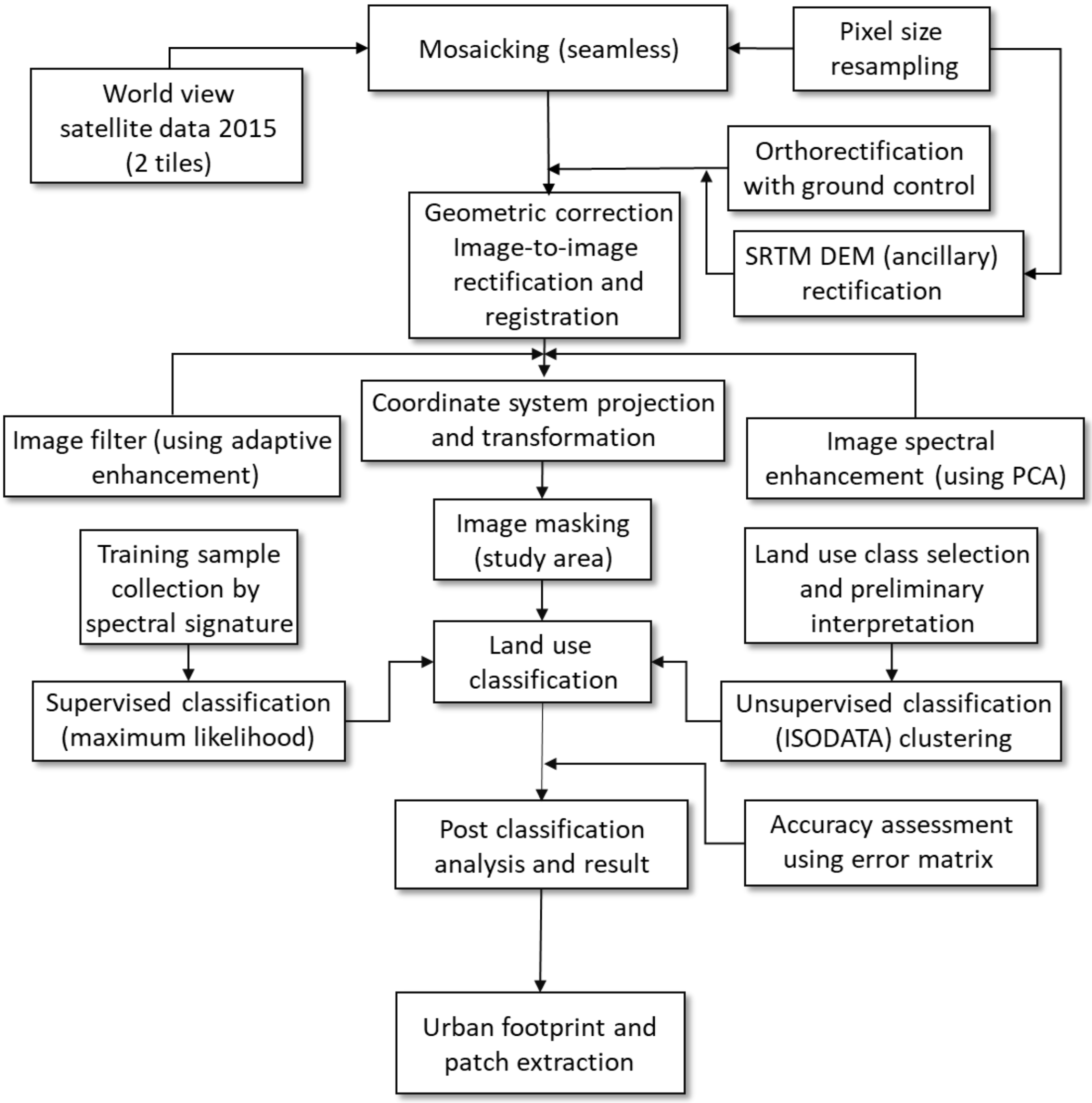

Fig.2 A methodological flow chart for the land-use classification and urban patch extraction

From ENVI the transformed image was exported to imagine raster (.img) for further correction concerning spectral and geometric distortion. The image was subjected to orthorectification processes in ERDAS IMAGINE photogrammetric software 2014 version. In carrying out orthorectification processes, 45 well-distributed ground control points within the study region and ancillary (SRTM DEM) data were employed. To further improve the image (SRTM data) spectral quality, it was resampled independently in ERDAS IMAGINE using the resample pixel size algorithm in the software. The bilinear interpolation resampling method was used. The bilinear interpolation method was preferred because it is the most appropriate resampling technique for continuous value data like elevation and slope. The DEM image was resampled from 30 x 30 m to 2 x 2 m. The reason for this is to avoid pixel conflict during image–to image rectification process. The rectified and enhanced world view data in IMAGINE raster format was clipped to the study region using the mask algorithm in ERDAS IMAGINE.

There are two types of image classification in GIS operation–unsupervised and supervised classification. Both procedures were applied to the image scene to get possible maximum accuracy in characterisation. The unsupervised classification with ISODATA (Iterative Self–Organising Data Analysis) clustering approach was applied, this allowed preliminary land-use class selection and interpretation. It automatically aggregated the multispectral data into several classes based on intrinsic similarity within the pixel of the image. This spectral detail assisted in the class selection and naming through on-screen visual assessment, which involves the careful grouping of pixels and delineating areas with a large quantity of a particular class. The proposed classes for the study region include urban or built-up area, vegetation area and water body. Other land-uses were not included because extracting the built-up area is the focus of the analysis. There were 5 initial classes. The pixel cluster that defined the urban area; those that defined the water body and those that defined vegetation were broken into riparian vegetation along the river; dense vegetation cluster and light vegetation clusters agricultural areas. Since the focus is the urban footprint, the riparian, dense and agricultural vegetation related classes were classified as vegetation. Generally, the unsupervised classification returned 121,705,593 pixels for built-up area; water body has 996,714 and vegetation has 333,596,613 pixels.

		Ground truth (Pixels)		
Class	**Built–up area**	**Waterbody**	**Vegetation**	**Total**
Unclassified	0	0	0	0
Built–up area	129,524	461	10,496	140,481
Waterbody	310	18,846	1,042	20,198
Vegetation	325	68	782,870	783,263
Total	130,159	19,375	794,408	943,942
		Ground truth (Percent)		
Class	**Built–up area**	**Waterbody**	**Vegetation**	**Total**
Unclassified	0.00	0.00	0.00	0.00
Built–up area	99.51	2.38	1.32	14.88
Waterbody	0.24	97.27	0.13	2.14
Vegetation	0.25	0.35	98.55	82.98
Total	100.00	100.00	100.00	100.00
Class	**Commission (Percent)**	**Omission (Percent)**	**Commission (Pixels)**	**Omission (Pixels)**
Built–up area	7.80	0.49	10,957/140,481	635/130,159
Waterbody	6.69	2.73	1,352/20,198	529/19,375
Vegetation	0.05	1.45	393/783,263	11,538/794,408
Class	**Prod. Acc. (Percent)**	**User Acc. (Percent)**	**Prod Acc. (Pixels)**	**User Acc. (Pixels)**
Built–up area	99.51	92.20	129,524/130,159	129,524/140,481
Waterbody	97.27	93.31	18,846/19,375	18,846/20,198
Vegetation	98.55	99.95	782,870/79,4408	782,870/783,263
Overall Accuracy = (931,240/943,942) 98.65%; Kappa Coefficient = 0.9521				

Tab.1 Confusion matrix for supervised image classification

The supervised classification was conducted by collecting training samples using the region of interest tool (ROI) of ENVI and these sample polygons were saved as a spectral signature file for further usage. This was achieved using the spectral information from the unsupervised classification method and additional details were extracted from various statistical computations during training sample creation. Land-use supervised classification was performed using the maximum likelihood algorithm with equal a priori probability weighting (which guarantee all classes having the same a priori probability).

Classification accuracy assessment for the image was carried out with about 100 randomly distributed ground truth points within the limit of the study region. The generated points are based on stratified random sampling type and stratification is proportionate (i.e. 40, 40 and 20 points for urban, vegetation and waterbody respectively) across all classes. These points were used to compute the confusion matrix for the classified data, based on the Kappa coefficient (Tab.2). The overall accuracy of the classification is 98.65% with a Kappa Coefficient of 0.95. The observed high level of classification accuracy was expected because three classes of land-use types were selected which correspondingly are the major classes distinctively captured by the very high-resolution imageries. Also, the various image spectral enhancements implemented made the classification less complex by grouping similar pixels. The classified land-use data were exported and entered into ArcGIS 10.4.1 software from where such data was manipulated using the raster calculator in the ArcGIS toolbox. The raster calculator was used to extract the built-up area from the classified raster. This was carried out by reclassifying the built-up area as 1 and others as 0 using the reclassify tool in ArcGIS. The raster calculator was then instructed to extract 1 (built-up area) as a separate layer. This facilitated statistical estimation and disaggregation of the classes and patches. The extracted urban patches were used as data for calculating the urban density and sprawl.

3.4 Indicators

Urban patch density

Density was quantified using a spatial metrics-urban patch density index (PD). The value of PD is simply the number of urban patches in a neighbourhood divided by the total landscape area (neighbourhood) in m^2. This was calculated using Eq.1 in Tab.2 presented by (McGarigal & Ene, 2014).

Indicators	**Formula/measurement**		**Description**
Density dimension			
Urban density	$PD = \frac{N}{A}\,(1{,}000{,}000)$	(1)	Density of built-up patch in a neighbourhood calculated by urban patch density index (PD).
	Diversity dimension		
Land-use mix	$(EI) = (-1) \times \frac{\left[\left(\frac{b1}{a}\right)\times In\left(\frac{b1}{a}\right)+\left(\frac{b2}{a}\right)\times In\left(\frac{b2}{a}\right)\right]}{In(n)}$	(2)	The proportion of jobs to housing location within neighbourhood-calculated by a spatial entropy index. The value of the index varies between 0 and 1.
	Design dimension		
Street intersection density	$SI\ Density = \frac{NoN}{A}\,(1{,}000{,}000)$	(3)	The density of street intersection within neighbourhood-computed by street intersection density index (SI Density).
The presence of sidewalks in the neighbourhood	Binary		Availability of sidewalk in the neighbourhood-measured with binary 1=yes; 0=no.
Destination accessibility dimension			
Distance to CBD	Average length		The average distance of the neighbourhood to CBD in Km.
Transit route density/accessibility dimension			
Transit accessibility	Count		Number of regular bus routes within the neighbourhood
Sprawl dimension			
Local sprawl	$H_n = -\sum P_i log_e(P_i)$	(4)	The index gives a value that varies from 0 to $In(n)$.

Tab.2 Definition of indicators for measuring built environment

In the formula *N* = overall sum of patches in the neighbourhood excluding any background patches; *A* = area coverage of the neighbourhood under consideration in m^2. To enable the interpretation of patch density per km^2, the PD value for each neighbourhood was multiplied by 1,000,000. FRAGSTATS spatial metric was used to conduct the calculation (Nkeki, 2016; Ramachandra et al., 2012). In the interpretation, increasing value of PD means disaggregation of the urban landscape (low density), while decreasing value of PD implies increasing density and more compacted landscape.

Land-use mix

Spatial entropy statistic was used to calculate the land-use mix utilizing data from the 200m x 200m quadrat this consist of the number of housing and job location for the 55 neighbourhoods in the study area. The major reason for modelling these land-use types is to create a spatial dataset for quantifying the built environment. The entropy index is fast becoming known and accepted as the most common method of quantifying land-use mix and diversity in global literature. For example, several studies have used it to quantify the degree of homogeneity or diversity of many land-uses, such as job and residential land-uses (Strauss & Miranda-Moreno, 2013; Silva, 2014; Kockelman, 1997). The entropy index as modified for the land-use mix by (Zahabi et al., 2012) is presented in Tab. 2. In the formulation (Eq.2 in Tab.2), EI = land-use mix entropy index; a = total number of land-uses of the two land-use categories; $b1$ = the job/commercial land-use category; $b2$ = the housing/residential land-use category; n = the total number of land-uses in the mix (in this case 2). The field calculator module in ArcGIS 10.7.1 was employed for the computation of this spatial entropy index based on the Eq. 2 specification. The resulting value of the index varies between 0 and 1, where 0 depicts a homogenous land-use scenario (i.e. a single land-use) while 1 corresponds with a perfect mix scenario (i.e. all land-use categories are equally present).

Street intersection density

Street Intersection (SI) density index was used here as one of the indicators for defining the design dimension of the built environment. SI Density was measured in this study by computing a neighbourhood based four-way street intersection points density. These points were extracted from the worldview satellite data and used to calculate the density of intersections per square kilometre of the respective neighbourhoods. The formulation developed to compute the SI Density index is presented in Eq.3 in Tab.2. In this specification, *NoN* = number of nodes (street intersection points in the neighbourhood); *A* = area of the neighbourhood in m^2 (to convert to km^2 the value of SI Density was multiplied by 1,000,000). By this, the SI Density index would be interpreted as the number of nodes per km^2. By implication, neighbourhoods with a higher intersection density may promote more pedestrian travel (Reiff, 2003). The density of the intersection points would aid the characterisation of the neighbourhoods based on the level of grid design they are structured. A neighbourhood characterised by grid design tends to promote short distance travel and may also discourage transit mode of travel. The SI Density index was calculated in ArcGIS. Another design dimension is the presence of a sidewalk in the neighbourhood (Tab.2).

Local sprawl

Quantifying sprawl has been a long-time issue in global literature. The specification of robust indicators has played down the problem of measuring sprawl. The entropy statistic in its diverse modification has become a steady resource for quantifying urban sprawl (Bhatta et al., 2010; Sarvestani et al., 2011). However, the Shannon entropy index was computed to quantify and detect the local sprawl pattern by estimating the degree of concentration or dispersion of urban patches in the neighbourhoods. Shannon's entropy statistic for measuring sprawl was calculated here with the formulation by Bhatta et al. (2010) in Eq. 4 in Tab. 2. The parameters are defined as H_n = Shannon's entropy index; P_i = proportion of urban patches i in each neighbourhood; n = Overall number of neighbourhoods in the study area. The index gives a value that varies from 0 to $In(n)$. A value near 0 implies the compactness of patches while a value near $In(n)$ indicates the dispersion of patches. Dispersion is interpreted as the occurrence of sprawl.

Distance to CBD

Distance to CBD was defined as destination accessibility dimension using the average distance of the neighbourhood centroid to the CBD through a regular bus route or a major road in such a neighbourhood.

Transit accessibility

Transit accessibility was used to define the transit route density dimension and it measured the field data on the number of regular bus routes within the neighbourhood.

3.5 Reclassification and rasterization of the indicators

The 7 indicators which were used to quantify the BE of the Benin region were further analysed to understand the interactions and how such indicators collectively play out to define not only the BE but also the travel-related prototypical neighbourhood. The essence of this is to advance knowledge on the travel outcome of the emerging BE. To achieve this, the indicators were rasterized (with a pixel size of 100x100) and using the raster calculator and reclassify tool in ArcGIS the indicators were systematically re-coded and classify into a common 3 components measurement scale where 1 represent car-oriented neighbourhood, 2 represent transit-oriented neighbourhood, and 3 represent pedestrian-orientated development. The reclassification was done in such a way that the BE characteristics that trigger certain TB were classified accordingly.

Neighbourhoods with high PD index values (ranging from 2,084.45-5,276.20) were classified as 1 (low density since the patches are less compacted); the neighbourhoods with PD index values ranging from 1091.16-2,084.44 were classified as 2; while the neighbourhoods with PD index values ranging from 17.71-1,091.15 were classified as 3. This approach was used to classify land-use index, SI density index, local sprawl index and distance to CBD index. Availability of sidewalk index has 2 categories 0 and 1. The neighbourhoods where sidewalks are present were classified 3, while others were classified 2. Neighbourhoods with transit accessibility index ranging from 2-7 were classified as 2 (high transit accessibility neighbourhoods); neighbourhoods with 1 index value were classified as 1 (low transit accessibility); while neighbourhoods with 0 index value were classified as 3. The weighted overlay operation was performed on the reclassified indicator raster images with equal-weighted influence to produce an output raster. The weighted overlay analysis assigns the most unique code (i.e. the classification code of 1,2 or 3) to a neighbourhood and this is derived from the most significant class of all the indicators for such neighbourhood.

4. Results and Discussion

This section presents the various methods for extracting and measuring BE indicators to be used in defining the study region for TB study. To accomplish this, numerous land-use indexes were implemented, they include urban patch density index (density), local sprawl entropy index, land-use mix entropy index (diversity), street intersection density (design). Other BE variables that were presented in this section are the average distance of the neighbourhood to CBD (distance accessibility) and the number of regular bus routes in the neighbourhood (transit accessibility).

4.1 Quantifying urban density

To generate data for the PD index, an image classification was conducted using GIS and remote sensing techniques which were discussed in detail in the methodology section. Over 1 million urban built-up patches were extracted from the land-use section of the image classification. These patches were entered into ArcMap and using the patch analyst algorithm in the spatial metrics tool the PD index was computed. The result of the PD index is presented in Fig.3a. The PD index result (Fig.3a) is interpreted as the number of patches per km^2. On the one hand, the lesser the value of the PD index, the denser the urban built-up area. It simply means that the associated urbanised portion is more compacted. On the other hand, the higher the value of the PD index, the sparser the built-up area. By implication, a PD index of one (1) means that there is 100 per cent built-up or that the patch is one whole block within such neighbourhood.

The result was displayed in a choropleth map using a natural breaks Jenks classification with 5-classes. As expected, the general pattern of PD (as revealed in Fig. 3a.) is that density reduces with increasing distance from the CBD. It shows that 14 neighbourhoods clustering contiguously in the core region (covering roughly 71 km^2) have a low PD index between 17-402 patches per km^2.

This means that the built-up patches are more aggregated. Hence, density is higher in these neighbourhoods. Among these neighbourhoods, Ugbekun has the highest density with the lowest PD index value of 17.71. However, the pattern of density spread was interrupted in Ewah, Ikpoba and Avbiama neighbourhoods. These neighbourhoods are where the Ikpoba River passes through which created a natural obstacle and slows down development.

At the outskirt, 5 neighbourhoods manifest the highest PD index (3,219-5,276 patches per km^2). By implication, they have the lowest urban concentration. These neighbourhoods are sparsely built-up and the closest to the King square/core region is over 10 km away.

4.2 Measuring land-use mix

Land-use mix was analysed with spatial entropy statistic which was modified to disaggregate the result of the entropy index values into neighbourhoods utilizing data from the 200m x 200m quadrat this consist of the number of housing and job location for the 55 neighbourhoods in the study area. The result of the analysis (Fig. 3b) shows that 7 neighbourhoods returned high entropy index values greater than 0.71 indicating strong heterogeneousness of land-use. These neighbourhoods are Umelu (with an index value of 1.00); Iwogban (0.99); Aduwawa (0.99); Ugbekun (0.97); Evbuoriaria (0.97); Ogbeson (0.89); Ewah (0.78). There is only 1 neighbourhood (Umelu) characterised by an entropy index equal to 1.00. It means that this neighbourhood's land-use components are heterogeneous and are in a perfect mix. Figure 3b shows that King-Square and 31 other neighbourhoods (such as Oghede/Obanyotor, Ugboikhiko, Urumwon, Egor, Idunwowina, Eyaen, Iyanomo, Evbuabogun, Ogua, etc.) returned entropy values less than 0.48, indicating that such neighbourhoods are characterised by homogenous land-use composition. This means that one land-use type is dominant in these neighbourhoods. The dominant land-use types for each neighbourhood is shown in Fig. 4. However, the general pattern of the region's land-use distribution is a complex mixture of residential and commercial land-uses which formed a cluster around the King-Square which in turn is defined by homogenous land-use characteristics.

In the peripheral area, neighbourhoods with a single dominant land-use type formed patches around the heterogeneous land-use composition. One weakness of the entropy index is that it does not show the dominating land-use type in areas of the homogenous composition. To identify the dominant land-use type in each neighbourhood, the percentage values of the land-use types were plotted against the corresponding neighbourhoods (Fig.4). Fig.4 shows that King-Square is the only significant homogenous commercial land-use-based neighbourhood.

This is because it returned an entropy index value of 0.24 of which 85 per cent of the buildings are commercially based. This is not unexpected since it has become the commercial hub of the region over the years. Furthermore, 32 neighbourhoods that returned entropy index values less than 0.50 which is the mean of the index are homogenous residential. By implication, these neighbourhoods are classified as residential areas (see Fig.4).

For planning and further explanation, the neighbourhood–based land-use diversity result was reclassified into groups based on entropy values. The first group are neighbourhoods that returned entropy values of 0.22–0.30, these were named *pure residential areas* and *pure commercial areas*.

The second group are neighbourhoods that returned entropy values of 0.31-0.39, these were named *largely residential*. Thirdly, neighbourhoods that returned entropy values of 0.40-0.47 were named *weakly mixed land-use*. Fourthly, neighbourhoods that returned entropy value of 0.48-0.71 were named *robust mixed land-use* and finally, those that returned entropy value of 0.72-1.00 were named *complete mixed land-use*.

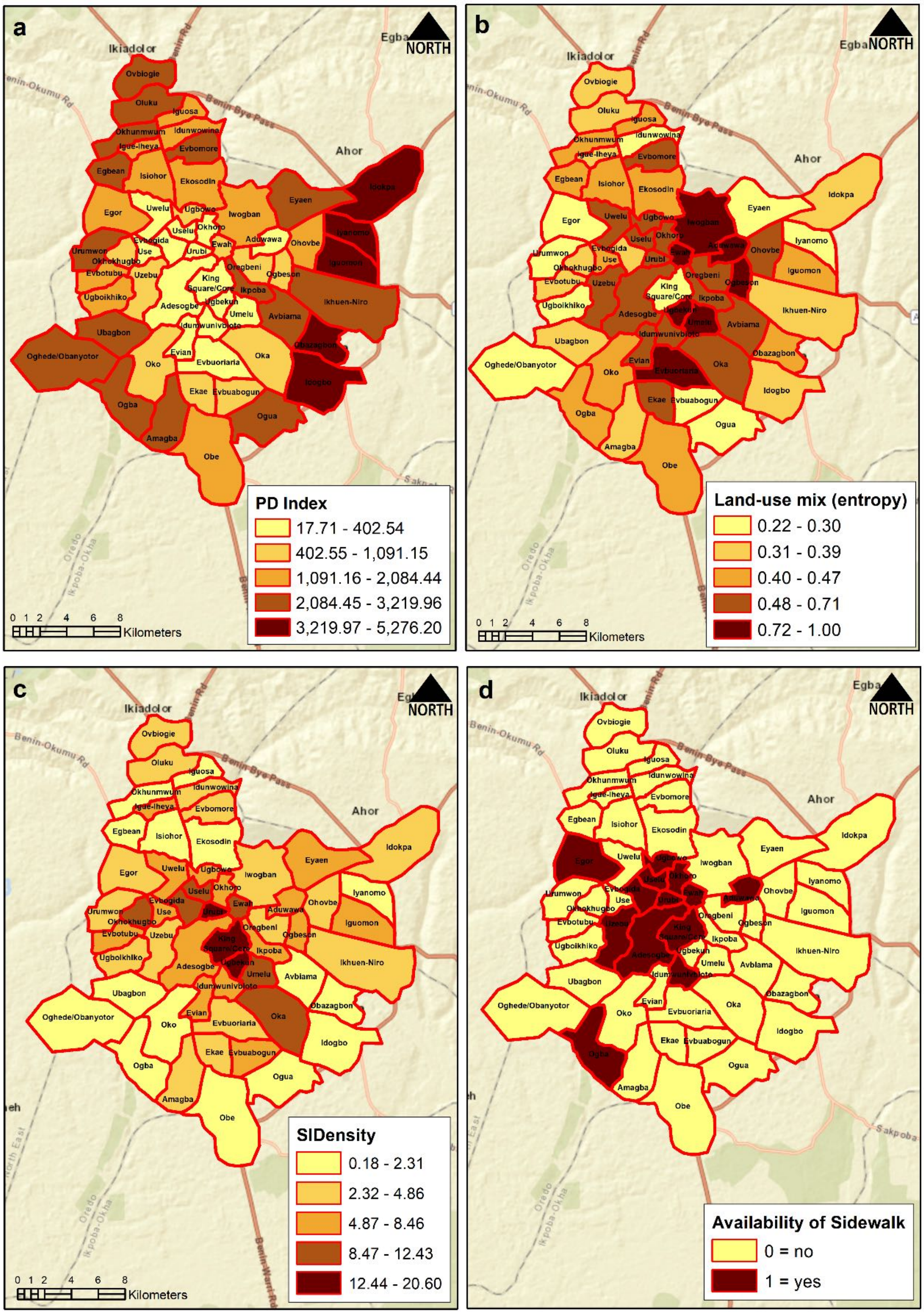

Fig.3 (a) is a patch density index (PD); (b) is a land-use mix entropy index; (c) is street intersection index (SI density), and (d) is the availability of sidewalk

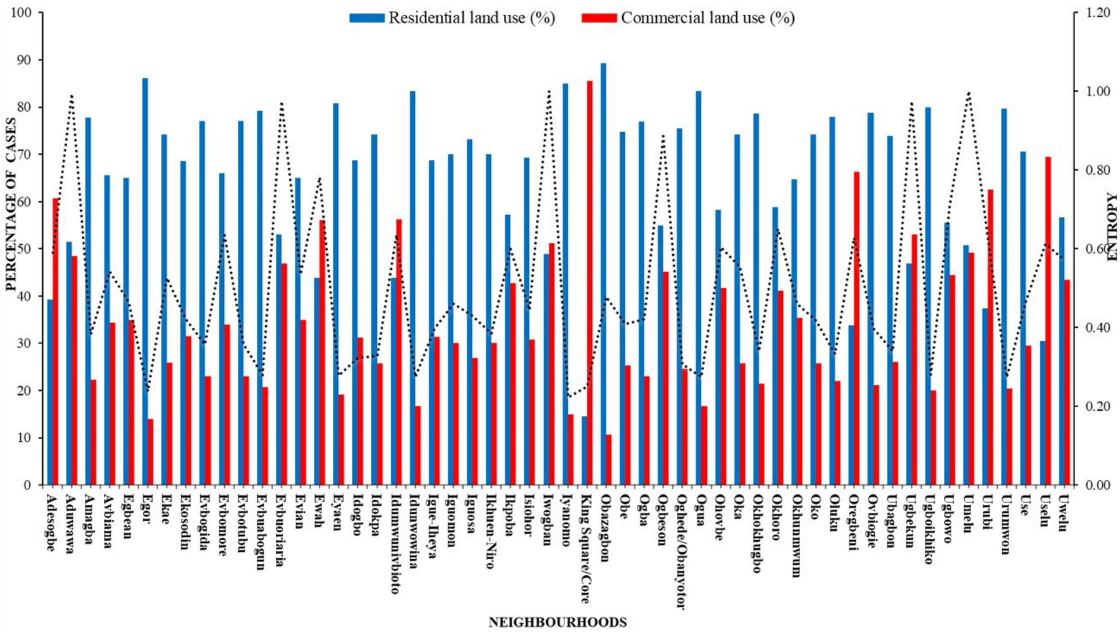

Fig.4 Neighbourhood-level comparison of land-use types concerning entropy index

4.3 Measuring SI Density index

Design dimension was generated from two platforms-the first is a GPS-based field survey for capturing neighbourhoods with sidewalks, parking spaces and the second is the use of GIS techniques to compute a Street Intersection (SI) Density index. This section is specifically designed to focus on generating spatial data which was used to quantify the BE of the study region. Generally, 2,024 4-way street intersections were found in the region and this was used for the computation of indicators. The result of the SI Density index is presented in Fig.3c. The result shows that Ugbekun has the highest SI Density index value of 20.6, indicating that the neighbourhood is characterised by roughly 20 street intersections per km2. This is followed closely by the King-Square and Urubi with roughly 15 street intersections each per km2. However, neighbourhoods with a higher density of street intersections tend to cluster in the centroid of the region. The majority of the neighbourhoods at the edge of the city have a low SI Density index of between 0 and 5.29 intersections per km2. A Higher SI Density index means a higher level of grid design and this structure may encourage short distance travel and may discourage transit mode of travel.

4.4 Availability of sidewalk

Another indicator of the design dimension is the availability of sidewalks within the neighbourhood. The presence of a sidewalk in a neighbourhood is an urban design issue that encourages people to walk more often to their place of work. Fig.3d revealed a binary measure of the status of sidewalk availability within neighbourhoods of the region where 0 represent no sidewalk and 1 represent yes (i.e. the presence of sidewalk). Fig.3d shows that among the 55 neighbourhoods, 13 have sidewalks and the majority of these neighbourhoods formed a cluster at the central or core axis of the study region. However, 3 neighbourhoods seem to be detached from the cluster because they are closer to the edge of the city. These neighbourhoods are Egor, Ogba and Aduwawa.

4.5 Distance to CBD

The average distance of each neighbourhood to the CBD was used to define the destination accessibility dimension. Distance to CBD was measured using the average distance of the neighbourhood to the CBD through a regular bus route or a major road in such a neighbourhood. The respective distances were entered into ArcGIS to generate a choropleth map of the region depicting the distance relationship of the adjacent neighbourhoods with CBD located in the King-Square neighbourhood (Fig.5a).

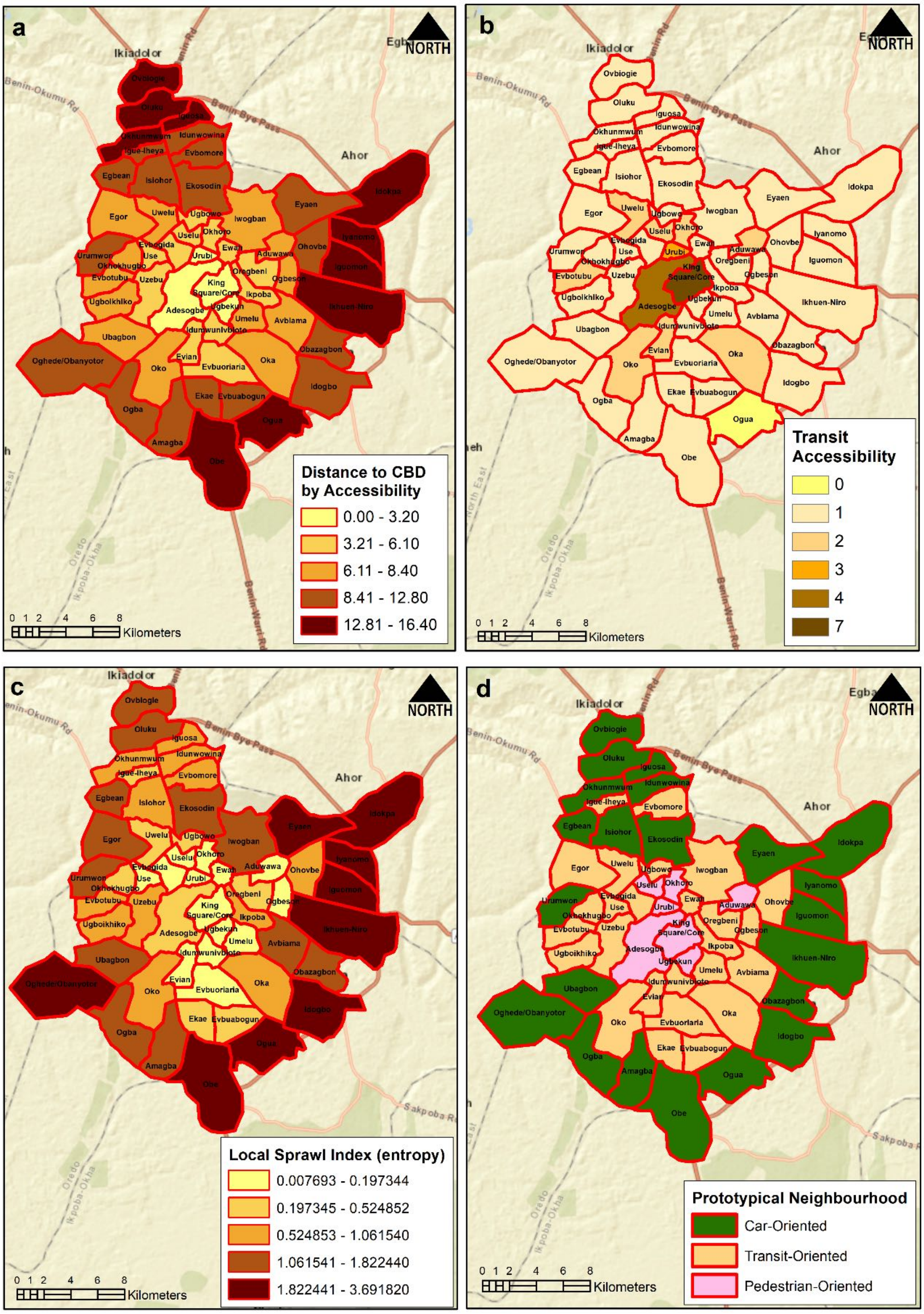

Fig.5 (a) is distance accessibility index; (b) is transit accessibility index; (c) is the local sprawl entropy index, and (d) is the type of neighbourhood in the Benin region

The general pattern is as expected–accessibility decreases with increasing distance from the CBD (the colour ramp in Fig.5a presents a clear visual explanation). Accessibility is lower in the peripheral areas, specifically the northwest, northeast and southeast parts of the region. This is because urban expansion is more rapid in these areas due to the influence of the high priority roads.

The overall average distance in the region is 8.94 km and the maximum distance to the CBD is 16.4 km, the minimum distance to the CBD is 1.7 km. Ovbiogie has the maximum distance from the CBD while Adesogbe has the minimum distance. This means that Adesogbe is the most accessible neighbourhood (by bus route) from the CBD and Ovbiogie is the least accessible neighbourhood (by bus route) from the CBD. 9 neighbourhoods returned the highest friction of distance from the CBD of over 13.1 km. These are depicted by the darkest shade in Fig.5a. For further computation, any neighbourhood whose distance from the CBD is higher than the regional average is interpreted as a neighbourhood with low accessibility while those with a distance lower than the regional average is interpreted as a neighbourhood with high accessibility. Low accessibility neighbourhoods may promote automobile usage. A custom filter result in Fig.5a revealed that 26 of the 55 neighbourhoods are low accessibility areas. This is because their distance values are above the regional average of 8.94 km. Some of these neighbourhoods are Ovbiogie, Idokpa, Oluku, Iyanomo, Okhunmwum, Ikhuen-Niro, Iguosa, Obe, Ogua, etc.

4.6 Transit accessibility

Transit route density/accessibility dimension was measured with the number of regular bus routes within the neighbourhoods. King-Square has 7 regular bus routes indicating that accessibility is higher in this neighbourhood. This is followed by Adesogbe (with 4 bus routes) and Urubi (with 3 bus routes). Other neighbourhoods are either 2, 1 or 0 number of regular bus routes (Fig. 5b). King-Square, Adesogbe and Urubi are characterised by not less than 3 regular bus routes, indicating higher accessibility correspondingly are part of the highest accessible neighbourhoods from the CBD (Fig.5a). Ogua has the least level of accessibility. This is because there is no regular bus route in the neighbourhood and it has a friction of distance of over 13 km.

4.7 Local sprawl

Spatial Shannon's entropy index for urban sprawl was used to empirically measure sprawl dimension in the study area and this was calculated at the neighbourhood level. The overall result of the computation is presented in Fig. 5c which is a choropleth map of the 5-class Jenks classification. The data used for the computation is the urban patch extracted from the classified World view image of the study region.

The entropy index value for the sprawl measurement ranges from 0 to $\log_e(n)$. Since the index was computed neighbourhood-wise and there are 55 neighbourhoods, then $n = 55$. $\text{Log}_e(55)$ therefore is 4.007. In this study, entropy values near 4.007 are interpreted as the occurrence of urban sprawl. Those near to 0 is interpreted as compactness (no sprawl). The result of the analysis shows that urban sprawl is stronger at the periphery specifically at the southwest, southeast and northeast part of the region. 9 neighbourhoods returned entropy values greater than 1.82. These are: Idokpa (3.69); Ikhuen-Niro (3.13); Oghede/Obanyotor (2.77); Idogbo (2.67); Obe (2.25); Eyaen (2.22); Iguomo (2.15); Iyanomo (2.15); and Ogua (2.12). Other neighbourhoods that returned entropy values greater than 1 (but less than 2) are: Iwogban (1.82); Obazagbon (1.81); Ogba (1.63); Ubagbon (1.60); Oluku (1.58); Avbiama (1.53); Ovbiogie (1.52); Amagba (1.50); Egor (1.46); Ekosodin (1.28); Egbean (1.25); Urumwon (1.22); Okhunmwum (1.06); and Evbomore (1.01). Among these, 5 neighbourhoods are located in the northwest while 2 are located in the northeast.

These 23 neighbourhoods whose entropy index values are greater than 1 and nearer to 4.00 ($\log_e(55)$) reveals the occurrence of sprawl. Though, Idokpa and Ikhuen-Niro manifest stronger urban sprawl occurrence. Ugbekun returned the lowest entropy index values (0.007693) indicating that it is more compact than any other neighbourhood since it is closer to zero (0). This confirms the previous result regarding PD that Ugbekun has the highest urban density in the region. However, the sprawl index values were saved for further analysis as data for measuring the BE.

4.8 Defining travel-related prototypical neighbourhood

Fig.5d depicts the result of the overlay analysis for defining the travel-related prototypical neighbourhoods. It shows that the quantifying of the BE of the region using 7 indicators, categorized BMR into 3 distinct prototypical neighbourhoods. 7 neighbourhoods in the inner cluster around the CBD formed the pedestrian-oriented zone and 26 neighbourhoods that concentrically formed a cluster around the pedestrian zone were categorized into the transit-oriented zone while 22 neighbourhoods likewise that formed a cluster around the transit-oriented zone were categorized into the car-oriented zone. The car-oriented zone is formed at the edge of the city and the neighbourhoods of this zone are characterised essentially by low density, a high degree of sprawl, low transit accessibility, high distance accessibility, and low street intersection density. These BE characteristics promote high dependency on car use (Cho & Rodriguez, 2014; Nkeki & Asikhia, 2019) and it is clear in literature such a level of dependency on combustible modes of travel poses a significant threat to human well-being (Fenu, 2012). The inner zone is characterised by high urban density, high land-use mix, low sprawl magnitude, high transit and distance accessibility, and availability of sidewalks in most of its neighbourhoods. This inner zone classified as pedestrian-oriented manifest the BE characteristics that encourage people to walk (Kim & Brownstone, 2013). This is because trip length is significantly reduced and potential destinations are brought closer together within walkable distance. The zone in between the car-oriented and pedestrian neighbourhood clusters is the transit-oriented zone. This zone is characterised by the BE indicators that promote transit mode of commuting and these are medium urban density, high land-use mix, medium street intersection density, medium distance and transit accessibility and medium-low degree off sprawl. The transit-oriented zone is a zone of intermediate level of BE indicators, especially those that favour transit performance.

5. Conclusion

In this study, the various indicators of the 6 dimensions of the BE in land-use-TB studies were modelled. These were used to quantify the BE of the Benin metropolitan region from the neighbourhood-scale perspective. This was achieved by implementing spatial metrics for measuring urban density, spatial entropy for quantifying sprawl and land-use mix, the index for quantifying urban design and other measurements of accessibility. The result shows that the urban density of the study region reduces with increasing distance from the core region. It was also discovered that 13 neighbourhoods, aggregately covering about 71 km^2 which formed a cluster in the core region have the highest urban density. These neighbourhoods formed the pedestrian-oriented zone and part of the transit-oriented zone which is a prototypical neighbourhood design for transit and pedestrian mode of travel.

The result of urban sprawl indicates that the region manifests urban sprawl characteristic which is stronger at the edge of the city specifically in the northeast, southwest and southeast part of the region. Fundamentally, the region is experiencing a dispersed and haphazard urban growth specifically taking place on the edge of the city and mostly along the corridor roads. Entropy statistics for land-use mix revealed that the general pattern of the region concerning land-use diversity is a complex mixture of residential and commercial land-uses. This is largely influenced by the location of the King-Square because the mixed cluster is formed contiguously around the King-Square neighbourhood which is itself a homogenous land-use neighbourhood. In the peripheral area, neighbourhoods with a single dominant land-use type formed patches around the heterogeneous land-use composition. King-Square is the only homogenous commercial land-use neighbourhood in the region. However, based on entropy statistic results, 5 land-use categories (from the residential and commercial land-uses) were identified and these were named *pure residential* and *pure commercial*, *largely residential*, *weakly mixed land-use* and *robust mixed land-use*.

The quantification of the SI Density index for urban design of BMR yielded a substantial result that seems to delineate the region into a cluster of neighbourhoods with high-density street intersections and a cluster of neighbourhoods with a low-density street intersection. The former is located around the CBD and the latter is formed in the periphery, contiguously around the CBD. Expectantly, the general pattern of accessibility in the region is a decrease in accessibility with increasing distance from the CBD. The result of the indicators has a common characteristic. They were able to distinctively separate the core axis from the peripheral axis and a zone of transition was also formed between the core and periphery from the interaction of the indicators. This indicates that there is indeed a core-periphery relationship in the region.

5.1 Policy and planning implication

An important policy consideration from the global perspective is to encourage concentrated density and promote mixed land-use developments. This is well articulated in literature and is fast becoming a sustainable method of solving the problem of long commuting distance and time, reduce vehicular traffic congestion, and cut down fossil fuel usage. This policy tends to discourage sprawl and any other urban structure that may promote over-dependent on cars for personal travel. Most large cities have started to leverage functional transit systems such as light rail transit and bus rapid transit that can convey a large number of people to multiple destinations. BMR is yet to key into the policy plan. This characterises most cities in Africa. However, the result obtained in this work can inform policymakers and urban planners on the existing urban structure and neighbourhood characterisation for a comprehensive master plan and future transport demand optimisation and regulations. Since the methodology adopted here was able to quantify each neighbourhood and define their BE structure based on their relationship with TB. The 3 prototypical neighbourhoods that emerged from the result of the analysis is a sign of a robust method of quantifying the BE which seems to reveal the influence of tradition planning apparatus.

Future planning and public policies for sustainable development must begin from the grassroots, such as neighbourhoods or communities. It is evident that from such a spatial entity, a development-oriented policy can be formulated specifically for different local areas. This is because peculiarity exists in different urban spaces, attempting to change these inherent local urban trails that have formed over a long time may be counter-productive. Hence, sustainable development can be achieved by implementing policies that would integrate properly into the urban fabric of concern. This understanding is key for a successful implementation of existing robust ideologies emerging from global scholars on travel and land-use. For example, there is a growing wishful concern for urban areas to be compact, activity-driven, accessible, mixed-use, transit-rich and pedestrian favourable, but this is yet to be achieved not only in the policies guiding Africa cities but also in large European cities (La Rocca, 2010). Several policy guidelines that show concern for the environment and urban liveability have been put forward. They include the integration of cycling into the transport policy (Fenu, 2012; Masoumi et al., 2020); mass transit mobility using light rail transit (LRT) and bus rapid transit (BRT) for corridor areas (Zacharias, 2020); and increased walking for good health and fitness purposes.

For these policies to be effectively implemented, urban governance must first be tailored towards understanding the complexity of the urban space and various interactions within. The approach put forward in this study would be of essential help to the policy and urban planners of BMR since it has identified local areas of need and the potential differential transport policy interventions that may be associated with neighbourhoods. For example, the delineated transit-oriented neighbourhoods can be improved by re-designing the corridor roads to allow for BRT deployment. Policies that promote walking and cycling must be advocated in pedestrian-oriented neighbourhoods. Every road in this neighbourhood cluster (undermining the surfacing type) must be designed to be pedestrian-friendly by constructing sidewalks and cycling lanes along the roads. These public infrastructures would encourage a change in the travel behaviour of the commuters. There is an urgent need to reduce the number of car-oriented neighbourhoods in the region. This can be achieved by manipulating the neighbourhood BE to reduce sprawl development through edge city growth restrictions or promoting self-contained suburban development. Alternatively, make these neighbourhoods transit-friendly by increasing transit accessibility.

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Image Sources

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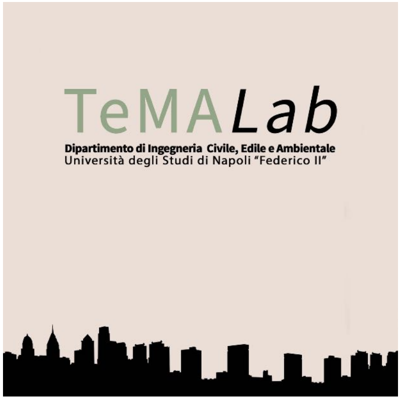

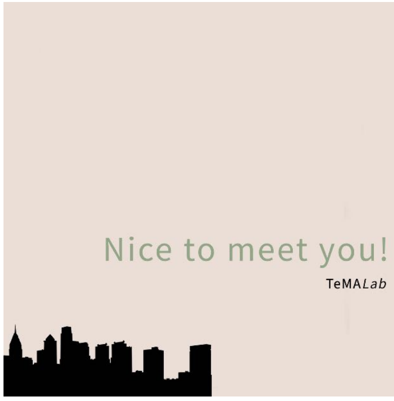

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Covid-19 pandemic and activity patterns in Milan. Wi-Fi sensors and location-based data

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Abstract

The recent development of location detection systems allows to monitor, understand and predict the activity patterns of the city users. In this framework, the research focuses on the analysis of a sample of aggregated traffic data, based on the number of mobile devices detected through a network of 55 Wi-Fi Access Points in Milan. Data was collected over 7 months (January to July 2020), allowing for a study on the impact of the Covid-19 pandemic on activity patterns. Data analysis was based on merging: (i) time series analysis of trends, peak hours and mobility profiles; (ii) GIS-based spatial analysis of land data and Public Transport data. Results showed the effectiveness of Wi-Fi location data to monitor and characterize long-term trends about activity patterns in large scale urban scenarios. Results also showed a significant correlation between Wi-Fi data and the density distribution of residential buildings, service and transportation facilities, entertainment, financial amenities, department stores and bike-sharing docking stations. In this context, a Suitability Analysis Index is proposed, aiming at identifying the areas of Milan which could be exploited for more extensive data collection campaigns by means of the installation of additional Wi-Fi sensors. Future work is based on the development of Wi-Fi sensing applications for monitoring mobility data in real time.

Keywords

Urban mobility; Traffic data; Wi-Fi sensors; GIS analysis; Covid-19 pandemic.

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1. Introduction

Urban Informatics (Foth et al., 2011) provides innovative assessment tools and metrics to support an effective planning of mobility services, within an evidenced-based and multi-disciplinary approach. Thanks to the recent development of advanced ICT solutions and the increasing availability of digitally widespread data sources, Big Data is becoming a valuable support to unveil hidden mobility patterns in the cities (Batty, 2013; Crist et al., 2015): "[...] as representing measures of the 'pulse' of a city, as a measure of locational focus that moves in space and time but correlates in diverse ways with the substrata of the city which change much more slowly, such as population and employment densities and related infrastructures" (Batty, 2010, p.576).

In particular, the development of location detection systems allows to monitor, understand and predict the travel behavior of city users, considering both micro (e.g., road intersections) and macro scale scenarios (e.g., large transport infrastructures) (Xhafa et al., 2017). These include the following techniques for data collection:

- images stream analysis and acquisition systems (Buch et al., 2011): AI and computer vision techniques for processing a sequence of photographs or a video clip collected through CCTV cameras or drones;
- radio frequency systems based on Wi-Fi or Bluetooth technology (Sapiezynski et al., 2015): antenna type sensors for scanning wireless devices through the media access control (MAC) address (i.e., *unique identifier of each network device*);
- cell network data acquisition systems (Becker et al., 2013): data derived from subscriber identity modules (SIM cards) and cell network technology;
- software development kit, Beacon and bid stream systems (Lin & Hsu, 2014): data derived from Global Positioning System (GPS) signal of navigation devices and Apps for smartphones;
- Occupancy Detection Systems (Odat et al., 2017): light pulse type remote detection techniques, including Laser Imaging Detection and Ranging (LIDAR) and passive infra-red (PIR) sensors.

Nowadays, monitoring traffic data has become even more crucial for the activity of transport planners and decision makers, considering the need to investigate the unprecedented effects of disruption of the Covid-19 pandemic on urban mobility and to assess the effectiveness of immediate and longer-term actions that cities have developed to respond to the crisis (Coppola & De Fabiis, 2020; European Platform on Sustainable Urban Mobility Plans, 2020). In just a few months the nation-wide lockdown and post-lockdown phases have drastically changed citizens behaviors and mobility patterns related to the cities, neighborhoods and streets in which they live (Deponte et al., 2020; Zecca et al., 2020). Taking advantage of a preliminary work already presented by the authors[1], the current paper is based on the analysis of a large sample of structured proprietary data gathered during a 7-month period (January to July 2020) through a network of 55 Wi-Fi sensors distributed in several department stores, shops and public services in Milan (Italy). The objective of the analysis is twofold. First, the research aimed at testing the effectiveness and reliability of Wi-Fi technology to collect aggregated data about activity patterns in large scale urban scenarios. In this framework, the number of mobile devices detected per day per hour during the entire period of reference was analyzed to estimate the effects of the Covid-19 pandemic on activity patterns. In particular, a time series analysis on trends, peak hours and mobility profiles was executed to compare results between the Pre-Covid-19 period (from January 1st to February 22nd, 2020) and the lockdown Phase 0, 1, 2 and 3 (from February 23rd to July 31st, 2020). Second, the research aimed at correlating the number of detected mobile devices (i.e., *time-variant data*) with the density distribution of relevant land and Public Transport data (i.e., *time-invariant data*), such as building typologies, green areas, amenities and Public Transport. Given the unprecedented effects of the adopted containment measures on urban dynamics (e.g., restricted mobility, partial opening or closures of public services, etc.), the proposed GIS-based analysis aimed at understanding which areas of the city were more

[1] See: https://research.systematica.net/journal/monitoring-big-traffic-data-through-wi-fi-sensors-the-evolution-of-the-lockdown-phases-in-milan/

resilient during the evolution of the lockdown phases, considering the variation of Wi-Fi data during the entire period of reference. Moreover, the results of the analysis were used to define a *Suitability Analysis Index* (Santos & Moura, 2019), aiming at identifying the areas of Milan which could be exploited for more extensive data collection campaigns by means of the installation of additional Wi-Fi sensors. The paper proposes a review of relevant applications and scientific contributions focused on the use of the Wi-Fi technology for collecting data about activity patterns in urban areas (namely traffic data), in order to provide a preliminary assessment of its advantages and limitations. Then, it presents the enabling data and methodology which sets the current work, and the results of time series analysis of Wi-Fi data and GIS-based analysis of location-based data. The paper concludes with final remarks about the achieved results and future work.

1.1 Related Works

Wi-Fi technology is recognized as one of the most effective sensors for monitoring activity patterns, considering both outdoor and indoor scenarios. This is due to installation and maintenance costs, precision rate, energy consumption, robustness to weather and light conditions (Bernas et al., 2018), and compliance to the General Data Protection Regulation (GDPR) (National Centre for IoT and Privacy, 2020). Additionally, the ubiquity of Wi-Fi sensors in cities enable the collection of data with high spatial and temporal granularity (Kontokosta & Johnson, 2017). In recent years, numerous studies addressed potentialities and shortcomings of Wi-Fi technology to enhance the existing traffic monitoring infrastructure, including the following:

- Transport for London (2019) conducted an extensive pilot research on Wi-Fi data collection and analysis to improve services. The study proved that Wi-Fi technology could enable more efficient planning and management of the transport infrastructure;
- Sapiezynski et al. (2015) investigated the possibility to accurately track students' movements on campus with a reduced number of existing Wi-Fi APs, due to low variability of activity patterns, and discussed the implications on user's privacy;
- Bellini et al. (2017) proposed a methodology to select existing Wi-Fi APs at optimal locations in order to produce accurate OD matrices, daily users' mobility behaviors analyses and forecasting;
- Kontokosta and Johnson (2017) estimate types of residents based on activity patterns of users connecting to the Wi-Fi network, with the aim to create a real-time census of the city;
- Soundararaj et al. (2020) used Wi-Fi probe requests to identify footfall patterns in retails, with a focus on methods to validate data;
- Kostakos et al. (2013) proposed an integration of magnetic loops traffic sensors with the existing Wi-Fi infrastructure to monitor cities in near real-time.

Among the limitations of Wi-Fi technology, it has to be noted that it does not allow to disaggregate data among different means of transportation (e.g., private motorized vehicles, cyclists, pedestrians, etc.). The capability of this technology to detect mobile devices depends on its connection features, its battery level and actual usage. The accuracy of Wi-Fi data can be also influenced by background noise due to fixed devices and systematic errors due to the device's orientation. Furthermore, the possibility to estimate traffic data is limited by the possibility to detect multiple mobile devices per users, leading to an oversampling error (Soundararaj et al., 2020).

2. Enabling Data and Methodology

Thanks to the collaboration with the Wi-Fi service provider FreeLuna[2], a large sample of proprietary data was collected through a network of 55 Wi-Fi sensors (see Fig.1 and Tab.1) from the beginning of January 2020 to

[2] See: https://www.futur3.it/en/

the end of July 2020. First, the proposed time series analysis was focused on the number of mobile devices detected per day per hour through the Wi-Fi sensors, in order to highlight trends, peak hours and mobility profiles during the entire period of reference. Then, results were compared against an extensive GIS-based analysis focused on relevant land and Public Transport data (see Tab.1), which were retrieved, sorted and filtered from geoportals and open data repositories. This information was analyzed to design a multi-layer map of Milan and to estimate the spatial distribution of each dataset considering the localization of the Wi-Fi Access Point (APs).

Fig.1 The location of the 55 Wi-Fi APs, with related radius of action (r = 80 m) and catchment areas (r = 280 m)

From a general point of view, the proposed GIS analysis was based on various attributes and characteristics of the urban area surrounding each Wi-Fi sensor. To do so, raw data related to the urban scale were extracted about surrounding areas of each Wi-Fi AP (see Fig.2 and Fig.3). A catchment area with a radius of 280 m (circular buffer areas of 0.246 km^2) was designed, considering the radius of action of installed Wi-Fi sensors (80 m) and the travel distance allowed from place of residence within the restricted territories during the lockdown Phase 1 (200 m), according to the national regulation enforced by the Italian Government[3].

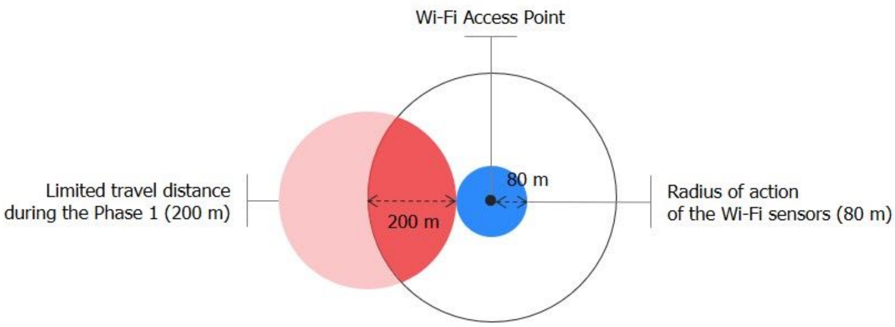


Fig.2 The catchment area surrounding each Wi-Fi AP is based on the radius of action of the Wi-Fi signal (r = 80 m) and on the travel distance allowed within the restricted territories during the lockdown Phase 1 (r = 200 m)

Data analysis was based on counting the number of mobile devices (e.g., smartphones, tablets, notebooks, etc.) detected per hour per day by means of the 55 Wi-Fi APs. A preliminary data validation allowed us to discard the Wi-Fi data collected from a few malfunctioning APs, characterized by an irregular signal. The clean data set consists of a total of 111,100,558 mobile devices, representing in an aggregated manner the traffic

3 See: http://www.governo.it/it/coronavirus-misure-del-governo

data (TD) observed in Milan during the entire period of reference and constituted by various means of transportation. Then, the time series of Wi-Fi data was post-processed and analyzed focusing on trends, peak hours and mobility profiles.

Indicator	Data typology	Parameter	Data Source	Year
Traffic Data	Wi-Fi APs position	-	FreeLuna	2020
	Timestamp (YYYYMMDDhh)	-	FreeLuna	2020
	Counted mobile devices	TD	FreeLuna	2020
Land Data	Residential Buildings	ReB	Geoportal Lombardy Region	2012
	Administrative Buildings	NReB_Ad	Geoportal Lombardy Region	2012
	Commercial Buildings	NReB_Co	Geoportal Lombardy Region	2012
	Industrial Buildings	NReB_In	Geoportal Lombardy Region	2012
	Service and Transportation	NReB_ST	Geoportal Lombardy Region	2012
	Green Areas	GA	Geoportal Lombardy Region	2012
	Education Amenities	A_Ed	Geoportal City of Milan and OpenStreetMap	2020
	Entertainment Amenities	A_En	Geoportal City of Milan and OpenStreetMap	2020
	Financial Amenities	A_Fi	Geoportal City of Milan and OpenStreetMap	2020
	Shops	A_Sh	Geoportal City of Milan and OpenStreetMap	2020
	Department Stores	A_DS	Geoportal City of Milan and OpenStreetMap	2020
	Sustenance Amenities	A_Su	Geoportal City of Milan and OpenStreetMap	2020
Public Transport Data	Bike-sharing Stations	PT_Bi	Geoportal City of Milan	2020
	Subway Lines	PT_Su	Geoportal City of Milan	2020
	Tram Lines	PT_Tr	Geoportal City of Milan	2020
	Bus Lines	PT_Bu	Geoportal City of Milan	2020

Tab.1 The list of proprietary and open datasets that were analyzed and merged for understanding the impact of the lockdown phases on activity patterns in Milan

The proposed GIS data analysis was based on extracting a series of location-based data from the areas surrounding each Wi-Fi AP, focusing on:

- Land Data (Geoportal of Lombardy Region[4]; Geoportal of the City of Milan[5]; OpenStreetMap[6]):
  - Residential buildings (ReB), administrative (NReB_Ad), commercial (NReB_Co), industrial buildings (NReB_Co) and service and transportation facilities (NReB_ST);
  - Green areas (e.g., parks, public gardens, flowerbed) (GA);
  - Amenities: education (A_Ed) (e.g., school, University, library, etc.), entertainment, arts and culture (A_En) (e.g., museum, cinema, etc.), financial (A_Fi) (e.g., ATM, bank), healthcare (A_He) (e.g., hospital, pharmacy, etc.), shops (A_Sh), department stores (A_DS) and sustenance (A_Su) (e.g., bar, restaurant, etc.);
- Public Transport Data (Geoportal of the City of Milan): bike sharing docking stations (PT_Bi), subway lines (PT_Su), tram lines (PT_Tr) and bus lines (PT_Bu).

The dataset, composed by punctual, linear and areal vectors, was analyzed through density-based calculation on catchment areas. For the purpose of comparing the various indicators among them, each one has been normalized on a 0-1 scale, creating Z-scores that follow the normal distribution of the values. The following step has involved the calculation of a series of correlations (using Pearson's Correlation Coefficient) between

[4] See: http://www.geoportale.regione.lombardia.it/en/home
[5] See: https://geoportale.comune.milano.it/sit/
[6] See: https://www.openstreetmap.org/

the normalized values of density for each indicator. The problem of accounting for autocorrelation of the variables included in this study was then considered by implementing a modified t-test of spatial association derived from the work of Clifford et al. (1989). This is mainly based on the corrections of the sample correlation coefficient between two spatially correlated variables and requires the estimation of an effective sample size. The modified t-test helped to adjust Pearson's correlation coefficients and the respective p-values, removing the variables whose p-value was no more significant if accounting for autocorrelation.

All the significant correlation coefficients were then included in the calculation of the Suitability Analysis Index (SAI). This was essentially based on a weighted summation of the normalized density values of the variables proposed in this study (taking into account autocorrelation results) and on the use of the open sourced H3 hexagonal grid presented by Uber Engineering in 2018[7]. This was aimed at identifying the areas of Milan which could be exploited for more extensive data collection campaigns of traffic data by means of the installation of additional Wi-Fi sensors.

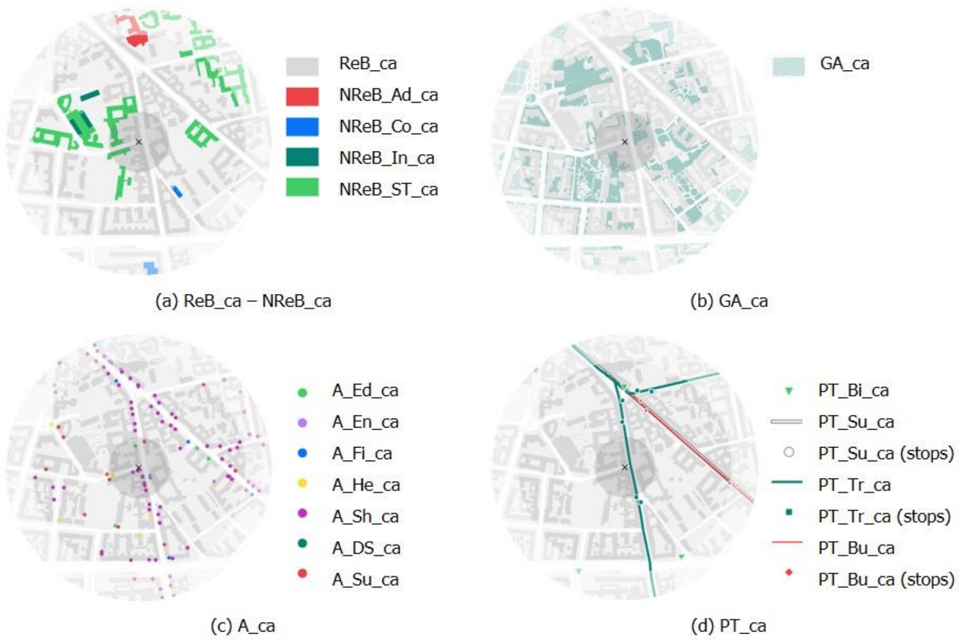


Fig.3 An exemplification of the procedure applied to extract the land and Public Transport data on catchment areas

3. Results

3.1 Time-series analysis

The analysis was aimed at identifying significant variations in the number of mobile devises detected through the Wi-Fi sensors during the Pre-Covid-19 period and the lockdown Phase 0, 1, 2 and 3. The definition of the lockdown phases is based on the containment measures enforced by the local and national governments, which gradually prohibited any movements to, from and within the restricted territories to contrast the spread of contagion[8]. A series of information related to the timeline of the lockdown phases are described below:

- pre-Covid-19 period (from January 1st, 2020, to February 22nd, 2020): The Covid-19 virus was first confirmed to have spread to Italy on January 31st, 2020. A cluster of cases was detected in the Lombardy Region on February 21st, 2020;

[7] See: https://eng.uber.com/h3

[8] See: http://www.governo.it/it/coronavirus-misure-del-governo

- phase 0 (from February 23rd, 2020, to March 8th, 2020): Milan was defined by the local government as a "yellow zone". The Duomo Church, the Scala theatre and other cultural sites were temporally closed, as well as schools and Universities; bars and clubs closed at 6 pm;
- phase 1 (from March 9th, 2020, to May 3rd, 2020): Milan was defined by the Italian government as a "red zone" (along with the entire Lombardy Region). In order to avoid gatherings, the access to green areas, educational, entertainment, sport, sustenance, religious and commercial public services was banned (apart from tobacco shops, food and do-it-yourself department stores). Public Transport capacity was reduced to 25% to allow social distancing. Any movement was prohibited to and from the restricted territories, as well as within the territories themselves. Apart from health and emergency reasons, the travel distance allowed from the place of residence was limited to 200 m;
- phase 2 (from May 4th, 2020, to June 14th, 2020): Gradual easing of the lockdown containment measures, as the epidemic curve was in a downward phase. Green areas, sustenance, commercial and religious public services were reopened, but strongly limited to a fixed quota of accesses and services hours. Public Transport capacity was kept at 25%;
- phase 3 (from June 15th, 2020, to July 31st, 2020): Further easing of the containment measures. Entertainment public service were reopened. Public Transport capacity was increased to 50%.

The analysis of Wi-Fi data trends (see Tab.2 and Fig.4) was based on the total and average number of mobile devices detected per day through the entire network of Wi-Fi sensors, from January 2020 to July 2020. Data analysis highlighted a significant difference between the datasets related to the Pre-Covid-19 period and the lockdown phases, caused by the evolution of the containment measures put in place to contrast the spread of contagion. The results of a series of independent samples t-tests[9] (two-tailed) showed a significant difference between the average number of mobile devices detected per day during the Pre-Covid-19 period and the lockdown Phase 0 ($t(66) = 7.583$; $p < .01$), Phase 1 ($t(106) = 31.857$; $p < .01$), Phase 2 ($t(93) = 21.254$; $p < .01$) and Phase 3 ($t(98) = 15.004$; $p < .01$).

Further data analysis was based on the calculation of the percentage difference between the moving average of the number of detected mobile devices (MA, time period: 3 days) and the cumulative average of values (CA, time period: 7 months). This allowed us to smooth out short-term fluctuations of data and to highlight long-term trends (see Fig.4), such as: (*i*) the downsized amount of traffic volumes observed during the first week of January, 2020, due to the holidays; (*ii*) the stable trend of data during the Pre-Covid-19 period; (*iii*) the gradual downward trend of data during the lockdown Phase 0; (*iv*) the flattened traffic volumes during Phase 1 (total lockdown); (*v*) the gradual increase of traffic data during Phases 2 and 3, due to the easing of the containment measures.

Phases	Time period	Total	Average	SD	Trend
Pre-Covid-19	From 01/01/2020	56,273,763	843.091	1,610.054	--
Phase 0	Until 08/03/2020	10,239,857	528.210	907.143	-37%
Phase 1	Until 03/05/2020	8,437,822	141.186	690.046	-83%
Phase 2	Until 14/06/2020	13,235,535	279.195	736.948	-67%
Phase 3	Until 31/07/2020	22,913,563	440.942	1,064.999	-48%

Tab.2 The total number of mobile devices detected during the Pre-Covid-19 period and the lockdown Phase 0, 1, 2 and 3, with daily average and standard deviation. The table shows the percentage decrease of each lockdown phase compared to the Pre-Covid-19 period

9 All statistics presented in this paper have been performed by using the software IBM SPSS Statistics v.27 and R v.4.0.5 (Spatial Pack), and they have been conducted at the p < .01 level.

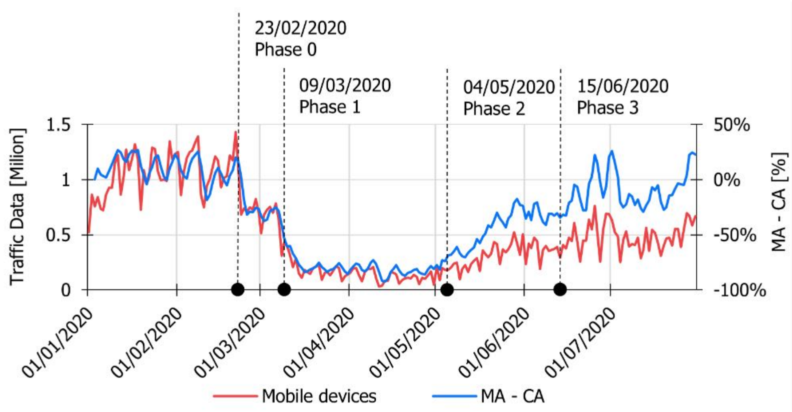


Fig.4 The number of mobile devices detected per day during the Pre-Covid-19 period and the lockdown Phase 0, 1, 2 and 3, and the percentage difference between the moving average (MA) and the cumulative average of values (CA)

3.2 Circadian rhythm and mobility profiles

The number of detected mobile devices was further analyzed to characterize peak hours (i.e., *circadian rhythm of the city*) (see Fig.5). Results showed that the Pre-Covid-19 period was characterized by peak hours in the working days afternoon (highest peak hour on Friday afternoon at 5 pm) and on Saturday evening and Sunday afternoon. Phase 0 was characterized by an overall decrease of traffic volumes, with relative peak hours in the afternoon. Phase 1 was characterized, instead, by a flattened temporal distribution of values during the entire week. Phases 2 and 3 were characterized by an increase of traffic volumes.

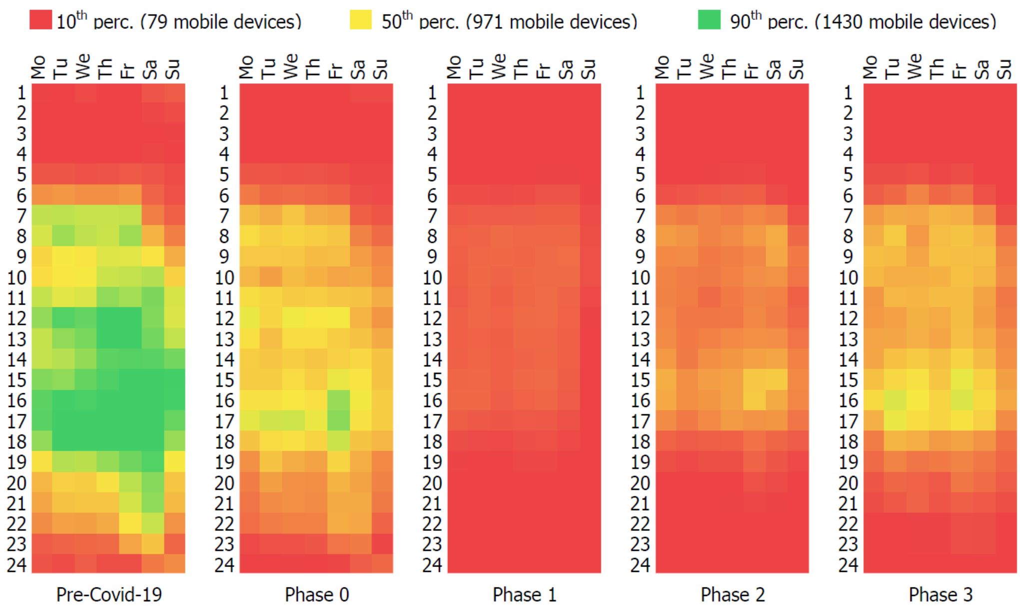
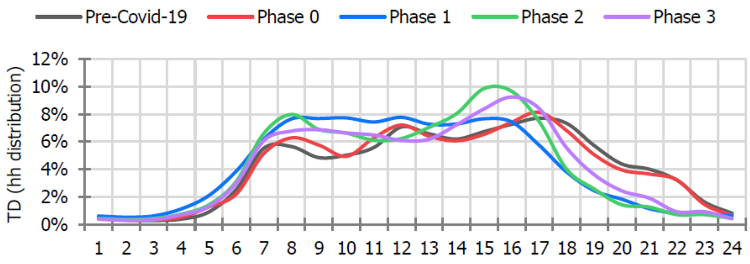
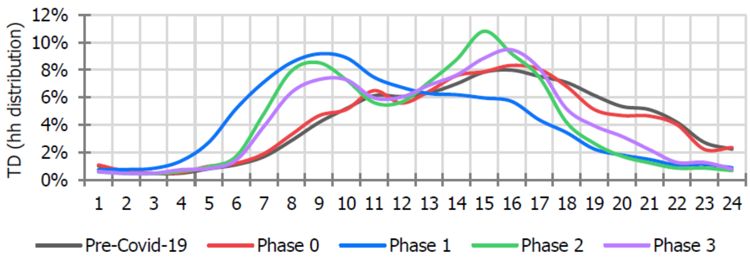


Fig.5 Peak hours per hour per day during the Pre-Covid-19 period and the lockdown Phase 0, 1, 2 and 3. Colour palette refers to the percentile frequency distribution of values for the Pre-Covid-19 period

The analysis of weekdays mobility profiles was based on the segmentation of the lockdown phases and on the calculation of the average hourly distribution of values (see Fig.6). Results highlighted consistent peaks for the Pre-Covid-19 period and all the phases (e.g., home-to-work and home-to-school mobility patterns, occasional demand related to leisure trips, etc.), exception made for the Phase 1. The flattened profile of Phase 1, from 8 am to 4 pm, is due to the absence of daily commuting and occasional leisure related trips. On the contrary, the analysis of weekends mobility profile highlighted an emerging phenomenon related to Phase 1, whose profile is an inverted copy of the one depicted for the Pre-Covid-19 period: whereas the latter showed a PM peak and a growing demand before noon, the former presented an AM peak and a decreasing demand after noon.



(a) Weekday profiles



(b) Weekend profiles

Fig.6 The (a) weekdays and (b) weekends average distribution of the number of detected mobile devices during the Pre-Covid-19 period and the lockdown Phase 0, 1, 2 and 3

3.3 Spatial analysis of land and Public Transport data

The proposed extensive GIS-based analysis[10] was executed to calculate the density distribution of building typologies, green areas, amenities and Public Transport located within the catchment areas surrounding each Wi-Fi AP (see Fig.3 and Tab.3).

Data	Measure	Average	SD	Pre-Covid	P0	P1	P2	P3
ReB_ca	[m^3/km^2]	6,177,670.273	2,115,604.956	•	•	•	•	•
NReB_Ad_ca	[m^3/km^2]	176,588.110	290,185.320	•	•	~	•	•
NReB_Co_ca	[m^3/km^2]	458,238.290	410,745.312	•	•	~	~	•
NReB_In_ca	[m^3/km^2]	72,873.005	170,419.409	•	•	~	•	•
NReB_ST_ca	[m^3/km^2]	903,631.974	1,071,623.767	•	•	~	•	•
GA_ca	[km^2/km^2]	0.150	0.116	•	•	x	•	•
A_Ed_ca	[No./km^2]	20.822	18.742	•	x	x	x	x
A_En_ca	[No./km^2]	10.042	12.003	•	x	x	x	•
A_Fi_ca	[No./km^2]	24.071	22.473	•	•	~	•	•
A_He_ca	[No./km^2]	21.339	11.781	•	•	•	•	•
A_Su_ca	[No./km^2]	181.786	75.624	•	•	x	~	~
A_Sh_ca	[No./km^2]	726.923	396.651	•	•	x	~	~
A_Ds_ca	[No./km^2]	29.461	57.364	•	•	~	•	•
PT_Bi_ca	[No./km^2]	8.934	6.604	•	•	•	•	•
PT_Su_ca	[No./km^2]	2.141	2.802	•	•	~	~	~
PT_Tr_ca	[No./km^2]	21.265	23.394	•	•	~	~	~
PT_Bu_ca	[No./km^2]	31.233	23.665	•	•	~	~	~

Tab.3 The density distribution of building typologies, green areas, amenities and Public Transport on catchment areas, and their closure/opening during the Pre-Covid-19 period and the lockdown Phase 0, 1, 2 and 3 (i.e., • open; ~ partially open; X closed)

[10] All GIS-based analyses presented in this paper have been performed by using the software QGIS v.3.16.1.

In this study, Clifford and Richardson (1989) effective sample size adjustment method was used to account for spatial autocorrelation in the Pearson's Correlation Coefficient, employing spatial correlation matrices for each variable to jointly measure the dependence between the number of detected mobile devices, namely traffic data, and the density distribution of building typologies, green areas, amenities, Public Transport (see Fig.7 and Tab.4). The results of the analysis showed:

- strong, positive correlation between the density distribution of department stores (A_DS_ca) and the traffic data collected during the Pre-Covid-19 period (R^2 = 0.575; r = 0.761; n = 52; $p < 0.01$), Phase 0 (R^2 = 0.484; r = 0.696; n = 52; $p < 0.01$), Phase 1 (R^2 = 0.259; r = 0.509; n = 52; $p < 0.01$), Phase 2 (R^2 = 0.492; r = 0.701; n = 52; $p < 0.01$) and Phase 3 (R^2 = 0.521; r = 0.722; n = 52; $p < 0.01$);
- moderate, positive correlation between the density distribution of residential buildings (ReB_ca) and the traffic data collected during the Pre-Covid-19 period (R^2 = 0.202; r = 0.449; n = 52; $p < 0.01$), Phase 0 (R^2 = 0.125; r = 0.354; n = 52; $p < 0.05$), Phase 1 (R^2 = 0.143; r = 0.379; n = 52; $p < 0.01$), Phase 2 (R^2 = 0.185; r = 0.430; n = 52; $p < 0.01$) and Phase 3 (R^2 = 0.138; r = 0.371; n = 52; $p < 0.01$);
- moderate, positive correlation between the density distribution of Service and Transportation facilities (ReB_ca) and the traffic data of the Phase 1 (R^2 = 0.137; r = 0.371; n = 52; $p < 0.01$);
- Moderate, positive correlation between the density distribution of entertainment, arts and culture amenities (A_En_ca) and the traffic data of the Pre-Covid-19 period (R^2 = 0.423; r = 0.643; n = 52; $p < 0.01$) and Phase 3 (R^2 = 0.296; r = 0.544; n = 52; $p < 0.01$);
- moderate, positive correlation between the density distribution of financial amenities (A_Fi_ca) and the traffic data of the Pre-Covid-19 period (R^2 = 0.138; r = 0.372; n = 52; $p < 0.05$) and Phase 1 (R^2 = 0.109; r = 0.331; n = 52; $p < 0.05$);
- weak, positive correlation between the density distribution of bike-sharing docking stations (PT_Bi_ca) and the traffic data of Phase 1 (R^2 = 0.094; r = 0.306; n = 52; $p < 0.05$);
- moderate positive correlation between the density distribution of education amenities (A_Ed_ca) and the traffic data collected during the Pre-Covid-19 period (R^2 = 0.152; r = 0.390; n = 52; $p < 0.05$). However, it has to be noted that this result was excluded from the analysis, since schools and Universities were permanently closed during the entire period of reference.

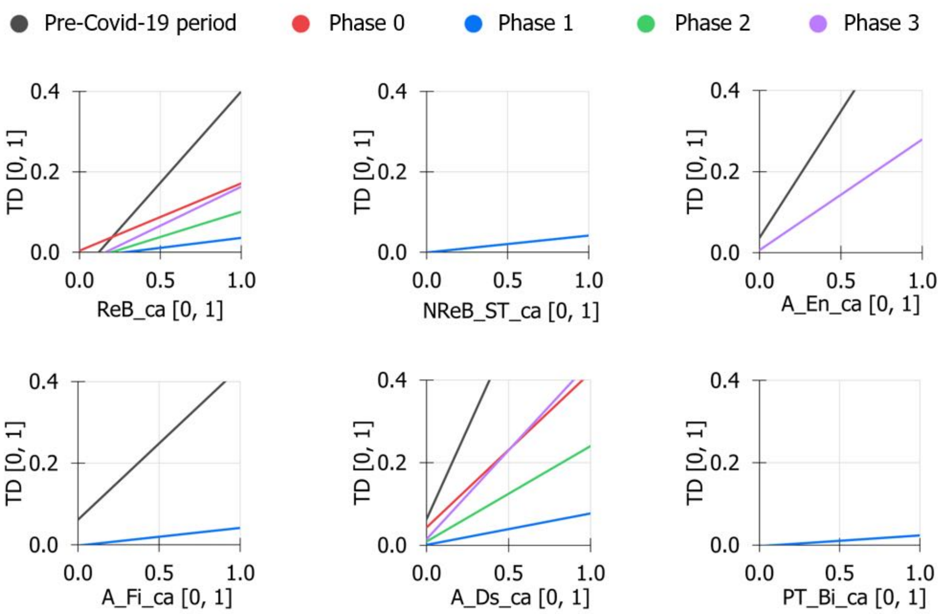


Fig.7 Linear trend lines show (when applicable and significant) the correlation results between Wi-Fi data (TD) and the land and Public Transport data extracted on catchment areas (z values in a range between 0 and 1)

Data	TD_Pre-Covid-19	TD_Phase 0	TD_Phase 1	TD_Phase 2	TD_Phase 3
ReB_ca	0.449**	0.354*	0.379**	0.430**	0.371**
NReB_Ad_ca	0.002	0.002	-0.037	-0.025	0.020
NReB_Co_ca	-0.168	-0.176	-0.142	-0.164	-0.018
NReB_In_ca	0.109	0.192	-0.003	0.013	0.118
NReB_ST_ca	0.326	0.149	0.371**	0.222	0.253
GA_ca	-0.085	-0.021	n/a	-0.171	-0.082
A_Ed_ca	0.390*	n/a	n/a	n/a	n/a
A_En_ca	0.643**	n/a	n/a	n/a	0.544**
A_Fi_ca	0.372*	0.206	0.338*	0.259	0.253
A_He_ca	-0.130	-0.145	-0.002	-0.069	-0.125
A_Su_ca	0.156	0.061	n/a	0.135	0.104
A_Sh_ca	0.274	0.231	n/a	0.254	0.197
A_Ds_ca	0.761**	0.696**	0.509**	0.701**	0.722**
PT_Bi_ca	0.253	0.112	0.306*	0.216	0.226
PT_Su_ca	0.289	0.164	0.154	0.133	0.174
PT_Tr_ca	0.047	-0.015	-0.047	-0.087	-0.063
PT_Bu_ca	-0.003	0.093	-0.054	0.121	0.060

Tab.4 Corrected Pearson's coefficient and adjusted p-values related to the correlation results between traffic data and the land and Public Transport data extracted on catchment areas (. Correlation is significant at the .01 level; *. Correlation is significant at the .05 level)**

3.4 Suitability Analysis Index

Focusing on the number of mobile devices detected during the Pre-Covid-19 period, the executed correlation analysis showed that some of the considered land and Public Transport data were effective indicators of higher Wi-Fi data, with reference to residential buildings (ReB_ca), education amenities (A_Ed_ca), entertainment amenities (A_En_ca), financial amenities (A_Fi_ca) and department store (A_Ds_ca). This was further analyzed to identify the areas of Milan which could be suitable for more extensive traffic data collection campaigns. Thus, a Suitability Analysis Index (SAI) was defined through the density distribution of relevant data on the entire territory of Milan:

$$\sum_{k=1}^{0} = {}_{K\_ReB}\, ReB(ce) + {}_{K\_A\_Ed}\, A\_Ed\ (ce) + {}_{K\_A\_En}\, A\_En(ce) + {}_{K\_A\_Fi}\, A\_Fi(ce) + {}_{K\_A\_DS}\, A\_DS(ce)$$

The proposed index was calculated through the weighted summation of normalized density distribution of values (z values in a range between 0 and 1) on the H3 hexagonal grid proposed by Uber Engineering in 2018. Among the several resolutions available for the H3 grid, the current work adopted the one characterized by cells with an average diameter of the circumscribed circle of 395 meters, in line with the commonly known comfortable walkable distance of 5 minutes (Buhrmann et al., 2019). The constant parameters K_ReB (corresponding to 0.15), K_A_Ed (corresponding to 0.15), K_A_En (corresponding to 0.15), K_A_Fi (corresponding to 0.15) and K_A_DS (corresponding to 0.4) were weighted by discretizing the r results of spatial autocorrelation analyses[11] (Lee Rodgers and Nicewander, 1988) (see Tab.4), in order to accentuate the impact of A_DS on SAI (∑ constant parameters = 1). Results (see Fig.8) showed the areas of Milan which could be effectively exploited for extensively monitoring high traffic data by means of the installation of additional Wi-Fi sensors (areas characterized by SAI ≥ .8). The granularity and widespread coverage of results showed the suitability of both central and peripheral areas of the city, as well as the overlap of the modeled data with the major transport infrastructures.

[11] The constant parameters related to strong (K_A_DS) and moderate correlation results (K_ReB, K_A_Ed, K_A_En and K_A_Fi) respectively correspond to .4 and .15.

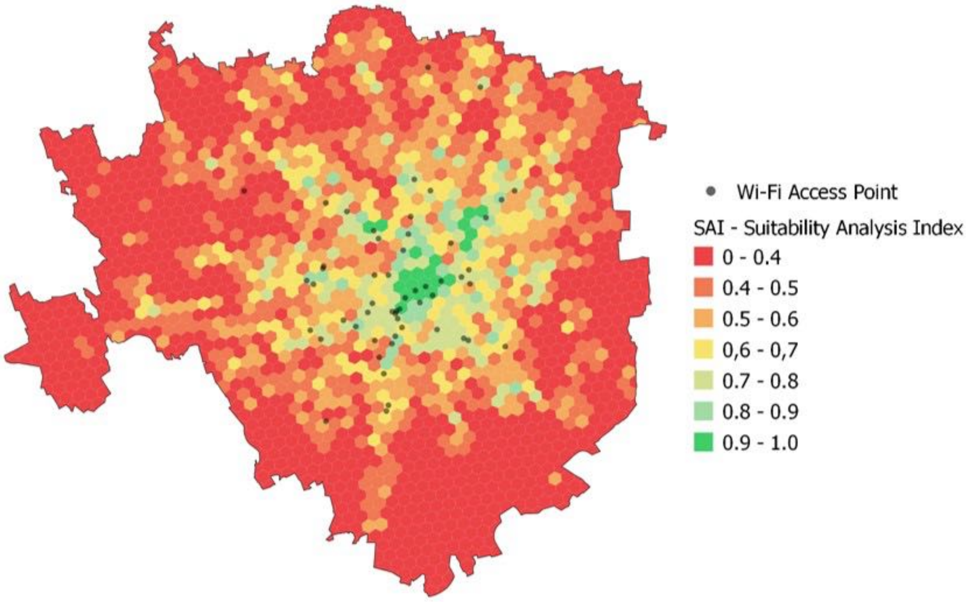


Fig.8 The map shows the results of proposed Suitability Analysis Index, aimed at identifying the areas of Milan which could be suitable for the installation of additional Wi-Fi sensors to collect traffic data (areas characterized by SAI ≥ .8)

4. Discussion

The development of location detection systems (e.g., image stream, radio frequency, cell network, bid stream, light pulse techniques) enables to monitor, understand and predict the mobility patterns of the city users. In particular, Wi-Fi technology is recognized as one of the most effective sensors for monitoring activity patterns with high spatial and temporal granularity (e.g., installation and maintenance costs, precision rate, energy consumption, robustness to weather and light conditions, compliance to the GDPR). However, the capability of this technology to collect reliable traffic data is limited by systematic under sampling and oversampling errors (Soundararaj et al., 2020) and by the difficulties in distinguishing traffic flow typologies (e.g., vehicular, pedestrian, etc.).

In this context, the proposed study was based on the analysis of a large sample of data collected during a 7-month period (January to July 2020) through a network of 55 Wi-Fi sensors distributed in Milan. The research was firstly aimed at testing the effectiveness of Wi-Fi technology to gather aggregated traffic data in large scale scenarios. From a general point of view, the achieved results confirmed the effectiveness of this data collection method for characterizing the evolution of the lockdown phases and activity patterns. The robustness of the proposed analysis of Wi-Fi data trends among the lockdown phases is based on the use of the same set of sensors, which has been preliminary validated among few malfunctioning Wi-Fi APs.

However, the accuracy of the presented results could be limited by an under sampling error due to technical, territorial and social factors: (i) mobile devices' sensitivity (e.g., connection features, battery level, orientation, etc.); (ii) arbitrary location of the Wi-Fi APs with respect to the entire territory of the city of Milan, as distributed in several department stores, shops and public services; (iii) socio-demographics characteristics of the population related to mobile devices' ownership; and (iv) partiality of the considered sample size compared to total amount of daily trips related to number of inhabitants (1,242,120) and workers (1,016,790) of the city of Milan (ISTAT-Italian National Institute of Statistics, 2011). Furthermore, the reliability of the collected data could be limited by an over-sampled representation of the population linked to: (v) possibility of a user of carrying multiple devices; (vi) multiple probe requests from a single mobile device to a Wi-Fi AP; and (vii) background noise due to fixed devices (e.g., routers, desktop computers, etc.).

In order to mitigate oversampling inaccuracies, filtering and clustering procedures have been taken by the data provider by removing probe requests from fixed devices, as well as by associating consecutive probe requests to the correct user. However, data sampling is estimated by the provider at being 2-10% above ground truth. Thus, future steps of this research will be based on further developing of a methodology to filter out background noise and improve data accuracy. Moreover, taking advantage of previous works already performed by the authors[12], future work will be based on the use of computer vision techniques (Zhao et al., 2019) to cross check the validity of Wi-Fi-based traffic data through images stream acquisition systems. Existing CCTV infrastructures or ad hoc installed cameras could be coupled with Wi-Fi sensors, with the aim to obtain comparable analyses and a validation methodology on vehicles and pedestrian activity.

5. Conclusion and Future Work

Location detection systems are becoming a valuable support for the activity of transport planners and decision makers by unveiling hidden mobility patterns in cities. Nowadays, this has become even more crucial considering the unprecedented effects of disruption of the Covid-19 pandemic on urban mobility. In this context, the proposed study focused on the analysis of number of mobile devices detected through 55 Wi-Fi APs, placed in several shops, department stores and public services in the city of Milan. First, time series analyses unveiled relevant trends, peak hours and mobility profiles. Then, the number of mobile devices detected during the Pre-Covid-19 period and the lockdown Phase 0, 1, 2 and 3 was correlated to several city features, such as building typologies, green areas, amenities and Public Transport, through an extensive GIS-based analysis. Here, the main purpose was to understand which characteristics of the city would create resilient neighborhoods during the different phases of the Covid-19 pandemic.

Results showed that the concentration of both residential buildings (ReB_ca) and department stores (A_Ds_ca) was positively correlated with Wi-Fi data among all lockdown phases. The containment measures put into place during Phases 0, 1, 2 and 3 were based, in fact, on reducing or prohibiting any movements from place of residence, apart from health and emergency reasons and food shopping. Furthermore, results showed that the catchment areas characterized by the concentration of service and transportation facilities (NReB_ST_ca) and financial amenities (A_Fi_ca) were more resilient during the lockdown Phase 1, considering the relative distribution of Wi-Fi data. The increase of Wi-Fi data during Phase 1 around catchment areas characterized by the presence of bike-sharing docking stations (PT_Bi_ca) could be related, instead, with the city users' need to avoid crowded transport infrastructures by using safe and contactless travel options, such as cycling. Furthermore, the correlation analysis focused on the Pre-Covid-19 period showed that some of the considered land and Public Transport data were effective indicators of higher Wi-Fi data, with particular reference to the concentration of residential buildings (ReB_ca), education (A_Ed_ca), entertainment (A_En_ca) and financial amenities (A_Fi_ca), and department store (A_DS_ca). This analysis has notable implications for future applications, considering the possibility to forecast traffic data through time-invariant characteristics of the urban settlement. Thus, results were further analyzed to define a Suitability Analysis Index, aiming at identifying the areas of Milan which could be suitable for more extensive traffic data collection campaigns based on the installation of additional Wi-Fi sensors. Results of correlation analysis focused on the lockdown phases open up debate on the need to design cities to have a polycentric structure, with several and distinctive areas of attraction for the city users (i.e., *15-minute city concept*), in order to be resilient to extraordinary events such as the Covid-19 pandemic. Almost 70 years after Jacobs (1961) arguments for smaller and connected neighborhoods were published, the world is beginning to fully grasp the importance of mixed-use urban planning (Song et al., 2013). Such plans are also in keeping with the General Theory of Walkability proposed by Speck (2013), which states that the level of pedestrian friendliness of urban areas is directly related to their level of usefulness and attractiveness, pinned down in metrics of land-use mix, street

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12 See: https://research.systematica.net/journal/looking-with-machine-eyes-how-deep-learning-helps-us-read-our-cities/

connectivity and commercial density as well as poly-centricity to ensure service coverage within short walkable distances. Future work will be based on the development of Wi-Fi sensing applications for monitoring traffic data in near real time (Li et al., 2020), considering that the triangulation of APs enables both outdoor and indoor data collection (Soundararaj et al., 2020). The planned activity could support the management of crowd dynamics on occasion of big events (e.g., trade exhibitions, music, art and cultural festivals, sport events), characterized by the scarcely predictable impact of extraordinary touristic flows. In analogy with the pilot study proposed by Transport for London (2019), the application of the Wi-Fi technology to monitor traffic data in real time in mass-transit and gathering facilities could enable, in fact, to assess the contextual conditions of service, detect anomalies, avoid service disruption and guarantee the comfort and security of the users.

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Former military sites and post-Covid-19 city in Italy. May their reuse mitigate the pandemic impacts?

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Abstract

The presence of former military settlements, along with other abandoned spaces in the Italian cities, constitutes an opportunity for developing inclusive and green cities through a good governance, especially after the 2020 pandemic outbreak. This paper develops an analytical matrix for comparing and evaluating the redevelopment projects of a number of case studies in the Italian metropolitan cities of Bologna, Milan, Rome, and Turin in the face of the challenges of the post-Covid-19 issues. Although the difficulties to evaluate still ongoing redevelopment projects, I found two main results. First, the Italian political and economic context is what most influenced the redevelopment process and not so much the intrinsic characteristics of former military sites. Second, it seems that the reuse of these urban voids will not match a couple of features of the so-called post-Covid-19 features, i.e. inclusive and good governance, though the redevelopments can seemingly develop green cities.

Keywords

Urban regeneration; Urban planning; Urban voids; Post-pandemic territories.

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1. Introduction

This work questions the management of former military sites in Italy and pinpoints how the programmed reuse of a number of case studies may succour health, social, and economic inequities in the post-Covid-19 city. In particular, the paper qualitatively evaluates and classifies the way the redevelopment of the selected case studies can contribute to build more inclusive and greener cities though a good governance.

This paper takes the redevelopment of former military sites in Italy as a starting point to examine the significance of these reuses in shaping new urban environment to mitigate the negative effects of the Covid-19 pandemics by analysing their correspondence to the so-called 'inclusive cities', 'green cities', and 'good governance'. The work is specifically focused in tracing in the commonalities and differences of these public-owned assets that have been privatised by selling them to real estate funds to boost their reuse. The research questions are the following: Are the current redevelopments of former military sites aimed to improve the quality of life of everyone or to materialise new profit-driven spaces? May these projects provide more inclusive, resilient, healthy sustainable, and safer environment in the context of the Covid-19 pandemic and beyond? For this purpose, the paper works with four cases of former military sites that exhibit significant characteristics to highly impact their context in the post-pandemic period: the Sani barracks in Bologna, the compound Baggio warehouses-Parade Ground in Milan, the Guido Reni barracks in Rome, and the La Marmora barracks in Turin.

In working toward the classification of the redevelopment projects affecting former military settlements in Italy, the paper advances the existing literature in three central ways. First, it identifies patterns across a specific type of urban void to redevelop in a comparative study where the dominant scholarship has been single case studies in Italy, with only few comparative studies of former military sites in diverse countries (Artioli, 2012; Ponzini & Vani, 2014). Second, it proposes an approach based on a systematic analysis of secondary sources through a case survey method along with specific fieldworks, interviews and archival work. Third, it evaluates ongoing redevelopment projects still to be carry out to expand on the comparative urban dimension on the critical urban studies analysis of former military sites that has been flourishing in recent years in Italy and abroad (Bagaeen & Clark, 2016; Camerin, 2020).

2. Theoretical framework

This work questions the management of former military sites in Italy and pinpoints how the programmed reuse of a number of case studies may succour health, social, and economic inequities in the post-Covid-19 city. In particular, the paper qualitatively evaluates and classifies the way the redevelopment of the selected case

After the end of the Cold War in 1989 and in the context of the crisis that shook the capitalistic system of the Western countries (creating significant budgetary deficits), the last decades of the 20th century has given rise to the reuse of surplus military properties and the transition to civilian uses. As claimed by Ashley & Touchton (2016: 391) «current scholarship describes this process and provides snapshots of transition, yet there is very little systematic knowledge of what follows base closure». Although the closure of a number of military bases has been affecting contemporary urban and rural areas and become a new challenge for city planning and policymaking, little attention has been paid to this complex topic at an international level. The military abandonment and redevelopment involves a great range of disciplines (from geopolitics to geography, from planning and urban studies and heritage and conservation) and agents (usually more than in ordinary land-use change, such as Ministry of Defence and *ad hoc* agencies). The vast majority of the research has focused on the following aspects: the reasons behind the military abandonment (Brzozska et al., 1995); the redevelopment of military settlements from the point of view of their polluting effects (Paukštys et al., 1998), including them in the issues of 'common' (Marin & Leoni, 2016), 'heritage' (Cocroft et al., 2005), 'brownfields' (Lotz-Coll, 2019), the recovery of 'ecological systems' (Havlick, 2014) and urban austerity (Adisson & Artioli, 2020); the citizens participation into the decision-making process on their reuse (Van Driesche & Lane, 2002); and the economic effects of the military closure (Paloyo et al., 2010).

Taking into consideration the Italian case, Gastaldi and Camerin (2018a: 673-675) and state-led inquiries (Corte dei Conti, 2017) pinpoint that uncountable former military sites are still waiting for their redevelopment as a result of a mix of factors. This failure led to the long-lasting abandonment of these areas up to date. In the context of post-pandemic period, Italian cities are plenty of urban voids proceeding from military use that may match the urgent requirements to provide a healthy and safe life for the citizenship. They constitute proper opportunities for redevelopments that truly improve the quality of life, and not only for creating new profit-driven spaces following the incessant search for profitability far from the reality of the local context and the real needs of the city as a whole (Alexandri & Janoschka, 2020). After the outbreak of the pandemic, numerous cities across the world adopted specific measures to deal with the impacts of Covid-19, such as the Swedish "Street Moves", also known "1-minute-city" (O' Sullivan, 2021), and the Milanese experiment "Open Streets" (Comune di Milano, 2020) or speeding up the policies adopted before the Covid-19, as *Paris en Commun*'s concept of the '15-minute city'[1] and the Barcelona's 'Superblocks' (Mueller et al., 2020). All these proposals refer to the wide range of short-term, low-cost, and scalable interventions and policies that catalyse long term changes in a specific neighbourhood, i.e. the so-called Tactical Urbanism (Garcia & Lydon, 2012), promote slow mobility, as well as a decisive bet for public transport over private transport (Gaglione, 2020; Fenu, 2021). In the frame of the growing research regarding the post-Covid-19 city (Guida, 2020), an aspect deserving attention is what to do with the emptied spaces result of the abandonment of diverse typologies of activities (Balletto et al., 2021), especially in terms of health emergency and economic and territorial implications (Capasso & Mazzeo, 2020). Among the wide range of voids, this study takes into consideration the current redevelopment of former military sites in Italy to understand if their reuse could be adapted to three of the key aspects of the post-Covid-19 city according to the survey by OECD (2020): inclusive cities, green cities and good governance[2].

3. Methodology

The work comprises three ways to obtain the information. First, archival research, i.e., cities' archives and Italian University's libraries. Second, a series of fieldwork, i.e. on-site visits and interviews with actors and stakeholders involved (including the architectural design studios involved in the redevelopment projects) conducted in Italy's Milan (November 2017), Rome (October 2018), Turin (May 2019) and Bologna (September 2019). Eventually, the search for international scientific literature using the bibliographic databases Scopus and JSTOR along with the grey literature (i.e., press articles, government's legislative documents, and local administrations' urban and territorial planning sources) was performed.

3.1 The case study selection

The case studies selection was made according to the following elements:

- location in Italian capital cities (i.e., Bologna, Milan, Rome, and Turin);
- inclusion in policies of military rationalisation and redevelopment according to specific memorandum of understanding signed between the Ministry of Defence, the City Councils, and the State Property Agency from 2014;

[1] https://www.paris.fr/dossiers/paris-ville-du-quart-d-heure-ou-le-pari-de-la-proximite-37.

[2] The analysis leaves behind the features of the 'smart cities' as their focus is on territorial-scaled measures and interventions, not being focused on specific urban voids.

- ownership, i.e. the current owner is a real estate fund (Invimit and CDP – *Cassa Depositi e Prestiti*)[3];
- high-consumption-land military settlements whose reuse works are still to carry out;
- the in-depth analysis of the processes of building, abandonment and regeneration of the case studies in Camerin (2020: 193-257).

3.2 The quantitative and qualitative analysis

This analysis aims to decipher the current redevelopment projects affecting four former military sites and was conducted on the basis of two methods: a quantitative and qualitative analysis as well as a gradual categorisation of the data. The data collection includes a review of the existing literature on the case studies and the interpretation of official documents released by the actors involved in the management of former military barracks (Ministry of Defence, State Property Agency[4], and City Councils).

The quantitative analysis comprises two parts that contribute to give a brief resume of the case studies.

First, the identification of the former military barracks' main features: plot size and gross floor area (m^2); number of buildings within the enclosure, and their volume (m^3); époque of building, abandonment and disposal; presence of listed buildings; involvement of local citizens in the decision-making process through community-based management and planning[5]; occupation of the area by local associations or homeless; average property prices district and city[6], cost of redevelopment works; and promotion of temporary reuse and activities before starting the redevelopment works. Second, each case study analysis comprises the morphological analysis of the context through a barrack-centred walkable catchment (400-m scaled map, see Figg. 1, 2, 3 and 4).

The qualitative analysis aims to classify the barracks redevelopments according to four variables of the inclusive cities, green cities, and good governance chosen from the 2020 OECD report (with values that fluctuate from 0 to 3, see tab.2. Each variables are indicate in Tab.2 with a letter)[7]:

- the building of inclusive cities, i.e. those that provide opportunities for all (OECD, 2020: 38), implies the following elements:

  a) projects aimed to provide social and community services for disadvantaged groups such as health care and home care (i.e. elderly and homeless people), through the design and implementation of ambitious social innovation strategies and a repurposing of empty buildings;

  b) ensuring that lower classes (i.e. low-wage workers and migrants) are targeted with customised employment and activation programmes that are adaptable, relevant, and flexible and respond to the new needs of the local labour market after the post-covid-19 crisis;

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3 Both The Investment Management Companies "CDP-Cassa Depositi e Prestiti Sgr S.p.A." and "Invimit- Investimenti Immobiliari Italiani Sgr S.p.A." created the real estate funds named "Investment facility for the enhancement of public assets - Extra Fund, FIV" in 2012 (https://www.cdpisgr.it/valorizzazione-immobili-pubblici/fiv-comparto-extra.html) and "i3 Stato-Difesa" in 2015 (https://www.invimit.it/#). Both funds aim to establish institutional collaboration among all those public entities interested in the military real estate assets' reuse (Ministry of Defence, State Property Agency, public and local authorities), to sell them in the market, to attract international and national private investors' interests, to drive urban regeneration processes, and to reduce the Italian public debt (Camerin & Gastaldi, 2018b).

4 The State Property Agency is an economic entity belonging to the Ministry of Economy and Finance created in 1999 with the aim of managing public-owned assets (Ponzini, 2008), including their exploitation in the real estate market according to the disposal regulations (https://www.agenziademanio.it/opencms/it/).

5 The participatory processes and the initiatives of local associations in Bologna, Milan, Rome and Turin can be found respectively in https://www.osservatoriopartecipazione.it/scheda-processo/84; https://www.legiardinieremilano.it/cronistoria/; http://www.urbanistica.comune.roma.it/news-edilizia/14-dipartimento/pianificazione/uo-prg/partecipazione.html?start=44; and Urban Center Metropolitano (2017a and 2017b).

6 Data retrieved from the Italian real estate portal https://www.mercato-immobiliare.info/ updated to February 2021.

7 By doing this research I also took into account the meaning of inclusive cities according to the World Bank (https://www.worldbank.org/en/topic/inclusive-cities) and the preliminary list of possible interventions of nature-based solutions for urban settings (European Commission, 2015: 28-51).

c) adjustment of housing quantity, quality and affordability to the variety of housing needs, with a view to promote social cohesion and integration with sustainable transport modes;

d) improving accessibility to soft mobility (i.e. cycling and walkability), including the needs of various categories of people (i.e. elderly, families with children, disables).

- the creation of green cities would result in the transition to a low-carbon economy (OECD, 2020: 38-39) through the following implementations:

  e) addressing negative agglomeration externalities, such as traffic congestion and air pollution, by reducing the use of private cars through congestion charges and ad hoc regulation that account for specific exemptions, and by improving multi-modal transport, such as active and clean urban mobility;

  f) exploitation of the advantages of urban density and urban form (compact or sprawl) through forward looking spatial and land use planning to prioritise climate-resilient and low-carbon urban infrastructure.

  g) encouraging more efficient use of resources, and more sustainable consumption and production patterns, notably by promoting circular economy to keep the value of goods and products at their highest, prevent waste generation, reuse and transform waste into resources;

  h) stimulating the local economy (i.e. local food production), while rethinking short mile logistics.

- according to OECD (2020: 39-40), a good governance should be on the ground of inclusive and green cities:

  i) promoting an agile and flexible model of city governance through innovative collaborative tools, partnerships or contracts that put the interest of local residents at the centre and increase resilience, including inter-municipal and international collaboration and public-private partnerships;

  j) co-ordinating responsibilities and resources across levels of government to meet concomitantly place-specific needs, national objectives, and global commitments related to health safety long term objectives, resilience and sustainable development, in an effective and transparent manner;

  k) adopting a functional approach at territorial level to policy action based on where people live and work to tailor strategies and public service delivery to the diversity of urban scales;

  l) strengthening strategic management and innovation capabilities of local public officials to design and implement integrated and resilient urban strategies fit for complex challenges.

I acknowledge that comparative research across one country and different cities is fraught with complexities and lacunae, such as the condensation of much information and the selection of few bibliographic references for each case study. It is also true that the qualitative interpretation of unfinished redevelopment of former military sites reduces the relevance of summative evaluations.

Nonetheless, this research could be an important step toward developing a comparative analytical framework for the evaluation of all kind of abandoned spaces in relation to the features of inclusive cities, green cities, and good governance.

4. Case study analysis

4.1 The redevelopment projects

This section is dedicated to the barracks-centred walkable catchment and the analysis of projects: the chosen parameters are summed up in Table 1 and successively in a discursive manner along with the functions located within a radius of 400 m.

Assets	Sani barracks	Baggio ware-houses–Parade Ground	Guido Reni barracks	La Marmora barracks
Plot Size (Gross Floor Area) (m^2) / volume (m^3) / buildings	105,540 (53.930)/ not given / 26	618.075 (23.954) / not given / 38	55,480 (72,000) / 223,827 / 28	19,978 (18,513) / not given / 8
Époque of building / abandonment / disposal	1860-1861 / 2003 / 2005	1923-1930 / late 1980s / 2005	1916/ late 1980s / 2005	1887-1888 / 2005 / 2005
Listed buildings	All area	1	None	All area (apart two buildings)
Community involvement	2008-2009	2014	2014	2017
Selling to real estate investment fund	12/2013 CDP	07/2016 Invimit	12/2013 CDP	04/2014 CDP
Date of masterplan / General Master Plan Modification	06/07/2017: Dogma (Bruxelles) / 2008	No masterplan / 2012 and 2019 General Master Plans	24/06/2015: Studio 015 Paola Viganò (Milan) / 2020	29/04/2016 Carlo Ratti Associates (Turin) / 2014
Occupation	11/2019, 02/2020 protests	2016-2018 homeless	02/2014 protests	04/2014 protests
2021 Average property prices district and city (€/m²)	3,000 / 3,100	2,100 / 4,250	4,750 / 3,250	2,850 / 1,800
New uses	Mix of functions	Area of centrality and urban forestry	City of Science	Co-living, co-making and co-working
Investment (million €)	110	No info	270	25-30
Temporary reuse	None	None	2016-2018	2006, 2017, 2020

Tab.1 Case studies data. Source: Author's elaboration (2021)

The Sani barracks

The 105,540-m^2 former Sani barracks (Fig.1) is located in the Bolognina working-class neighbourhood in the northern periphery of Bologna at the crossroad of a residential and industrial-tertiary areas, whose average property prices are below the city ones. The barracks-centred walkable catchment shows the presence of a mix of functions (housing, green areas, industries and tertiary activities), with poor space for slow mobility but a good connection with the city centre by bus lines.

After a number of reuse projects proposed in the second half of the 20th century, the barracks abandonment occurred in 2003 (Camerin, 2020: 227-234). The 2008 Structure Plan included the settlement within the so-called "Railway City" urban regeneration plan along with a dozen of post-industrial voids (Evangelisti, 2017), followed by the 2008-2009 *Laboratorio Bolognina Est* participatory process (Sprega, Frixa and Proto, 2018). Then, the selling to CDP fund in 2013 was followed by the 2016-2017 International Urban Design Competition "Progetto Sani"[8]. The new future gross floor area of 53,930 m^2 would be divided in 47,490 m^2 for private housing, 3,170 m^2 for public housing, and 3,270 m^2 for collective facilities and services (school and neighbourhood services)[9], connected by the 41,000-m^2 existing open spaces dedicated to a public park[10]. The minimum amount of affordable housing unequivocally demonstrated the exclusive character of the redevelopment in a working-class sector.

8 http://www.progettosani.it/?lang=en.

9 The total gross floor area –53,930 m^2–, would be articulated as follows: 70% for residential functions; 10% for tertiary activities; 7% for commerce; 5% for craft activities; and 4% for both financial and insurance activities.

10 Despite being a listed area, the winning project by Dogma studio seeks to replace some of the ruins.

Fig.1 The Sani barracks-centred walkable catchment and photos

Only 10% of the total amount of the housing's surface – set up private and public housing, totalling 50,660 m² – was allocated to house the lower social classes. The local association Xm24 occupied the barracks in late 2019 to protest against the profit-driven approach of the reuse – whose cost will be approximately 100 million €. No temporary reuse took place in the Sani barracks, but the area will enjoy a new bike lane through the implementation of the 2019 BiciPlan. Eventually, the 2020 Recovery Plan[11] does not involve the Sani barracks.

[11] http://www.comune.bologna.it/trasporti/servizi/2:3026/3295/; https://www.emiliaromagnanews24.it/recovery-il-comune-di-bologna-fa-un-passo-avanti-sulla-via-della-conoscenza-169333.html

The Baggio warehouses–Parade Ground

Fig.2 The Baggio warehouses–Parade Ground-centred walkable catchment and photos

The Baggio warehouses–Parade Ground (Fig.2) is located in the western Baggio low-income neighbourhood, whose average property prices district is half of the city one. The barracks-centred walkable catchment shows nearby active military settlements (barracks and hospital) and social housing units, with a good provision of metropolitan system connection, footpaths and car parks. Even so, private car is the primary mode of mobility.

Two general master plans affected the barracks redevelopment. The 2012 Territory Government Plan applied a buildability of 0.70 m^2/m^2 to create a total buildable area of 432,652 m^2, a half of which for public equipment and public housing, corresponding to 216,326 m^2. Instead, the half of the former barracks' plot size –

corresponding to 309,037 m^2 – would be used for public green (Comune di Milano, 2012; Pugliese, 2016). On the basis of the 2014 public participation, the local associations asked for the maintenance of the existing urban morphology and the creation of new "urban forestry" to replace the Parade Ground. The area was sold to Invimit in 2016[12] and immediately occupied by homeless until 2018. Afterwards, the 2030 Milano-Territory Government Plan modified the precedent 2012 Plan by arguably stating that the former military site could be a suitable area to host strategic functions «of public use and/or of public or general interest, also private [...] to increase the functions of excellence and, in general, the global city attractiveness»[13] (Comune di Milano, 2018: 63) due to its condition of a large urban void, its accessibility, location, and shape. Additionally, the classification of the area in the broader concept of "great urban function" automatically reduced its expected buildability from 0.70 m^2/m^2 to 0.35 m^2/m^2. In late 2019 the Superintendence declared only one building of the Baggio Warehouses worth preserving, so most of the existing urban fabric was demolished. The 2020 Milano Adaptation Strategy Open Streets will foster slow mobility in the former military sites' surroundings[14] and the redevelopment still do not include temporary activities.

The Guido Reni barracks

The Guido Reni barracks (Fig.3) is located in the northern Rome's Flaminio neighbourhood, with mostly pre-existing social housing – the former 1960 Olympic Village – and tertiary services within a radius of 400 m. The existing mobility infrastructures favour private cars as the primary mode of mobility within this area, which is plenty of car parks and careless footpaths. Despite this, the access to the city centre is guaranteed by a good tram line connection.

The former barracks is involved in the 2005 "The Neighbourhood of the City of Science-the Urban Project Flaminio" to boost Flaminio's cultural and tourism accessibility through a new cultural district centred on a number of outstanding architectural pieces, i.e. the Auditorium (1994-2003), the MAXII museum (1998-2010), the Music Bridge (2008-2011), and the City of Science to replace the Guido Reni barracks (Rossi, 2020). After the selling of the barracks to CDP fund in 2013, a participatory process took place in 2014 according to the redevelopment project boosted by the 2014-2015 International Urban Design Competition[15]. The new gross floor area will be 51,000 m^2 (72,000 m^2 of gross usable surface), 14,000 m^2 of which to be transformed into public spaces, 10,000 m^2 (27,000 m^2 of gross usable surface) for the "City of Science", and 27,000 m^2 will be new private housing development. Therefore, private housing will occupy half of the plot size and is expected to produce 29,000 m^2 of gross usable surface for homes to sale or rent and 6,000 m^2 of gross usable surface for rent-controlled and cost-subsidised flats[16]. The cost of the urban project will approximately be 270 million €, while the cost of selling the private areas –residential, commercial, offices, touristic facilities – in the real estate market will fluctuate around 4,800-5,000 €/m^2 (Nartello, 2015), more than the Flaminio's average property prices (4,750 €/m^2).

CDP promoted the "Guido Reni District" urban marketing strategy[17] through the action marketing, events and advertising society "Ninetynine" from December 2016 to May 2018 (Delgado-Jiménez, 2018). More than a million people visited the temporary activities, which contributed to create new 287 jobs and generate 30

12 The area was auctioned in 2018, but failed (https://www.invimit.it/piazza-darmi-a-milano-ferrarese-noi-rilanciam/).
13 Translated from Italian to English by the author.
14 https://www.comune.milano.it/documents/20126/7117896/Open+streets.pdf/d9be0547-1eb0-5abf-410b-a8ca97945136?t=1589195741171
15 http://www.progettoflaminio.it/?lang=en; http://www.urbanistica.comune.roma.it/aree-militari/arremilitari-ex-stabilim-guido-reni.html
16 Eventually, 5,000 m^2 of new gross usable surface will be devoted for each touristic and commercial uses.
17 http://guidorenidistrict.com/

million € of volume business[18]. The 2020 Recovery Plan establishes an amount of 60 million € for a new tram line in the former barracks surroundings[19].

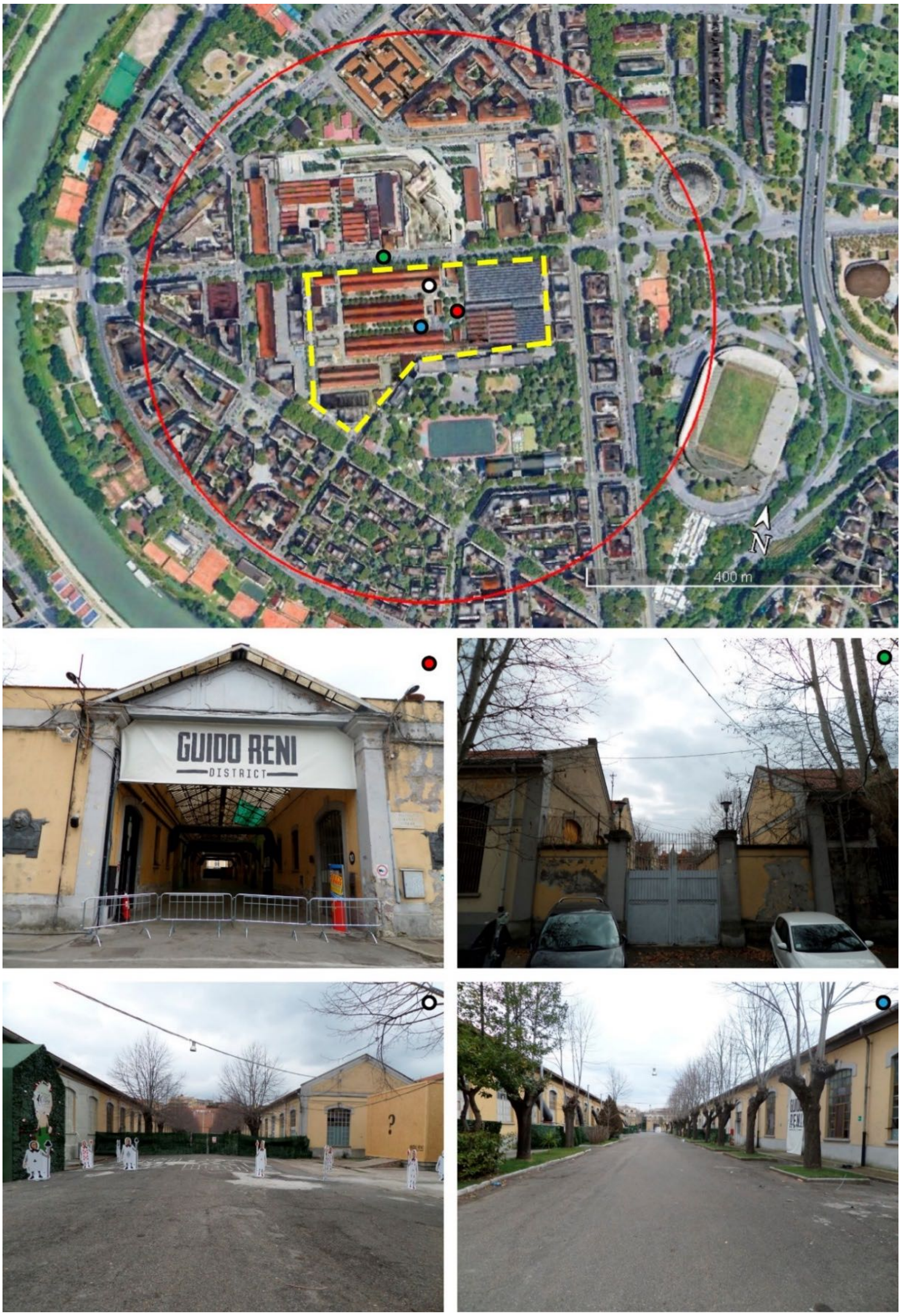

Fig.3 The Guido Reni barracks-centred walkable catchment and photos

18 https://roma.corriere.it/notizie/cronaca/18_aprile_23/guido-reni-district-chiudeora-lavori-futuro-incerto-1cb5abfa-4657-11e8-9661-d18d4bfcda1f.shtml and https://www.monitorimmobiliare.it/guido-reni-district-dalla-riqualificazione-alla-crescita-economica_20177181151

19 https://www.comune.roma.it/web/it/notizia.page?contentId=NWS652606

The La Marmora barracks

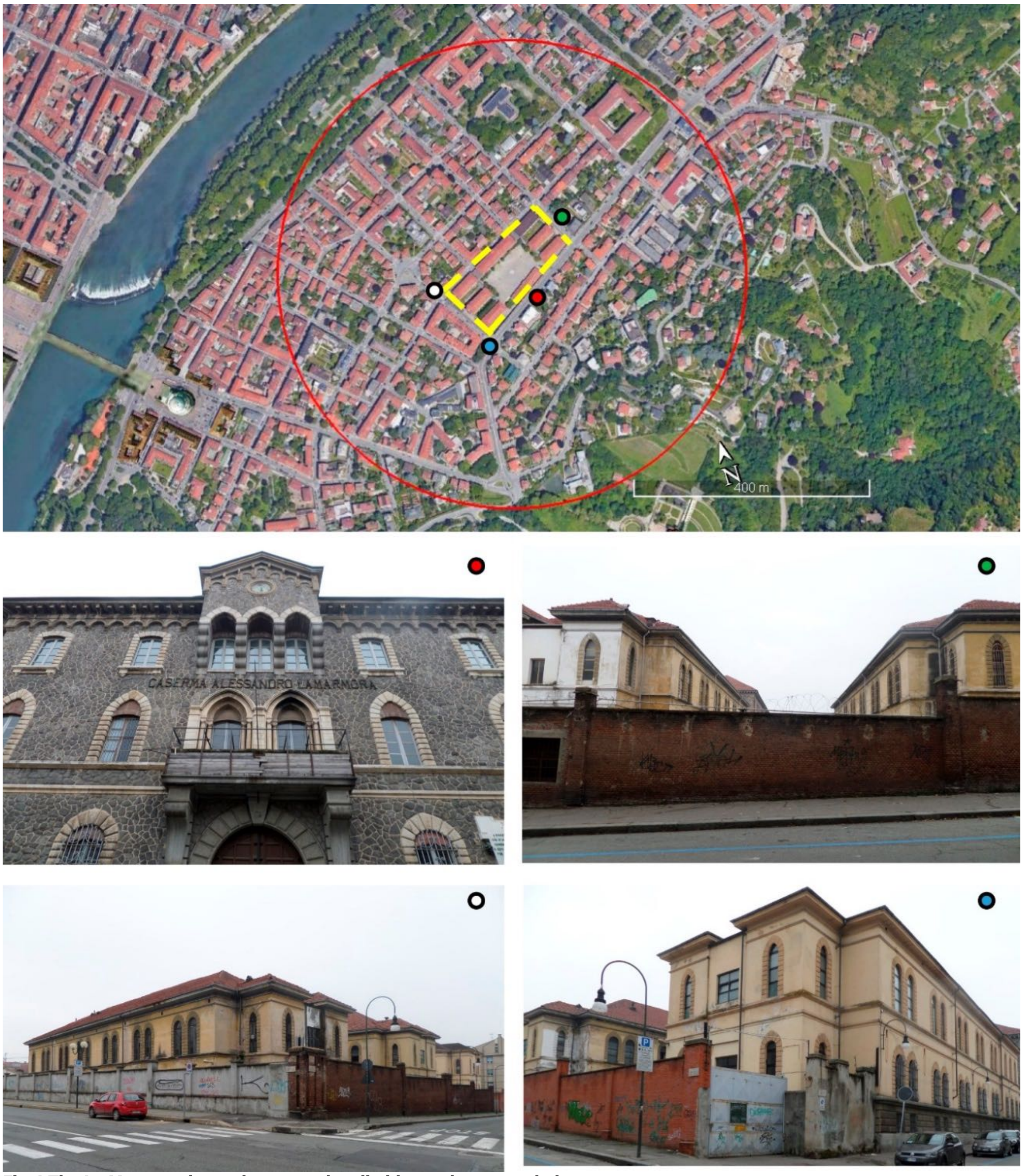

Fig.4 The La Marmora barracks-centred walkable catchment and photos

The La Marmora barracks (Fig.4) lies in the wealthy neighbourhood of Borgo Po,[20] set up by an orthogonal grid scheme generating a diversity of rectangular blocks. The nearby functions are mostly residential, the buildings' ground floors are dedicated to commercial and workshops and the blocks are occupied by mostly private gardens. Although Borgo Po is provided with a functional bus transport system, the existing mobility infrastructures favour private cars as the primary mode of mobility within this area and access to the city centre.

After temporary reuse activities in 2006 for the Olympics volunteers and migrants accommodation, the barracks was sold in 2014 to CDP. The redevelopment project was embedded with the 2014 General Master Plan Modification with the attempt to search for new capital gains (Città di Torino, 2014). The local association

20 The 2021 Average property prices district is 2,850 €/m², while the Turin one is 1,800 €/m².

"Freed Via Asti" occupied the barracks against the selling to spread cultural activities between April and November 2015. Meanwhile, the masterplan was entrusted by the owner to the architectural firm Carlo Ratti Associates. Under the motto of the so-called "co-living", "co-making" and "co-working", the reuse will equip the former barracks with two main functions for the wealthy: 60% of the gross floor area will be housing (between 120 and 140 units, whose square meterage will range from 20 to 180 m^2) and up to 40% of the gross floor area to workplace. The cost is estimated around 25-30 million € and would provide Turin with a new and iconic public space based on the former military central main square within the buildings (Carlo Ratti Associates, 2017). The aim of transforming this open space into the 100-metres-long-and-80-metres-wide rectangular-shaped "Place of Arts" – under which it is argued to build an underground car park – is to create another great *piazza* similar in scope to Vittorio Veneto square, one of the city's most emblematic landmark. Additionally, a public equipment would take place, i.e. the 2,200m^2-built-up-area Museum of the Italian Resistance. As the historical events[21] of the 20th century profoundly affected the barracks, this museum manifests itself as the "price" to pay for launching such profit-oriented urban transformation (Boccalatte, 2018). As occurred in the case of the Guido Reni barracks, also the La Marmora hosted temporary activities related to the incubator for emerging arts named "Paratissima"[22]. No interventions related to post-Covid-19 regard the site.

4.2 Are the redevelopments dealing with the inclusive cities, green cities and good governance?

This section is dedicated to the relationship between the redevelopments and inclusive cities, green cities and good governance, resumed in Table 2.

Assets	**Inclusion in post-Covid-19 actions**	**Inclusive city**				**Green city**				**Governance**				**Total**
		a	**b**	**c**	**d**	**e**	**f**	**g**	**h**	**i**	**j**	**k**	**l**	
Sani barracks, Bologna	None	0	0	1	2	3	3	3	0	1	1	1	0	15
Baggio warehouses-Parade Ground, Milan	Milan 2020 Adaptation strategy Open Streets	0	0	1	2	3	3	3	0	1	1	1	0	15
Guido Reni barracks, Rome	Recovery Fund Plan: tram line	0	0	1	2	3	3	3	0	1	1	1	0	15
La Marmora barracks, Turin	None	0	0	0	2	3	3	3	0	1	1	1	0	14

Tab.2 Case studies categorisation according to a number of features of the post-Covid-19 city. Legend: 0 - none, 1 - low, 2 - medium, 3 - high

Inclusive cities

The redevelopment of the former military sites does not fit the paradigm of inclusive cities as they do not provide opportunities for all. In fact:

a) The redevelopments are mainly aimed for the wealthy and do not provide any functions for the disadvantaged groups;

b) Nor customised employment or activation programmes are considered in any of the case studies;

[21] https://www.museotorino.it/view/s/81a5de46dd7d422d8939868c084bde65

[22] https://paratissima.it/la-nuova-sede-e-la-caserma-la-marmora-di-via-asti/

c) None of the projects establish a balanced percentage of social housing: less than 10% of housing of the Sani barracks will be meant for the lower social classes; the Milan's 2030 Plan still do not specify the new functions apart of the urban forestry; the Guido Reni barracks will provide a small percentage of rent-controlled and cost-subsidised; and the redevelopment of the La Marmora barracks does not include any social housing;
d) The redevelopments of three case studies will foster the soft mobility due to post-Covid-19 interventions bordering the former military sites: a new bike line affecting the Sani barracks; a tram line between the Music Bridge and Auditorium adjacent to the Guido Reni barracks; and the implementation of Open Streets affecting Forze Armate Street bordering the Baggio warehouses-Parade Ground.

Green cities

The case studies are embedded with measures aimed to build green cities through the following implementations:
e) Walkability is at the centre of the four former barracks redevelopments, and after the pandemic outbreak all the four cities will combine supply-side and demand-side transport management policies;
f) The reuses include new green buildings and spaces to absorb gaseous pollutants and trap particulates, and the production of renewable energy where feasible;
g) Measures as pollution and waste reduction, good indoor environmental air quality, and use of non-toxic, ethical and sustainable materials will be taken in the construction and/or conservative reuse of the buildings;
h) Nor the stimulation of the local economy or rethinking short mile logistics are taken into consideration in any of the case studies.

Good governance

Few aspects of good governance have been taken into account to design and implement successful strategies and policies to redevelop the former military voids, in shared responsibility with stakeholders:
i) The memoranda of understanding between City Councils, State Property Agency and Ministry of Defence represents the tool to start the rationalisation of the military presence and the redevelopment into new functions in the four case studies. The Sani barracks in Bologna is included in the so-called "Unitary Territorial Valorization Program" – *Programma Unitario di Valorizzazione Territoriale*, P.U.Va.T. in Italian. The basic principle was the grouping of a critical mass of former military sites in a municipal-scaled urban intervention so as to trigger the private initiative able to finance the redevelopment. Both initiatives established the base for the public-private partnerships, but did not comprehend any residents- and resilience-centred policies;
j) The memoranda of understanding have been signed according to the Italian Laws for the disposal of military real estate assets aimed to both wipe the public debt and enable urban regeneration processes. Despite being publicly spread, there is no commitments related to health issues, resilience and sustainable development;
k) No authentic public participation was carried out in the four case studies as they were procedures to inform citizens of the already established projects. The approach of the participation mostly relied on round tables in which the major stakeholders involved in the redevelopment (i.e., City Council, State Property Agency, Ministry of Defence, architectural firms) informed the citizens but without integrated them into the decision making-process. The top-down approach resulted in local associations' protests against the redevelopment projects in the four study cases and occupation of the Sani, Guido Reni and La Marmora barracks;
l) The City Councils provided specific urban planning guidelines for the redevelopment of former military sites after the memoranda of understanding, mostly through the modification of the existing planning tools. The tasks of design are generally entrusted to private architectural firms through international design competition

projects (the Sani and Guido Reni barracks) or the designation by the private owner (the Carlo Ratti Associates chosen by CDP in the case of the La Marmora barracks). Up to date, none of the cases has involved integrated and resilient urban strategies.

5. Discussion

Compiling the findings in Tables 1 and 2 allows to draw a discussion based on the following elements. First, and most important, the redevelopment of high-consuming piece of land require a comprehensive urban scale planning based on a shared medium- or long-term scenario of the territory, but the particularity of the Italian context contributed to inhibit the redevelopment.

On the one hand, as claimed by Palermo & Ponzini (2012), the Italian political and public life and urban-policy making are experimenting a declining phase due to the high turnover of Italy's government since the 2000s (the last crisis was in January 2021; Johnson, 2021). On the other hand, the regulations released since the 1990s focused on public land privatisations and military land was valued in solely financial terms, in spite of the expectation that the disposal of Defence-owned assets should result in public social, economic and environmental benefits (Quarta, 2016). Also, the continuous lack of public resources and the stagnant real estate market since the 2007-2008 crisis (Mattarocci & Cerasoli, 2018) made the high-cost redevelopments economically inviable in the short-term (110, 270 and 25-30 million € for respectively the redevelopment of the Sani, Guido Reni and La Marmora barracks).

Temporary reuses and interventions related to the tactical urbanism may be consequently suitable solutions to proceed with the reuse. Intrinsic factors of the military lands (i.e. physical dimensions, morphology, and locations) are less of a factor than extrinsic circumstances.

Second, as former military settlements are in highly lucrative and desirable locations, their redevelopment is subjected to real estate pressures, huge financial investments and risky endeavours, whose impacts may be speculative. The score of the redevelopment projects in inclusive cities is very low and good governance is low. This is a symptom of the financial approach of the Italian regulation and the urban welfare crisis (Berdini, 2014).

Although the reuses targeted issues of technical, procedural, and financial feasibility, public participation and communication have been mainly meant to inform than to involve citizens. The reuse operations sought high profits from the redevelopments so lower social classes are not the main targets (Brenner, Marcuse & Mayer, 2012). This may cause illegal occupations and protests of the local associations, as it usually happened in the case studies.

At the same time, bad governance in the management of the projects is the result of the neoliberal approach to the disposal of military land aimed to wipe the public debt, but failing to put local residents at the centre of the redevelopment projects (Olmo, 2018). The reuse projects, as a matter of fact, favour territorial-scaled functions, such as the Rome's City of Science and the Turin's Place of Arts. The reuse projects would surely improve quality of life, but they would increase property values pricing out vulnerable residents and drawing in new and wealthier residents (Blok, 2020), such as in the case of the Guido Reni barracks.

Third, the barracks redevelopments are poorly embedded in the measures adopted – or at least foreseeable – for the post-Covid-19. Bearing in mind that the abandonment and disposal took place in the best case more than 15 years ago, the existing urban morphology is decaying and urgently need demolition. The Recovery Fund constitutes an opportunity to reverse the profit-driven approach behind these interventions, but nowadays each project is a done deal. Redevelopments have been thoroughly managed in the pre-Covid-19 phase, but the new functions should have been relied on making cities and human settlements inclusive, safe, resilient and sustainable, thus being in line with the goal no. 11 "Make cities and human settlements inclusive, safe, resilient and sustainable"[23] from UN Agenda 2030.

Reversing an already ongoing process appear to be quite difficult, but more research is needed to guarantee a better city for everyone, for instance by setting up a database on studies and proposals that include abandoned public-owned assets within the approaches dealing with the pandemic (Fabris et al., 2020).

6. Conclusions

European Commission and Parliament agreed in May 2020 to help succour the economic and social negative effects of the pandemic through the so-called "NextGenerationEU" (European Commission, 2020). Cities across Europe are preparing their proposals to create more inclusive and greener urban environments, but also promoted their own initiatives, such as the Parisian 15-minute city and Barcelonian Superblocks. In this context, urban voids may play a fundamental role for the recovery plan as they can provide a more inclusive, resilient, healthy sustainable, and safer environment in the context of the Covid-19 pandemic and beyond. An aspect worth to study is the way current reuses of abandoned spaces are managed, such as the former military sites in Italy. The barracks redevelopments relied on pre-pandemic situation, but the long-standing abandonment may constitute an opportunity to rethink new locally-centred functions.

The lessons learned of this piece of paper are the following. The analytical matrix can be applied to compare the redevelopment of former military sites and other types of voids across different cities and countries. Nevertheless, more research is required to assess the suitability of this approach for a broader range of cases and address its limitations. For instance, this study has examined a small number of cases with a limited sample of types before the outbreak of pandemic.

The analysis was based on four variables of inclusive cities, green cities and good governance provided by a specific report. Results might be different while taking into consideration other inquiries, former military sites located in rural environment, and international cases.

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Image Sources

All figures are elaborations of the Author (2021).

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Investigation of the effects of urban density on Covid-19 pandemic

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Abstract

Decisions regarding land use are amongst the most important decisions of a city planning process, and density arrangement is one of the key parameters for it. The effects of urban density on the Covid-19 infection are investigated in this study through the sample case of İskenderun district, in which 3 different urban density areas are selected for this investigation (high, medium, low). The course of the Covid-19 pandemic was then followed through the number of cases in the period of September-December 2020 for these regions via a novel indicator Pandemic Index (PI). The case data were obtained from the "HES" application developed by the Ministry of Health of the Republic of Turkey to monitor the spread of the Covid-19 pandemic, and the case density maps recorded in the application for this purpose were digitized through an in-house image processing software. As a result of the examination, it was understood that the high-density zone has higher values for Covid-19 "cases and contacts percentage" and "PI rating" (61 and 173 respectively), whereas for the low-density zone these values drop significantly (23 and 39, respectively). The results are indicative that the lack of urban land production and high population concentration, which have become important problems of developing countries and regions due to rapid population growth, are indeed strong factors for the spread of diseases, such as the Covid-19 pandemic.

Keywords

Covid-19; Land use; Urban density; Image processing.

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1. Introduction

Decisions regarding land use are amongst the most important decisions of a city planning process. Land use planning covers a broad range of activities, from the development designs that take on new empty land to put into a function, to reorienting of the existing structures into a new form factor, or to the redevelopment of individual areas or whole neighbourhoods as new building areas with new uses. Determining how the physical configuration of the used area should change, develop, and adapt to meet the present and future needs of their residents, is a crucial task indeed.

Acting as a connection between the spatial dimensions of past and future, urban planning is a fundamental design process that affects every human living in that particular area of the civilized world. The social behaviour, education, health, welfare, agriculture, transportation, and other similar issues that are related to human-human and human-environment relations are directly influenced by the outcomes of urban plans and decisions.

It has long been accepted that the decisions regarding the use of the land must, therefore, take numerous aspects into account, such as economy, industry, education, transportation, religious activities, and agriculture, housing, trade, military, and health affairs. That being said, the potential impacts of a pandemic have not been considered a prevailing aspect in this process, at least at a significant level, until recently. The emergence of the Covid-19 pandemic, however, has changed many aspects of human society, and land-use decisions regarding the urban density are starting to get their fair share of impact from the pandemic as well.

Indeed, the field itself has been open to changes throughout its history. Land use and land cover decisions have already been changing as time progresses, as things that influence these decisions or are influenced by them change over time (Tira, 2021). Up until now, the effects of humans in urban spaces have been the fundamental causes of changes in land, particularly for the last century. Human influence has been so influential that some researchers consider the term "land use planning" as the practice and processes associated with the "urban and regional" strategic planning (Stevens et al., 2018).

Urban health, however, is starting to be seen as a global health priority (Etingoff, 2017), which was further accentuated with the rapid spread of the Covid-19 pandemic. It has been understood that urban planning and related policies can influence public health directly or indirectly, through factors like housing, employment, protection from environmental risks, access to primary health care, and protection and proximity to disasters, etc. The relation between cities and the spread of diseases has been an increasing concern for WHO since the 1990s. A key factor in this issue is the city planning stage, along with the relevant decisions taken during the planning (TÜRKOĞLU, 2020). The mechanism related to the spread of pandemics is now also being added to this list as a very influential factor (Etingoff, 2017). These are, then, being included in the list of factors that are considered when making decisions for deciding urban density.

And yet, the exact mathematical reflection of these mechanism of spread of various types of diseases has not been fully explored in terms of land use decision making. Studies that focus on urban density in different locations of a given town to reveal the effects of it on the incidence rate are only a handful in number. Considering the fact that the world is open to further pandemics, whether born as part of normal social life or following wars and natural disasters, it is important to reveal mechanics that are based on the relationship between population and housing density and the spread of diseases.

That being said, measuring the exact impact of such factors on urban, public, and individual health has been a challenging task. WHO (World Health Organization) has provided certain criteria for cities to be considered "healthy". These criteria include a sustainable eco-system, a clean, quality, and safe physical environment, the fulfilment of the basic needs, an optimum level of public health, access to treatment and health systems, and fewer diseases and more healthy individuals on average, compared to a location's counterparts (WHO, 1997). Covid-19 has shown to the world that large-scale health problems and diseases are not exclusive to underdeveloped regions and countries. In fact, as of January 2021, developed countries have arguably suffered more than their underdeveloped counterparts, where heavily urbanized and densely populated cities like Istanbul, Beijing, New York, Paris, and Rome had seen the highest spread ratios for the disease as it is seen in the reports of United Nations and World Health Organization (UN, 2020; Covid-19 and Healthy Cities, 2021). The reaction of the academicians to the Covid-19 pandemic was very fast. This reaction started with health care and vaccine and medicine researches as expected. When the initial panic ended, however, studies in a wider range of fields started to shape up in the literature that involved social, physical, and environmental effects and results of the Covid-19.

The relation regarding the public spaces and the spread of the Covid-19 pandemic has been investigated by Gehl (Gehl, 2020), through surveys performed in Copenhagen. The idea of that study was to understand the mechanics of Covid-19 to be able to prepare alternatives for post-pandemic times, as a way for adaptation to future crises. From the mobility and usage points of view, it was seen that the use of public spaces like recreation areas and parks had regressed to lower levels than that of the streets of trade and city centres.

In the study of Alrouf (Alraouf, 2021), it was proposed that new lessons were learned from the lockdown times and these will be reflected on architecture and planning as novel behaviors. The researcher believes this will be performed through approaching a "new normal" in the way places, neighbourhoods, and cities are designed and planned.

The relation between land-use, urban density and population density is intricate. As the population density only deals with the number of people living in a unit area, urban density covers all the aspects and it is considered as an important factor in understanding the function of cities. Whereas land-use investigated the area in a broader concept, regarding the decisions of human use and density.

There are various studies about the effect of decreasing air pollution and its effects on the spread of Covid-19 (Krecl et al., 2020), involving aspects like the decreases in transportation and industrial activities that took place, particularly focusing on high-density urban areas (Cadotte, 2020). In the example of the Metropolitan Area of São Paulo, the decrease in transportation and industrial activities was found to range between 34% and 68% (Krecl et al., 2020). Similar studies were also performed on intermediate-sized areas as well covering the urban morphology and air-pollution (Oshrierh and Valipour, 2020).

The effect of the pandemic on urban mobility has also been researched as another significant aspect. Fatmi (Fatmi, 2020) discussed that the behaviors of individuals and groups changed drastically during the times of the pandemic, and some of these changes are expected to become permanent. Another study has shown an average of 10% decrease in the "Mobility Index" for a total of 40 metropolitan cities that are in 5 different continents (Soucy et al., 2020). The decrease in mobility has also been determined in the public transport services, with the highest drop observed with 93% in Spain (Aloi et al., 2020).

The relationship between urban activities and urban industrialization with the transmission of the disease and its medical geography was evaluated for Salem, Iran (Salari et al., 2020), and the researchers proposed some managerial data. The effect of urban density on Covid-19, however, has been studied only in a few instances. Carozzi et al. (2020), for example, focused on the link between urban density and Covid-19 spread. It was emphasized in that study that the density variable has influenced the timing of the outbreak in each county, where denser locations were found to be more likely to have an early outbreak. The digitalization in these studies regarding the base data is limited, however, and does not include spatial information. Instead, these focus solely on the number of cases and the population. Only one study that was performed in Turkey (Gündoğan et al., 2020) focuses on the relationship between the urbanization process and the demographic structure, which were examined considering epidemic diseases that occurred in the past, particularly following earthquakes. It has been evaluated in that study that the metropolitan cities in Turkey, İstanbul in particular, have been planned without considering pandemics as a parameter.

Differing from previous studies, this study aims to evaluate the effects of urban density on the spreading mechanics of the Covid-19 pandemic. The well-known phenomena that crowded spaces will increase the spread of contiguous diseases especially within respiratory systems, is tired to be investigated regarding the urban density that directly effects the population density and human interaction within an urban area. As a unique study relying on location and time-based data supplied by a governmental system, it is believed that the reliability of the analysis is more than adequate. It is also hoped that the monitoring of the course of a pandemic with image-processing software will be another contribution of this study to urban science knowledge.

2. Methodology

2.1 Data acquisition

The Republic of Turkey Ministry of Health has developed a mobile application named "Hayat Eve Sığar" (HES, Life Fits into Home) to monitor the course of the Covid-19 pandemic, and the data was also made public through the application. HES was initially published to application stores on the 20th of May 2020 with basic functionality, and the application has been updated numerous times for increased functionality since then. HES is connected to the Ministry's GIS databases and uses GPS to locate the users.

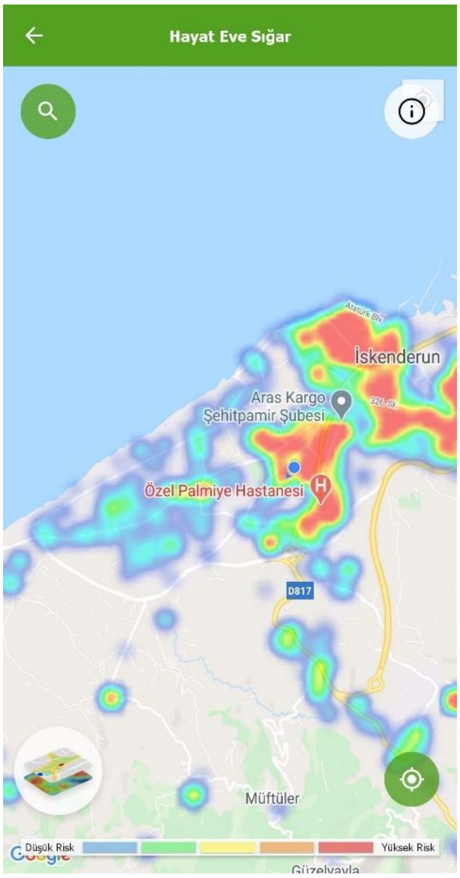

Fig.1 Screenshot of HES application at 22.12.2020

In this study, the data for the Covid-19 cases and people in proximity with infected individuals as determined by official filiation personnel was gathered using the heat map functionality of the HES application. This map (Fig.1) provides a risk potential density for Covid-19 cases and individuals contacted by them using a rainbow color scale legend. The information in this map is updated when the Ministry decides so a methodological update in the data is not the case.

The data between the 9th of September and 27th of December was collected by taking screenshots of the heat map screen of the HES application. The maps are based on the GIS-based databases of the Ministry of Health, which were updated with irregular intervals. For this reason, screenshots as data sources were not taken regularly either, but enough screenshots (Tab.1) have nonetheless been obtained. This time interval covers the second peak of pandemic in Turkey. As like all around the world first peak has caught everyone unexpectedly. The HES started to produce heat maps just after first peak of pandemic in turkey and the data is collected regarding these.

Number	Date	Number	Date
1	19.09.2020	11	27.11.2020
2	22.09.2020	12	28.11.2020
3	30.09.2020	13	02.12.2020
4	02.10.2020	14	06.12.2020
5	05.10.2020	15	07.12.2020
6	16.10.2020	16	09.02.2020
7	01.11.2020	17	13.12.2020
8	06.11.2020	18	22.12.2020
9	18.11.2020	19	27.12.2020
10	24.11.2020	-	-

Tab.1 The dates of the screenshots taken for data collection

2.2 Data processing

For the digitization of the data, the images were processed using an in-house GNU-Octave-based program developed solely for this purpose, which runs on a simple image processing routine. The program classifies the density of the risk using the 6 colour categories as a means of rating. These categories are Red (6), Orange (5), Yellow (4), Green (3), Turquoise (2), and Blue (1). Red defines the highest risk with a coefficient of 6 (number of cases and contacts) while blue represents the lowest density with a coefficient of 1.

Fig.2 The processed image of the case area

Fig.2 shows the image of a processed sample image (for the date 22.12.2020) where all 6 colour groups have been replaced with black colour for sake of checking the consistency of the program. This figure is used for the verification of the image processing as it is seen the heat map of HES application is totally covered.

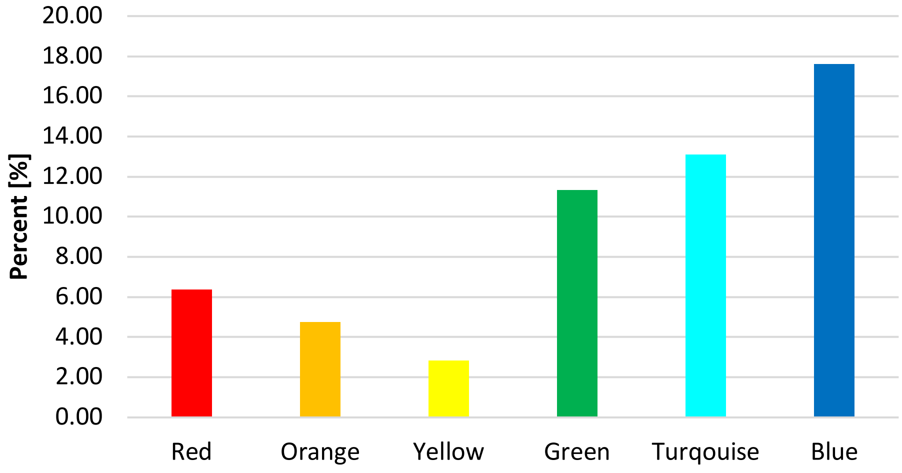

Fig.3 The percent of risk categories in 22.12.2020

The course of the pandemic is evaluated with this digitalization process, where the percentages of the six categories in the land areas represented by the HES screenshot images were calculated. Fig.3 shows a sample for the evaluation of the behaviour of the program. As the percentages of colour levels are separately given. It can be seen that, on that particular day, 55.97% of the land areas (in the processed image) were marked with a colour, at least by the blue (rating 1).

$$PI = \sum_{i=1}^{6} i * Percentage_i \qquad i: 1 - 6: Blue - Red \qquad (1)$$

Pandemic Index (PI, Eq-1) is the summation of the 6 categories' coefficients with the percentages calculated. Using the above equation, the weighted sum of this particular day was found as 151 PI. PI is an indicator of the risk level for the Covid-19 in the area, and the higher the number, the higher the risk is.

3. Case Area: Iskenderun

The study has been conducted on the selected parts of the greater Iskenderun urban area. The township of Iskenderun is located on the east Mediterranean coasts of Turkey (Fig.4) and is a district of the city of Hatay. The town has a population of 248.000 in the city centrum, and around 400,000 additional people live in the greater urban area around it that covers parts of Arsuz and Belen districts as well.

Fig.4 Iskenderun in Turkey

The city is well known for its seaports, iron and steel industries, fisheries, and clean seas that see high volumes of tourism activities. As an industrial city with ample amounts of trade and tourism city, Iskenderun presents a very cosmopolitan and complex social diversity. The history of the town starts as early as 333 BC as it was founded by Alexander the Great, with the initial name of Alexandria.

As being one of the biggest counties in the country with a wide range of economic diversity as well as rapid changes in the urban texture and urban density Iskenderun area is selected as a case for investigation of the relation between urban density and Covid-19 pandemic.

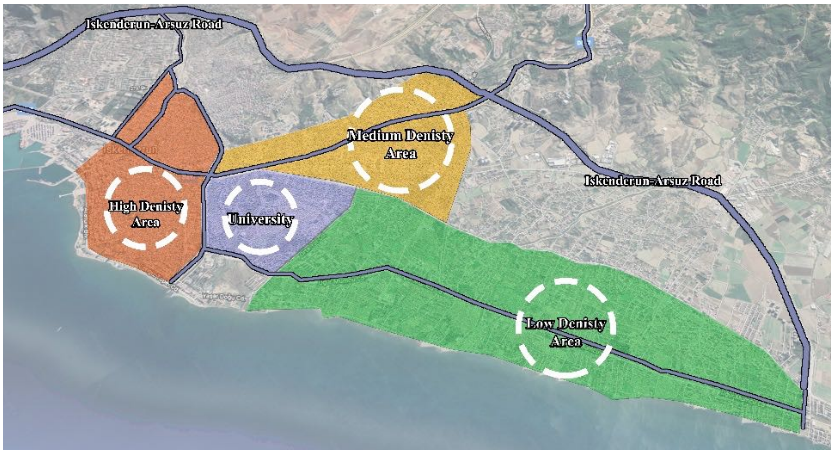

Fig.5 Density zone in the case area

The case areas selected for the study were categorized in one of the three groups as high, medium, and low-density urban areas (Fig.5). The high-density area is mostly consisting of the city centre which has a population density of 301-600 individuals/ha (gross), and where a mixed land-use is in place with trade centres, offices, education establishments, and residences are present (Fig.6).

(a) High Density

(b) Medium Density

(c) Low Density

Fig.6 Study areas (Self Photograph archive)

The population of the area has been determined as approximately 60,000 people in 2019. It is also worth mentioning that the average floor number in the development plan of 2020 was between 4 and 6 for this area. The texture of this area has relatively few open areas. When the figure-ground analysis (Fig.7) is examined in order to better analyse the structure and open area relationship of three different tissues, it is remarkable that the voids are quite low in the high-density tissue. Contrary to the high-density texture, the low-density texture shows that the empty spaces are quite high, and the construction is less.

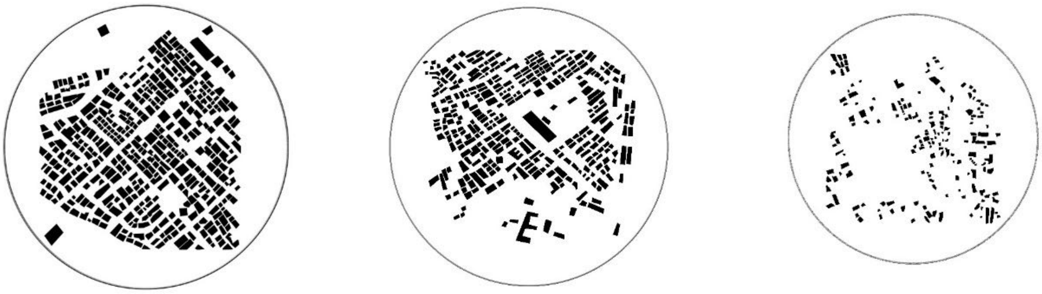

Fig.7 Figure-ground analysis maps of three density zones high, medium, and low respectively.

On the other hand, the medium-density area has a population density of 151-300 individuals/ha (gross) and consists mostly of the "Mustafa Kemal Neighbourhood" where the mainland usage is "housing". There are some small trade and business establishments, and the population was determined as 40,000 in 2019 data. The region can be described as a location where the structures create a discrete pattern and that has numerous open areas. The neighbourhood is on the road that leads to the Belen district.

The low-density area consists solely of the Karaağaç neighbourhood with a population density of 51-150 individuals/ha (gross). This area is appertained to the Arsuz district in terms of civil authority but is geographically located in the greater urban area of Iskenderun. The area has a population of 20,000 according to 2019 data. The land-use area mainly involves housing, with only three stores and large, open, agricultural spaces. The most dominant housing type in the area consists of two-store single housings.

Fig.8 Traffic Density through in the case area

Moreover in order to understand the density in regions traffic density in the area has been mapped (Fig.8) using Google traffic data (Google Maps, 2021) since the traffic data is a crucial indicator for human interaction density as well as other indicators (Kanyepe et al., 2021)

4. Results and discussion

As the aim of the study was to reveal the relationship between the spread of the Covid-19 pandemic in the İskenderun area with urban density, the data gathered from the image processing based computer program was tabulated first (Tab.2, Tab.3 and Tab.4) and for low, medium, and high urban densities, respectively. These tables represent the Covid-19 cases (positives or contacts) for the areas of the defined densities land boundaries. The date, colour level, and total coverage of the Covid-19 patients and contacts and PI (Pandemic Index) is tabulated in these tables as the crucial raw data of the study.

Day_Month (2020)	Red %	Orange %	Yellow %	Green %	Turquoise %	Blue %	Total %	PI
19_09	0.00	0.00	0.00	0.00	0.76	16.15	16.91	17.7
22_09	0.00	0.00	0.00	0.03	0.95	16.85	17.84	18.9
30_09	0.00	0.00	0.00	0.15	0.94	6.89	7.98	9.2
02_10	0.00	0.00	0.00	0.24	2.45	9.15	11.83	14.8
05_10	0.00	0.00	0.00	0.00	0.17	8.37	8.54	8.7
16_10	0.00	0.00	0.00	0.00	0.14	2.26	2.39	2.5
01_11	0.00	0.00	0.00	0.00	1.40	7.81	9.21	10.6
06_11	0.00	0.00	0.00	0.00	0.40	2.78	3.17	3.6
18_11	0.00	0.00	0.00	0.38	5.66	12.63	18.67	25.1
24_11	0.00	0.00	0.00	0.55	5.49	12.18	18.23	24.8
27_11	0.05	0.50	0.58	3.99	7.24	15.14	27.49	46.7
28_11	0.06	0.54	0.61	3.99	6.98	14.46	26.64	45.9
02_12	0.32	0.69	0.67	4.72	10.22	17.29	33.91	59.9
06_12	0.62	0.49	0.83	8.90	18.21	15.61	44.65	88.2
07_12	0.50	0.49	0.45	6.26	17.51	18.01	43.22	79.1
09_02	0.54	0.89	1.21	8.17	14.37	18.56	43.72	84.3
13_12	1.38	1.18	1.74	9.23	14.11	16.03	43.68	93.1
22_12	0.75	0.60	0.65	3.98	12.45	20.16	38.59	67.1
27_12	0.00	0.43	0.77	3.92	8.67	14.11	27.90	48.4
Average	0.22	0.31	0.40	2.87	6.74	12.87	23.40	39.40

Tab.2 The results for the low-density area

A portion of the studied period coincided with the second pandemic peak. As the values represent the density of the cases and contacts for the given times and areas, the comparison of the tables for different population densities reveals that urban density is significantly influential over the spread of the disease.

Day_Month (2020)	Red %	Orange %	Yellow %	Green %	Turquoise %	Blue %	Total %	PI
19_09	0.00	0.00	0.00	4.29	20.31	17.80	42.41	71.3
22_09	0.00	0.00	0.00	4.65	17.30	17.88	39.83	66.4
30_09	0.00	0.00	0.00	1.84	10.64	20.46	32.93	47.2
02_10	0.00	0.00	0.00	1.33	9.75	15.16	26.24	38.7
05_10	0.00	0.00	0.00	0.45	7.62	12.85	20.91	29.4
16_10	0.00	0.00	0.00	0.00	3.03	18.47	21.51	24.5
01_11	0.00	0.00	0.00	5.84	10.74	20.72	37.29	59.7
06_11	0.00	0.00	0.00	0.54	9.07	21.11	30.72	40.9
18_11	0.00	0.51	1.48	12.56	15.08	14.22	43.85	90.5
24_11	0.00	0.31	1.45	14.40	14.12	11.09	41.37	89.9
27_11	7.95	6.44	5.66	17.90	8.67	14.48	61.09	188.0
28_11	8.17	6.80	4.98	18.11	9.18	13.60	60.84	189.2
02_12	9.71	7.96	3.95	15.63	8.39	13.64	59.28	191.1
06_12	16.93	5.95	4.30	13.61	8.34	13.25	62.37	219.3
07_12	15.62	5.95	4.41	15.91	9.02	13.49	64.41	220.4
09_02	15.75	5.80	4.02	14.55	8.49	9.30	57.90	209.5
13_12	23.78	7.47	4.58	15.68	10.08	11.21	72.79	276.7
22_12	10.30	6.94	3.87	11.85	8.11	9.67	50.73	173.4
27_12	3.89	5.56	5.41	20.81	12.76	14.33	62.77	175.1
Average	5.90	3.14	2.32	10.00	10.56	14.88	46.80	126.3

Tab.3 The results for the Medium-density area

Day_Month (2020)	Red %	Orange %	Yellow %	Green %	Turquoise %	Blue %	Total %	PI
19_09	0.00	0.00	0.00	0.28	19.76	30.63	50.67	71.0
22_09	0.00	0.00	0.09	5.07	24.07	24.63	53.86	88.4
30_09	0.02	0.51	0.67	9.01	14.85	28.93	54.00	91.0
02_10	0.00	0.48	1.51	11.43	17.19	26.27	56.88	103.4
05_10	0.00	0.00	0.00	8.86	21.21	28.00	58.07	97.0
16_10	0.00	0.00	0.00	1.89	15.06	24.81	41.76	60.6
01_11	0.00	0.35	0.90	14.87	26.04	19.23	61.39	121.3
06_11	0.00	0.00	0.00	0.21	8.10	26.95	35.26	43.8
18_11	0.00	1.21	3.05	24.69	20.83	17.18	66.96	151.2
24_11	0.00	0.99	3.16	21.47	21.62	17.54	64.78	142.8
27_11	15.07	9.85	6.98	23.25	13.15	9.40	77.70	273.0
28_11	14.21	11.67	6.62	24.22	12.18	9.62	78.52	276.7
02_12	17.82	13.32	5.37	22.14	10.75	9.91	79.30	292.8
06_12	19.47	7.60	6.14	20.23	9.43	5.75	68.63	264.7
07_12	17.71	7.46	5.46	21.24	9.88	7.86	69.61	256.7
09_02	19.43	7.75	6.69	20.49	9.28	8.72	72.35	270.8
13_12	28.32	9.15	4.61	16.99	8.27	6.30	73.62	307.9
22_12	17.05	10.50	7.22	2.33	11.33	8.05	56.48	221.4
27_12	10.09	6.91	6.69	2.60	12.13	14.53	52.95	168.4
Average	8.38	4.62	3.43	13.22	15.01	17.07	61.73	173.8

Tab.4 The results for High-density area

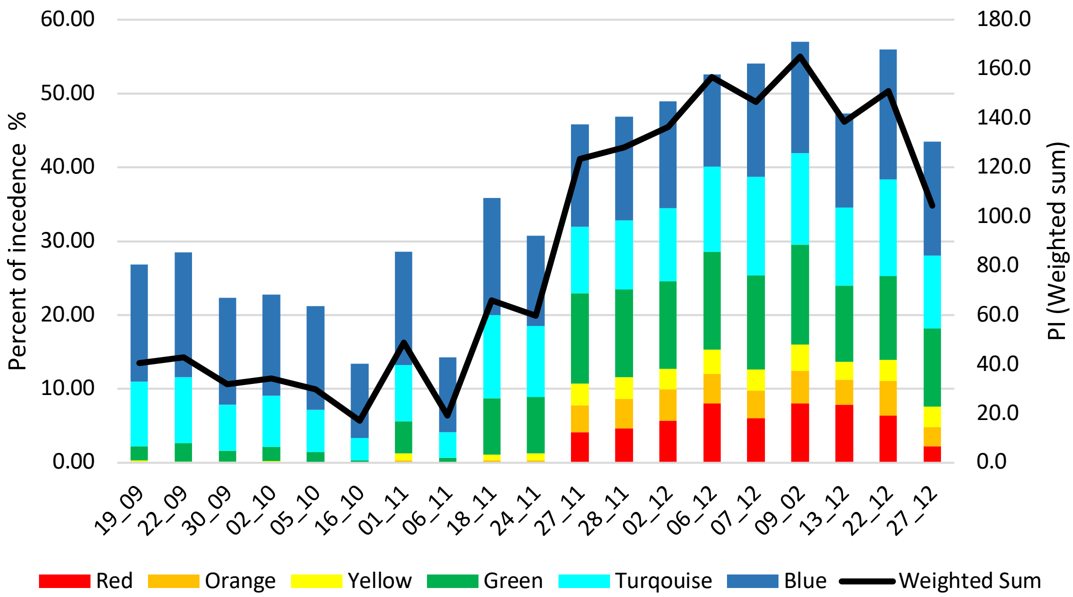

Fig.9 The course of Pandemic in overall Iskenderun

In Fig.9, the situation of the Covid-19 spread in the Iskenderun area can be seen in terms of colours of the heat map, now transformed into a bar graph over the days. Each colour represents the percentage of incidence of Covid-19 in specific date.

The situation is in harmony with the general outline of Turkey's case progress as given in (Covid.msb.gov.tr). In the figure, the densities of the cases and contacts can be tracked by zones of colour as described. This figure gives the fundamentals for Covid-19 progress in the city.

The 2nd peak of the pandemic starting from late November dominantly covers the figure where the increase in the red and orange colours represents the fact that the total PI index reaches up to 200s.

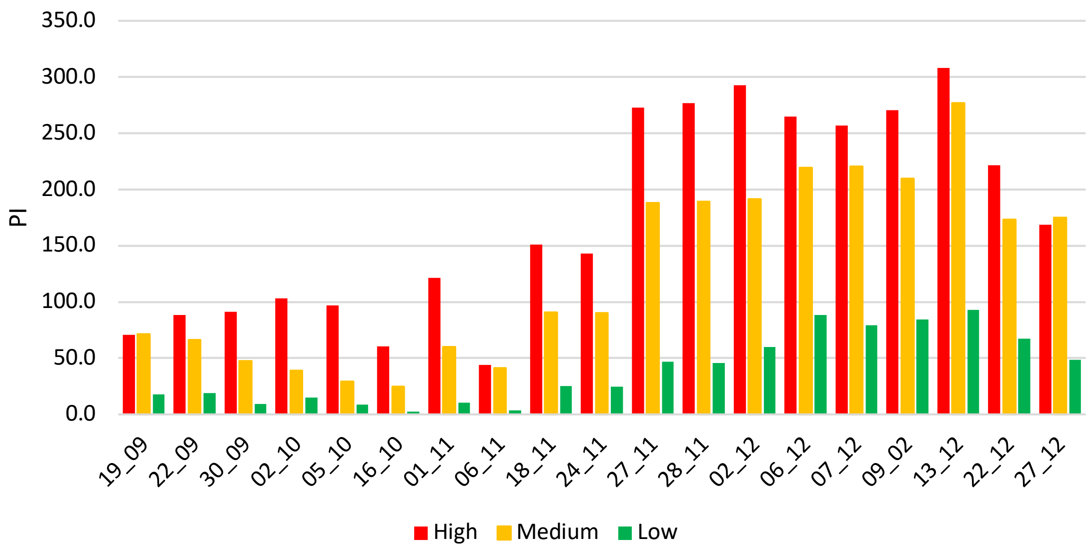

Fig.10 The course of Pandemic thorough Pandemic Index

After evaluating the Covid-19 pandemic status for Iskenderun in the given time interval, the evaluation of the 3 density zones in the case area was visualized by PI values in Fig.10. The figure shows that for all the dates for the high-density zone, the PI is higher than both that of the medium and low-density zones', but the gap is much more relevant in peak periods that start late November. Furthermore, when the rates of increment are evaluated it's once again seen that the increase rate (differential) of the PI in the high-density zone is higher, compared to its medium and low counterparts. The levels are similar between the high and medium density zones as of the 6th of December, as the medium density zone seems to follow the high-density zone with a delay. The predominant difference of the low-density zone with other areas can be seen for all dates.

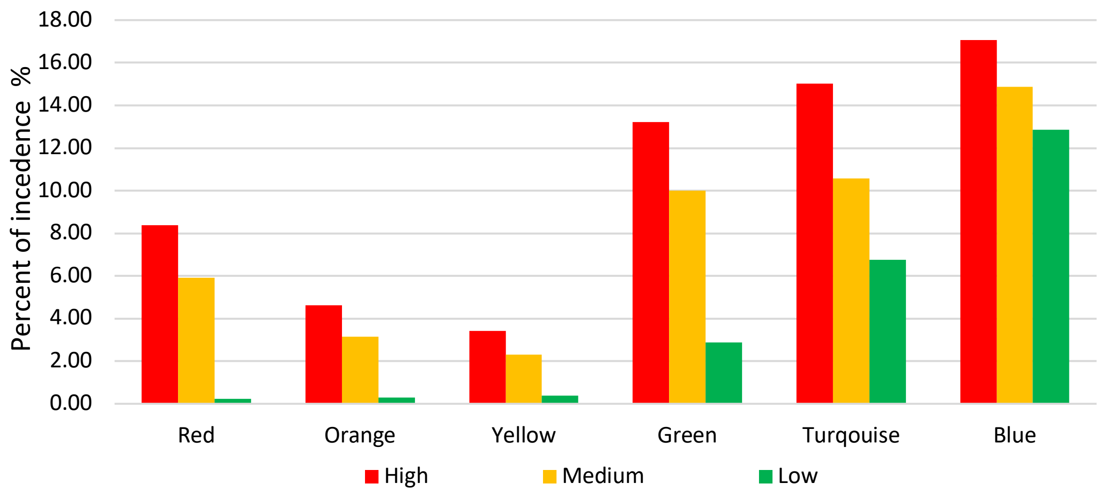

Fig.11 The average percentages of 6 PI levels for the three density areas

In Fig.12, the average values for all dates for each of the three density zones are given as a percentage of coverage and PI index. It is evident that the high-density zone has the highest percentage and PI values with 61 and 173, respectively, whereas these values are 23 and 39 respectively for the low-density zone. The tendency of the numbers is as expected which holds true for Fig.11 as well, where the six categories for three density zones are shown. Interestingly, the high-density zone has the highest value in all categories in Figure 8, even in the blue rating.

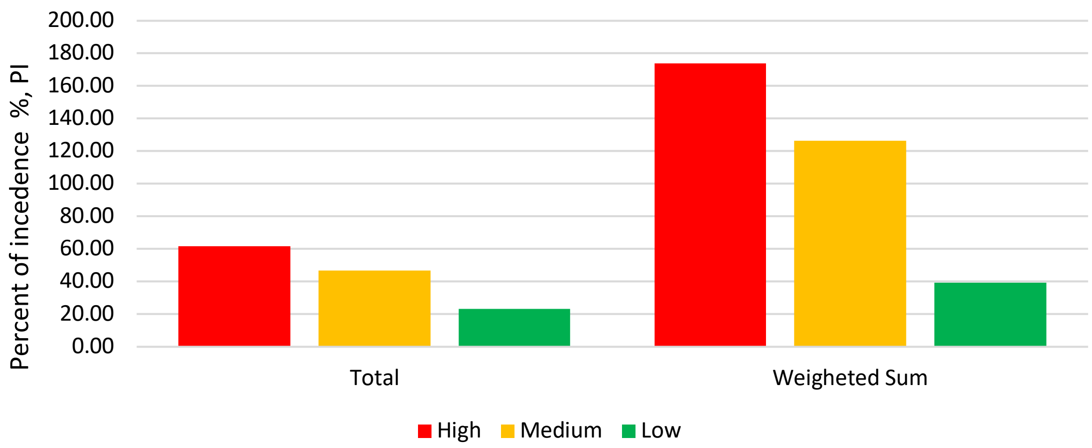

Fig.12 The average of total percentages and PI as the weighted sum for three areas.

A close look-up to the dates 19th of September and 13th of December are provided in Fig.13 and Fig.14, respectively. These dates are chosen to reflect the times where the first wave of Covid-19 was finally suppressed, and only a small number of cases were being reported at the beginning of the summer. As opposed to this, the December period is the peak of the second wave of Covid-19 pandemic that occurs in Turkey. The difference is clear from the density of the values, as in December the majority of the area is in Red and Orange ratings.

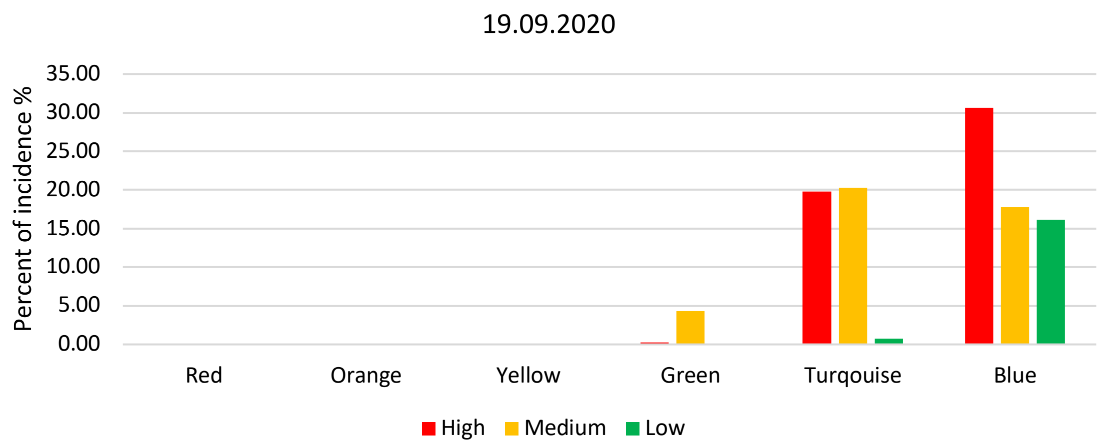

Fig.13 The percent values of 6 levels on the 19th of September

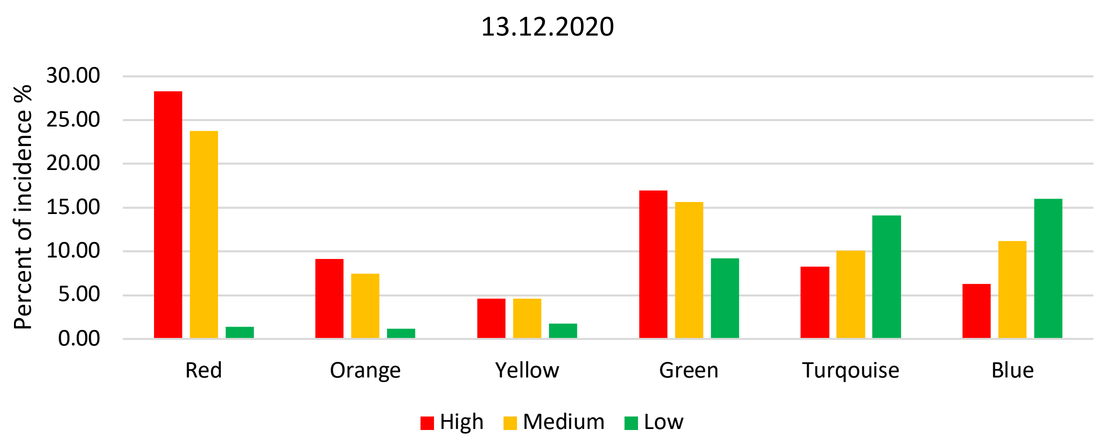

Fig.14 The percent values of 6 levels on the 13th of December

On the other hand, there are no Red or Orange areas in September. When the urban density is considered it can be seen that the ratings for the density of cases and contacts, as well as the PI index, is higher in the high-density areas, for all the dates. Only the Turquoise and Blue rating levels on the 13th of December are "high" in the low-density area, which is an indication of the benefits of low-density housing in terms of pandemics.

5. Conclusion

Urban density is considered to be one of the most important parameters of urban planning. It is for this reason that the course of the Covid-19 pandemic was evaluated in this study in terms of the effects of the urban density parameter on the spreading mechanics of the pandemic. Density arrangements are crucial parameters when the land-use decisions are taken, as they influence the decisions and actual use cases regarding the function, transportation, and formation of a locale. All of these are then reflected in other, emergent parameters like the overall urban density, transportation density, access to public transportation, and temporary proximity to other individuals during actual use. The Covid-19 pandemic has shown that proximity to others is the primary means for the spread of the disease, resulting in the link that starts from the decisions made during the planning phase to the spread of contagious diseases. For all these reasons, it seems now that for a given location, resilience to pandemics is becoming another important criterion when trying to achieve sustainable urbanization.

The data obtained from the HES application developed by the Ministry of Health of the Republic of Turkey to monitor the Covid-19 pandemic were used as the key elements in the study. Heat maps that displayed contacted individuals (actual cases, and contacts with cases) were gathered as screenshots and were processed by an image processing software developed in-house. Although there are some limitations regarding the image data such as the time-frequency, resolution, mixed representations of actual cases, and contacted individuals, the data is still the most accurate location-based publicly available data available for Covid-19 in Turkey, and probably in the world. Other similar examples around the world only provide the city-based data for Covid-19 cases.

This study brings a different perspective regarding the investigation of pandemics by comparing the spread mechanics of the disease in different density zones. The results clearly show that the high-density zone has higher values for Covid-19 "cases and contacts percentage" and "PI rating" (61 and 173 respectively), whereas for the low-density zone these values drop significantly (23 and 39, respectively). A similar trend is observed when the increment rates are evaluated, where it's once again seen that the increase rate (differential) of the PI in the high-density zone is higher than that of others, particularly during the start of the second peak period. The gap between high and low-density zones in terms of the spread of the disease is much more relevant in peak times, starting in late November. The high-density zone has the highest value in all categories, including the lowest rating of blue.

The results are indicative that the lack of urban land production and high population concentration, which have become important problems of developing countries and regions due to rapid population growth, are indeed strong factors for the spread of diseases, such as the Covid-19 pandemic. Also for controlling and appeasing the disease the urban density is also crucial especially in lock-down periods. It is much easier to control human traffic for sustaining imperative need with out avoiding social distance within lower denser urban areas.

For future studies, it is suggested that the evaluation of the relationship between urban density and the spread of the Covid-19 where the data for such research is available. Even when the exact number of cases is not provided and the information is not revealed to the public, heat maps or other similar infographics can be used as shown in this study to create an arbitrary but accurate scale, if they are available. Further studies should also be performed regarding other disease outbreaks if possible, to determine if the urban density affects all diseases in similar manners. As for this study, it is humbly hoped it will provide a new perspective for land use decisions when considering the relationship between urban density and spread of diseases, along with the introduction of a new approach and a methodology when trying to evaluate existing areas in terms of public health.

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Image Sources

Fig.1 Screenshot of HES application at 22.12.2020, SOURCE: https://play.google.com/store/apps/details?id=tr.gov.saglik.hayatevesigar&gl=TR;

Fig.2 The processed image of the case area, SOURCE: Original;

Fig.3 The percent of risk categories in 22.12.2020, SOURCE: Original;

Fig.4 Iskenderun in Turkey, SOURCE: Created by the author using google earth image;

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Fig.7 Figure-ground analysis maps of three density zones high, medium, and low respectively, SOURCE: Created by the author using google earth image

Fig.8 Traffic Density through in the case area, SOURCE: http://maps.google.com/;

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Fig.11 The average percentages of 6 PI levels for the three density areas, SOURCE: Original;

Fig.12 The average of total percentages and PI as the weighted sum for three areas., SOURCE: Original;

Fig.13 The percent values of 6 levels on the 19th of September, SOURCE: Original;

Fig.14 The percent values of 6 levels on the 13th of December, SOURCE: Original.

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Evergreen section

Chaos and chaos: the city as a complex phenomenon

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Evergreen section

This article - published in Italian in 1993 with the title "Caos e caos: la città come fenomeno complesso" as a contribution in the volume "For the XXI century – an encyclopedia and a project" – is published again in this new section of TeMA Journal, Evergreen, in its literal English translation with the addition of new images. This section aims at drawing the attention of the international scientific community to papers that, despite the passing of time, still present elements of significative scientific interest – insights, anticipations and reflections – enough to deserve careful read back.

Abstract

To say that the city is a dynamically complex system is to affirm that the city can be traced back to a set of components in relation to each other (system), that the processes of the system cannot be managed and controlled with deterministic tools (complex system) and, lastly, that the future evolution of the city-system cannot be predicted linearly on the basis of knowledge of the initial conditions (dynamically complex system). The degree of complexity reached by the city, as a modern expression of collective life, is such that it is unable to provide a compatible and adequate solution to the problems of the "city-system", which is subject, like all systems, to processes of entropy maximisation.

Keywords

Complexity theory; Urban system; Entropy.

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Laplacian determinism was slowly replaced by a problematic approach in scientific research in the early twentieth century which, over the years, took shape in rigorous terms: the chaos theory. Deterministic systems[1] even very simple ones made up of a few elements, can exhibit "aleatory" behaviour. This aleatory nature is an intrinsic quality of the system itself and does not depend on the type or amount of information available.

The first insight into randomness is attributable to Henri Poincaré (1903), who observed that "chance" phenomena can occur in a system[2]. This kind of randomness was given the name "chaos" in later times.

One of the principles on which the chaos theory is based is Heisenberg's uncertainty principle[3] according to which "the exactness with which classical concepts can be sensibly applied to the description of nature is limited by so-called uncertainty relations".

This principle, which has become one of the foundations of quantum mechanics, provides a convincing explanation of certain random phenomena on a very small (atomic) scale.

1 "A system is deterministic if exact knowledge of its initial state makes it possible to predict its future with certainty. Let us suppose the laws of physics are deterministic; will we be able to predict the future of the universe in detail, as Laplace claims? In practice, this statement is neither likely nor true. It can be admitted that the universe, which is an extremely complex system, presents the phenomenon of sensitive dependence on initial conditions. If our knowledge of the initial state of the system is even slightly incomplete, our predictions will quickly be subject to considerable error: determinism, therefore, does not imply predictability and the rigour of physical laws does not contradict the contingency of the facts of everyday life". Ruelle, D., "Determinism and predictability" in Le Scienze n.82, Le Scienze S.p.A. Publisher, August 1984.

2 "A very small cause which escapes our attention brings about a considerable effect which we cannot fail to see and so we say that the effect is due to chance. If we knew exactly the laws of nature and the situation of the universe in its initial state, we could predict exactly the situation of the same universe at a later time. But even if it were the case that natural laws no longer held any secrets for us, even then we could know the initial situation only approximately. If this would enable us to predict the next situation with the same approximation, we would not need more and we would have to say that the phenomenon has been predicted, that it is governed by laws. But this is not always the case; it can happen that small differences in the initial conditions produce very large differences in the final phenomena. A small error in the former produces a huge error in the latter. Prediction becomes impossible and you have a chance phenomenon". Poincaré, H., "Science et Methode", Flammaron, Paris, 1908.

3 "Thus today's science, more than the previous one, has been imposed by nature and the ancient problem of grasping reality by means of thought must be posed anew and solved in a quite different way. Previously, the model of exact science could lead to philosophical systems in which a certain truth - such as Descartes' cogito, ergo sum - formed the starting point from which all questions concerning the conception of the world had to be addressed. But now, in modern physics, nature has reminded us very clearly that we cannot hope to understand all knowledge from such a firm basis of operations. On the contrary, in the event of any substantially new knowledge, we must always find ourselves in the situation of Columbus, who had the courage to leave all the land known until that time, in the almost insane hope of finding other land beyond the seas". Heisenberg, W., "Mutamenti nelle basi della scienza", transl.it., Einaudi, Turin, 1944, p. 27.

On a larger scale, the reasons for unpredictability have rarely found valid scientific verification; the random motion of fluids is an exception that confirms the rule. However, it is not necessary to resort to such complicated systems in order to verify the existence of random behaviour, which is also found in relatively simple systems.

In general, the pre-eminent characteristic of a chaotic system is its high sensitivity to even the smallest actions that can occur at any point in its being and becoming. Thus, the degree of uncertainty that a chaotic system can reach is extremely high and, in addition, any phenomenon, even insignificant ones, can very quickly reach macroscopic proportions. In other words, in the presence of chaos, any prediction can reach significant inaccuracies.

The dynamical systems theory can be regarded as the indispensable support in the development of the conceptual framework for the study of "chaos"'[4]. The definition of a dynamical system is given by the elements and the relationships between the elements of the system, as well as the laws and criteria of evolution (of the state) over time. The space of existence of the system's evolution is known as the space of states or the space of phases; this space is a purely conceptual abstraction, the coordinates of which are the components of the state.

Of course, the coordinates of the phase space change with the context; for example, for a mechanical system, they might be found in position and speed, for an ecological system in the populations of the various species. Although it is recognised that the behaviour of chaotic dynamical systems is unpredictable, the space of states can be useful in representing this behaviour in geometric form.

[4] "An apparent paradox is that chaos is deterministic, i.e., generated by fixed rules that, in themselves, contain no random element. In principle, the future is completely determined by the past but, in practice, small uncertainties are amplified; thus, although behaviour is predictable in the short term, it is unpredictable in the long run. In chaos there is order: underlying the chaotic behaviour are elegant geometric shapes that create randomness in the same way as a papermaker shuffles the pack of cards or a cook shuffles the dough for a cake. The discovery of chaos has created a new paradigm amongst scientific models. On the one hand, it implies the existence of new fundamental limitations to our ability to make predictions; on the other hand, the determinism inherent in chaos implies that random phenomena are more predictable than previously thought. Seemingly random information gathered in the past (and dismissed as too complicated) can now be explained in terms of simple laws. Chaos enables us to discover order in systems as diverse as the atmosphere, a dripping tap and the heart. This has resulted in a revolution that is affecting many different branches of science. Crutchfield, J. P., Farmer, J. D., Packard, N. H., Shaw, R. S., "Chaos", Le Scienze n.222, Le Scienze S.p.A. Publisher, February 1987.

At present, chaos theories do not provide a solution to the problem of predicting the evolution of systems, mainly because there are still many unknowns about the actual incidence and significance of chaos. However, it is unequivocally agreed that one measure of chaos is entropy.

The concept of entropy is based on the second law of thermodynamics: every time energy is transformed from one state to another, the available energy is reduced in favour of the unavailable energy. To use Rifkin's definition, one can say that the transformation of energy requires "paying a price". Yet again, "this cost is represented by a loss of energy available to perform work of a certain type in the future. The term that describes this fact is entropy. ... An increase in entropy, therefore, means a decrease in available energy"[5]. When energy (and matter) become unavailable, the result is the greatest possible disorder and, thus, chaos.

The second principle of thermodynamics[6] refers, not only to energy, but also to order and, above all, to the organisation of systems; in this sense, this (principle) applied to a physical system is defined as a statistical principle of energy degradation, of disorder of the constituent elements and therefore of disorganisation.

Thus emerges the centrality of organisation as an intrinsic quality of complex systems[7].

5 See Rifkin, J., "Entropy", Arnoldo Mondadori, Milan, 1982, pp.44-45. In the same pages, Rifkin, making the terms of his statements explicit, reiterates: "Let's take a car engine as an example. The energy in petrol is equal to the work done by the petrol engine, plus the heat generated, plus the energy in the exhaust products. Again, the most important thing to remember is that it is not possible to create energy. No one has ever succeeded in creating it and no one ever will. The only thing that can be done is to transform energy from one state to another. It is difficult to understand this concept if one does not consider that everything is made up of energy. The appearance, form and movement of anything in existence is really only an expression of the different concentrations and transformations of energy. A person, a skyscraper, a car and a blade of grass all represent energy that has been transformed from one state to another".

6 The pervasiveness of this principle and, in general, the growing popularity of certain fundamental concepts of the main scientific theories can be seen in the countless quotations and references in recent popular scientific literature. Amongst them, attention is drawn to the effective trivialisation of the entropy constraint by L. De Crescenzo in a widely circulated popular text ("Il dubbio", Arnoldo Mondadori Editore, Milan, 1992, p. 57 ff.): "When God expelled Adam and Eve from the earthly paradise... he said: You man will work with sweat and you woman will give birth with pain! Then, when he saw them coming out of the gate, he cast the last anathema on them: And both of you will be haunted forever and ever by the Second Principle of Thermodynamics!"

7 "We are surrounded by complex objects, but what is complexity? Living organisms are complex, mathematics is complex and the construction of a space probe is complex. But what do these things have in common? Likely the fact that it contains a lot of information that is difficult to obtain. We are currently unable to create living organisms from scratch, we have great difficulty in proving certain mathematical theorems and we need a lot of work to conceive and

Organisation can be defined as the form, distribution and intensity of the relationships between the components that make up a complex unit or system. Ultimately, the ability to organise is one of the fundamental properties of a system and can be expressed as the evolution of relational interactions into organisation.

Organisation[8] thus becomes the constituent property of a system.

The variety and multiplicity of existing systems makes it possible to build a hierarchy and categorisation of systems. The determination of the hierarchical level of a system depends essentially on the choices and decisions of the observer, on which the very conceptualisation of a system ultimately depends. In other words, in the definition of a system, there are always, at the base, decisions and choices of a subject, which operates within the polysystemic interior of the selections in relation to its own aims, to the available tools and in relation to the cultural and social context.

However, the chaos theory also implies degrees of complexity within the scientific method of testing a theory; until now, the classical method involved making predictions and then comparing them with experimental data. For chaotic systems, the impossibility of making long-term predictions means that the verification of a theory becomes a very delicate activity full of pitfalls, relying on statistical and geometrical properties rather than detailed and precise predictions.

Amongst the infinite systems into which physical reality can be broken down, it is indispensable, for the renewed and extended purposes of the most recent "research" on the territory, to consider the city as a dynamic system of high complexity.

To say that the city is a dynamically complex system is to affirm that the city can be traced back to a set of components in relation to each other (system), that the processes of the system cannot be managed and controlled with deterministic tools (complex system) and, lastly, that the future evolution of the city-system cannot be predicted linearly on the basis of knowledge of the initial conditions (dynamically complex system).

The degree of complexity reached by the city, as a modern expression of collective life, is such that it is unable to provide a compatible and adequate solution to the problems of the "city-system", which is subject, like all systems, to processes of entropy maximisation.

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implement a space probe." It can be concluded that "*an object (physical or intellectual) is complex if it contains information that is difficult to obtain*." Ruelle, D., "Caso e caos", Bollati Boringhieri, Turin, 1992, p. 149.

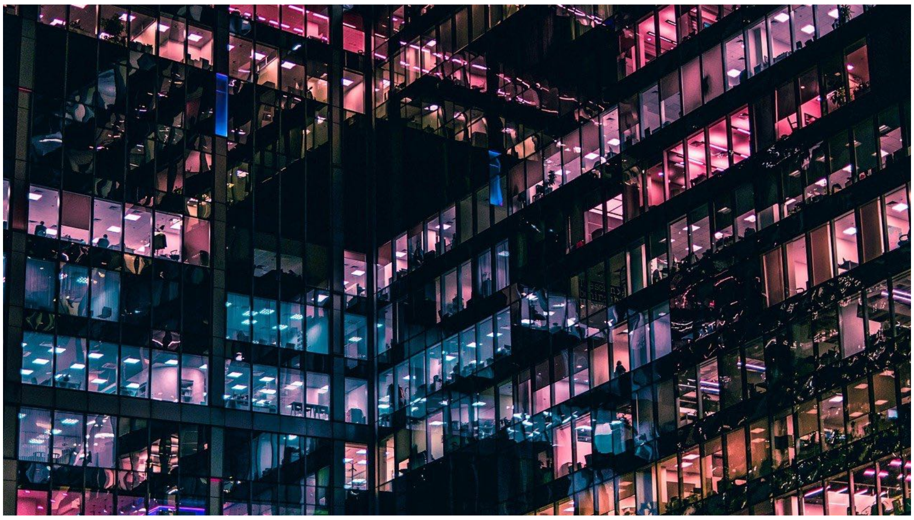
8 "What is organisation? First definition: organisation is the arrangement of relationships between components or individuals that produces a complex unit or system, endowed with qualities that are unknown at the level of the components or individuals. Organisation interrelatedly connects different elements, or events, or individuals who consequently become components of a whole. It provides a relative solidarity and solidity to these links and thus guarantees the system a certain possibility of durability, despite random perturbations. Organisation, therefore: *transforms, produces, connects, maintains*". Morin, E., "Il Metodo", Idee/Feltrinelli, Milan, 1983, p. 133

Whilst in some periods of urban history the city has developed in harmony and compatibility between its parts, in recent decades, the occurrence of extremely variable and changing events in the urban fabric, which are difficult to attribute to one cause and one alone, has led to unbearable conditions of intolerability and congestion. These conditions are almost always the result of difficult-to-understand causes, accompanied by an inability to control and manage complex phenomena, due, not only to the inadequacy of the procedures adopted, but also to the unavailability of effective tools.
In addition to all of this, the introduction of new technologies, involving all levels and all sectors of associated life, generates new knowledge and new progress. Thanks to these distinctly self-propulsive characteristics, the capacity for affirmation and diffusion of technological progress goes beyond the narrow limits of economic-productive activities and has a profound impact on ways of being and thinking and, therefore, on social, political and, of course, territorial aspects.
In short, the multiplicity, multiformity and variety of existing relationships - in a word, the complexity - within the city-society system requires appropriate methods of interpretation and analysis, as well as innovative tools and control techniques.
For some years now, scientific research in the urban and territorial field has agreed to consider the city as a "system" defined by the elements (the various urban activities and functions) and by the interactions and relations between its many components (material and immaterial communications) which produce, with different intensities and modalities, effects that are difficult to identify in all parts of the city (McLaughlin, 1973)[9].
In this perspective, the "complexity paradigm" seems to offer greater guarantees of relevance and relationship in the interpretation of the variety and interdependence of urban phenomena and may also assume a central

9 "Our daily experience confirms that the relationship between man and the environment can be understood in terms of an *ecological system or ecosystem*. In terms of human behaviour, we identify the components of the system as spatially localised activities. Activities interact or are interlinked through physical, or intangible, communications flowing along certain channels. The behaviour of individuals and groups is clearly competitive and is motivated by a constant investigation of the environment which, from time to time, is expressed in actions to modify activities, spaces, communications, channels or some combination of these, or their relationships. Obviously, these processes are complex, both in themselves (i.e., per individual or group) and in the way they can be interrelated; but a certain structural simplification is necessary and possible". Mc Loughlin, J.B., "Urban and Regional Planning", transl.it., Marsilio, Padua, 1973, p.17.

role in the definition of tools and methods for problem solving. A challenge to which the future of the city is entrusted.

The reading of the city aimed at identifying, not only its physical aspects (its shape, its streets, its houses), but also its functional aspects (the relationships that exist between its components and the laws that regulate these relationships), leads us to adopt and make our own the systemic-procedural approach, oriented, precisely, towards defining the becoming of reciprocal influences between the elements of the system and between the system and its components.



The theoretical support to refer to can be found, *inter alia*, in Thom's theory of catastrophes[10] and Morin's philosophy of heterogeneity, considering the city system as a structure, the state of which is continually modified by the supply of "energy" it receives from the outside and which it consumes incessantly. From this, it is deduced that its state of equilibrium is only apparent given that, in reality, it is in stationary equilibrium or in dynamic stability; that is, the city is a system characterised by an inextricable complementarity between "disordered phenomena" and "organising phenomena", which regulate themselves in a subsequent (only) stationary state of equilibrium.

In order to govern such a system, it is firstly necessary to relate its overall structure to an interpretative model made up of intelligible elements and relationships. Once the approach criterion has been defined, it is necessary to know which are the constituent elements and which are the main relationships of the (modelled) system. Lastly, it is necessary to determine the characteristics of the elements and the laws governing their integration, without which (elements, laws and integration) it is not even possible to think of modelling the "city-system".

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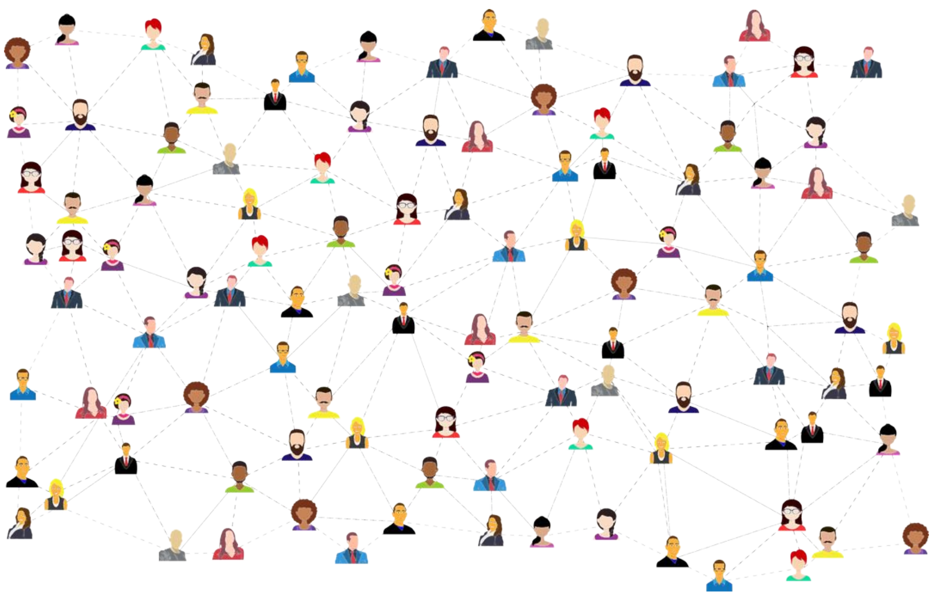
[10] "The most innovative and relevant qualitative-quantitative approaches, from a methodological and heuristic point of view, are René Thom's topological approach of the "catastrophe theory" and the theory of "bifurcations". Both theories study (the first in a more restricted field, but with taxonomic intentions; the second in a more general field) dynamic systems characterised by multiple equilibria, in which the passage from one equilibrium to another may imply a discontinuity, a sudden jump, a "catastrophe" and in which the temporal paths of the variables may under certain conditions present a bifurcation, a clear alternative between trajectories that subsequently follow a different history. In both cases, the time trajectories appear largely irreversible and the system does not return to its initial state when the direction of time is reversed, unlike Newtonian dynamics, which assumes harmonic systems and reversible trajectories. The essential element that arises from these theoretical approaches is *the criticality of the initial conditions* of the system, which follows from the fact that a certain path can only be replicated by chance and that, as mentioned above, it cannot be carried out in the (temporally) reverse direction". Camagni, R., "Economia urbana - principi e modelli teorici" (Urban Economy - principles and theoretical models), La Nuova Italia Scientifica, Rome, 1992, pp. 319 and 320.

The essential characteristic that allows a generic system to exist is what Edgar Morin (1977)[11] calls "organisational antagonism". Every organisational interrelation presupposes the existence and play of attractions, affinities, the possibility of connections or communications between the elements. But the preservation of differences likewise presupposes the existence of forces of exclusion, repulsion and dissociation, without which everything becomes confused and no system is conceivable.

In other words, every system, including the urban system, produces both antagonisms and complementarities within it; to govern a system, it is therefore necessary to know the rules (insofar as they can be found) by which antagonisms and complementarities are organised.



[11] "Unlike thermodynamic equilibria of homogenisation and disorder, organisational equilibria are equilibria of antagonistic forces. Every organisational relationship and, therefore, every system, therefore involves and produces antagonism at the same time as it produces complementarity. Every organisational relationship necessitates and *actualises* a principle of complementarity and necessitates and virtualises, to a greater or lesser extent, a principle of antagonism". Morin, E., The Method, trans. it., Idee/Feltrinelli, Milan, 1983, pp. 152 and 153.

Like and before Morin, von Bertalanffy (1968) had stated that every totality is based on the competition between its elements and presupposes the struggle between its parts.
One cannot, therefore, speak of a system without presupposing the idea of antagonism; but this idea carries, as an implicit and direct consequence, "potential disorganisation" or disorder. In fact, the moment the system breaks down, disorder spreads. But the system comes into crisis when differences turn into oppositions and complementarities into antagonisms.
In light of these considerations and in order to better clarify the terms of the question, it is appropriate, at this point, to recall the systemic-functional approach to the city, which is proposed here.
This approach is directly related to the general theory of systems, which, applied to the urban phenomenon, allows for the construction of a cognitive model useful for the interpretation and decoding of urban complexity. In this sense, as early as in the reading and analysis of the city-system, it is necessary to combine the characteristics of the individual parts with the characteristics of the whole system, with the aim of defining the interrelationships that link the individual parts to the whole and vice versa.
The path (circuit) on which the passage from the parts to the whole and from the whole back to the parts is triggered is of a poly-relational type in that the elements must be defined in their characteristics, in the relations in which they take part, in the overall organisation in which they exist and, ultimately, in that specific "breeding ground" in which they are inserted (that specific system); conversely, the system must be defined in its specific characteristics, in the relations existing between its elements and in the relations with each of its elements.
With reference to this scientific approach and from observation of the urban system, it can be said that the city is undoubtedly a dynamically complex system.
On the basis of the above considerations and the theory of dynamic systems, it can be deduced that the evolution of the city cannot be predicted linearly on the basis of the initial conditions.
To say, therefore, that a city is a dynamically complex system is to say that said system is defined, not only by its own characteristics, but also by laws and criteria of state evolution that change over time.
The dynamic complexity that characterises the city depends essentially on four main variables:

- levels of hierarchy;
- the type and quality of relationships;
- the number of elements;
- the speed and laws of change.

The various levels of hierarchy enable the urban structure to be read from various points of view.
The type and quality of possible relation paths refer to the interconnection between the various elements of the system and depend on the ability to know the range of effects that each action performed, even on a single part of the system, may generate on one or more different parts and on the other relations.
Having thus defined the reference concepts for a "modelling" of the urban system that allows for the identification of reading methods and analysis techniques, the next step must be oriented towards the definition of procedures aimed at governing the "organisation" of the system.
These procedures must allow for the definition of control tools and techniques oriented to the re-functionalisation of the relational sub-system and to the recovery and reuse of the physical sub-system.

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REVIEW NOTES – Urban planning literature review

Ecological transition: perspectives from U.S. and European cities

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Abstract

Starting from the relationship between urban planning and mobility management, TeMA has gradually expanded the view of the covered topics, always remaining in the groove of rigorous scientific in-depth analysis. This section of the Journal, Review Notes, is the expression of a continuous updating of 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 aims at presenting recent books and journals, within global scientific panorama, on selected topics and issues.

This contribution proposes a further insight into the complex ecological transition, with a focus to U.S. and European cities. Cities have faced a worldwide health and economic crisis due to the outbreak of a new coronavirus in 2019 and now, with progressive and massive vaccination and never experienced financial tools, a new era seems to start: significant financial resources, plenty of room for economic maneuvers may turn the ongoing pandemic into an opportunity, for the following years, to build more sustainable societies and environments. Within this scenario, urban areas play an essential role. According to shared and universal goals to achieve a more sustainable model of society and economy, how ecological transition is run by policymakers, stakeholders and citizens strongly depends on cities' backgrounds and structures.

Keywords

Ecological transition; Urban planning; Strategies.

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1 Introduction

When it comes to well-being and health, the Covid-19 pandemic is undoubtedly a priority issue in policymakers agendas worldwide. The outbreak of a new coronavirus has required health protection responses with far-reaching consequences for society, livelihoods, and the broader economy. Future enquiries will eventually evaluate the success of responses at all scales, from restrictive policies to economic and financial support, for families and enterprises, from healthcare management to massive vaccination plans. Thus, emerging lessons highlight immediate implications for addressing the growing climate crisis through a recovery from Covid-19 that advances population health, economic regeneration and climate action (Śleszyński, 2020; Laurent, 2021).
This contribution proposes a further insight into the complex ecological transition, with a focus to U.S. and European cities. Cities have faced a worldwide health and economic crisis due to the outbreak of a new coronavirus in 2019 and now, with progressive and massive vaccination and never experienced financial tools, a new era seems to start: significant financial resources, plenty of room for economic maneuvers may turn the ongoing pandemic into an opportunity, for the following years, to build more sustainable societies and environments. Within this scenario, urban areas play an essential role. According to shared and universal goals to achieve a more sustainable model of society and economy, how ecological transition is run by policymakers, stakeholders and citizens strongly depends on cities' backgrounds and structures (Meng at al., 2021).
As highlighted in the recent Global Risks Report of the World Economic Forum (2021), extreme weather, climate action failure and human environmental damage are expected to be the three most dangerous risks by likelihood. At the same time, for what concerns their impacts, according to a survey, infectious diseases seem to warn people the most. Moreover, the economic and social crises have broken globally financial dogmas. This significant step is allowing policymakers to manage wide-ranging and innovative financial maneuvers. Hopefully, new generations of professionals, academics and entrepreneurs will experience a *Renaissance* of economies that will embrace effective and sustainable climate actions (Gao et al., 2020).
Environmental and energy transitions are iterative processes of build-up and breakdown over a period of decades. In a transition model, change agents – for example pioneering regions and cities – start to experiment with ideas, technologies and practices towards a climate-neutral and circular economy. Over time, pressure to transform current socio-ecological systems (e.g. the current food system) builds up. Such pressure destabilises the current production and consumption system and creates space for alternatives to emerge, e.g. more sustainable food production systems. Change agents operate in parallel to so-called incumbents – actors (e.g. enterprises) that profit from the current, potentially unsustainable model. Incumbents can (and often do) prevent the successful emergence of new business models and institutional structures, such as renewable sources of electricity, cleaner fuels for mobility or more sustainable agricultural practices. During the process, elements of the old structure(s) that do not transform are broken down and phased out. The actual transition is chaotic and disruptive, and eventually leads to changed socio-economic systems, such as a sustainable food system or a sustainable energy system.Within this framework, cities are where many of the most critical actions for health, greenhouse gas (GHG) emissions reduction, resilience and risk reduction must be taken, supported by national governments, multi-lateral agencies, and other stakeholders. Rapid decarbonization across all sectors of society is needed over this decade: further delay will seriously reduce the possibility of achieving the targets set out in the Paris Agreement. Now is therefore an especially important juncture for cities to act for both the near-term imperatives of the post-Covid recovery and the long-term welfare of their residents and of the whole planet (Borkowski et al., 2021). From a design perspective, cities are in a unique position when it comes to climate change. Among the largest sources of emissions globally, they are also highly vulnerable to its consequences. According the most recent IPCC report (2019), 70% of cities worldwide are already dealing with the effects of climate change, and nearly all cities face some kind of risk. But they are also potentially powerful agents of change (Schmidt et al., 2021). As highlighted in the previous Urban Planning Literature Section of Review Notes, ecological transition to more sustainable models is needed, but

many and complex cause-effect reactions need to be taken into account.Policy at the national level has moved painfully slow in most countries, but urban areas have the authority to make meaningful changes in land use and zoning, green space, energy policy and transportation. Sutainable mobility and transportation solutions are the focus of this contribution, with a deeper insight into European and U.S. post-Covid-19 cities.

2 Ecological transition through mobility solutions

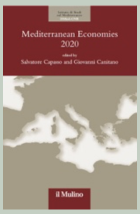
Mobility is an essential part of everyday day life and affects the wellbeing of citizens. Alongside with transport, mobility is the backbone of the well-functioning of national and international markets, fair competition and of utmost importance for socioeconomic and territorial cohesion, as well as for ensuring accessibility and connectivity, within urban areas and from rural zones to cities. It concerns all of us and we therefore have a responsibility to make sure that sustainable, high-quality transport is available with no one left behind. This requires that all transport policies take into account different social dimensions of underrepresentation, such as age, gender, socio-economic status or background, health, (dis)ability status, language barrier, employment situation or the region we live in. While this sector is crucial for the development of any economy, it also has a large role to play in any meaningful efforts to ecological transition to a low- carbon future. Therefore, it is necessary to view the transportation sector through the lens of sustainability, which encompasses economically viability, as well as human and environmental health. In Europe, mobility has a significant ecological footprint, being responsible for over 27% of all greenhouse gas emissions in the EU. While the EUs overall emissions decreased between 1990 and 2019, transport in the only sector whose emissions increased. Moreover, mobility is a major contributor to air pollution by emitting particulate matters and numbers. As outlined in the European Commissions' Green Deal, the sector needs to cut 90% of its emissions by 2050 and is therefore key for the EU to achieve climate neutrality in 2050 as set out in the European Climate Law (Gargiulo et al., 2012). Moreover, the sector needs to undergo a thorough digitalisation process on all levels to embrace the future, which will lead to profound changes in the sector and ensure competitiveness and efficiency, while also providing new opportunities. Even though European and U.S. cities have been characterized by different development models, which have led to compact European cities and American metropolis, their trends in GHG emissions in transportation sector seems to be close. From United States perspective, the transportation sector is one of the largest contributors to anthropogenic greenhouse gas emissions. According to the Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990 - 2019 (the national inventory that the U.S. prepares annually under the United Nations Framework Convention on Climate Change), transportation accounted for the largest portion (29%) of total U.S. GHG emissions in 2019 (EPA, 2020). Cars, trucks, commercial aircraft, and railroads, among other sources, all contribute to transportation end-use sector emissions. Since United States President Joe Biden has moved to reinstate the U.S. to the Paris climate agreement just few hours after being sworn in as president, his administration is rolling out a cavalcade of executive orders aimed at tackling the climate crisis. This political and institutional effort signs for a greater commitment: scientists and researchers agree that, without U.S. engament in Paris agreement, the already controversial and complex efforts of nations will be in vain. In the light (and hope) of the new era post-Covid, and renewed commitments towards climate crisis, innovative strategies are being delved into, promoting new forms of transport and society: electric and autonomous vehicles, shared mobility are some of the solutions that stakeholders and policymakers have to consider. Of course, Covid-19 restrictions and smart-working policies have deeply modified urban dynimics, that needs to be taken into account. Hence, in this contribution three significant studies are presented: they offer three different perspective to analyze the topic here discussed. The first (Nouvellet, 2021) one considers mobility and its relation to Covid-19: as data have proved, urban environments have been the epicentres for the transmission of the new coronavirus, but this research investigates about the actual responsibility of mobility trends in cities. In the second box, a book edited by Capasso and Canitano (2020) offers interesting insight to Mediterranean economies and society, through the lens of mobility opportunities.The third (Badr et al., 2020) review concerns an in-depth focus to U.S. cities in the Covid-19 scenario.

Reduction in mobility and Covid-19 transmission

Authors/Editors: Pierre Nouvellet
Publisher: Nature Communications
Publication year: 2021
DOI: 10.1038/s41467-021-21358-2

In response to the Covid-19 pandemic, countries have sought to control the transmission by restricting population movement through social distancing interventions. As mentioned before mobility data represents an important proxy measure of social distancing. The study characterizes the relationship between transmission and mobility for 52 countries around the world. Transmission significantly decreased with the initial reduction in mobility in 73% of the countries analyzed, but the study has found evidence of decoupling of transmission and mobility following the relaxation of strict control measures for 80% of countries. For the majority of countries, mobility explained a substantial proportion of the variation in transmissibility. In countries with a clear relationship between mobility and transmission both before and after strict control measures were relaxed, mobility was associated with lower transmission rates after control measures were relaxed indicating that the beneficial effects of ongoing social distancing behaviors were substantial. The study analyzed 52 countries for which both epidemiological and mobility data were available. This included 36 countries for which we had both Google and Apple mobility data and 16 countries for which we had only Google mobility data. The median mobility across the 52 countries reached its minimum on the 11th of March 2020, with a reduction of 63% from baseline. Mobility then recovered, with an estimated median reduction in mobility on the 25th of October 2020 reaching 14% from baseline. The 10 countries with the smallest changes saw mobility reduction within a range of 37 to 51% from baseline (smallest to largest changes observed in Moldova, Afghanistan, Switzerland, Ecuador, Paraguay, Sweden, Ukraine, Panama, Dominican Republic and Denmark). The 10 countries with the largest changes saw mobility reduction within a range of 72 to 83% from baseline (smallest to largest changes observed in Honduras, Poland, Costa Rica, Italy, Guatemala, Peru, Philippines, Argentina, France, Bolivia). The study found consistent evidence that automated measures of mobility correlate well with transmission intensity of Covid-19 over time in several countries. The relationship holds for 12 mobility data-streams based on Apple and Google mobility data and was robust to assumptions about the likelihood and serial interval distribution. The study also found strong evidence that the relationship between mobility and transmissibility changed over time, typically, a dampening indicating that smaller reductions in mobility can result in epidemic control likely due to other social distancing behaviors. As mobility data increasingly become available in real-time future epidemiological analysis may increasingly rely on this type of data. The study concluded that for the 52 countries having experienced, or still experiencing, substantial active Covid-19 transmission, there was a strong link between mobility measures and transmissibility, supporting the implementation of population-wide social distancing interventions to control the epidemic. Encouragingly, in the majority of countries, the study found clear evidence of a recent dampening of the relationship between transmission and mobility, suggesting alternative control strategies have been successfully implemented and significantly decreased transmission. This, however, was insufficient to prevent a second wave of infection in many countries as mobility, and thus contact rates, gradually increased. Mobility measures seem to reflect the level of contact and therefore level of transmission well. As such measures could be made available in real-time, mobility data could become an important aspect of forecasting efforts. An earlier version (May 2020) of this analysis explored such aspects, but the change in relationship demonstrated here means that more needs to be understood about additional drivers of transmission before reliable forecasting based on mobility can be achieved.

Mediterranean Economies 2020



Authors/Editors: Salvatore Capasso, Giovanni Canitano
Publisher: il Mulino
Publication year: 2020
ISBN: 978-88-15-29082-3

The report on Mediterranean Economies presents an updated summary of the socio-economic research conducted by the Institute for Studies on the Mediterranean (ISMed) of the National Research Council (CNR). The report has been

published since 2003 and has an annual frequency. In recent years, international economic relations and political conditions in the South-Eastern Mediterranean countries have been changing. In this context of major change, the objectives and instruments of the European Mediterranean policy need to be reconsidered, in order to gather together elements useful for strengthening it and suggesting new orientations. A relaunching of cooperation strategies between the banks of the basin requires a good knowledge of the structural characteristics and political and economic dynamics of the economies of the southern and eastern shores of the basin. The report aims to respond to a demand for knowledge of these dynamics, which comes from economic and institutional actors and which is also reflected in the university and postgraduate training offer, which often identifies the Mediterranean as a case study representative of relations between the North and South of the world. The Mediterranean is a very integrated space within it, as the data on interchange and logistics show in a clear way, but it also presents all the critical aspects of an inhomogeneous space in which countries with deep economic inequalities, various indicators of human development, processes of democratization in progress and the results still uncertain and conflicts never dormant that feed a perennial state of political instability enter into contact. Therefore, while maintaining its character as a permanent observatory on the Mediterranean Economies, it is hoped that the report will gradually open up to political-institutional issues, instruments of analysis essential for reading an international scenario in which geopolitical and geoconomic dynamics have a decisive influence on global economic growth. The reflection on the future of cooperation on the need for a rethinking of Euro-Mediterranean policies, which also emerges from the most recent community programmes such as Horizon 2020, stems from the awareness that global economic instability requires the search for regional responses, since the negative repercussions of the crisis on national markets and the need to build new development paths based on the strengthening of intergovernmental cooperation are evident. The report on the Mediterranean economies is intended to represent an original publication compared to other research products in Italy. These relations are characterized by an exclusively political focus, analysis of Euro-Mediterranean relations and identification of foreign policy strategies to manage emergency situations (control of political instability outbreaks, management of migration flows) or solely for the economic cutback, to support companies interested in investing in SEMCs. The ISMed report would like to place itself at the intersection of these two different disciplinary approaches, a product of research and reflection able to make politics interact with the economy. Moreover, the report does not only aim to update the state of the various areas of economic interest examined, but also to propose interpretative lines, present facts and figures, giving them a reading capable of capturing the current trends.
The report aims to be an observatory on the dynamics of socio-economic cooperation in the Euro-Mediterranean context, analysed in their fundamental aspects (population, trade, foreign investment, environment, etc…) and focused on Euro-Mediterranean relations and interdependencies that are manifested between the three shores of the basin. The report could be of great usefulness to give a new impetus to the politics of Italy in the Mediterranean, which loses commercial positions on the southern and eastern shores of the basin to the advantage of non-EU European powers, such as Germany, and sees its logistical centrality diminished, with the downgrading of Italian ports increasingly exposed to competition from other Mediterranean and South-Mediterranean European airports. The need that Europe has to manage complex phenomena, such as migratory pressure, the presence of old conflicts that have never been resolved on the south-eastern shore of the basin (the Arab-Israeli conflict, the continuous inter-ethnic tensions in Lebanon) and new civil wars in Libya and Syria, the request for asylum of populations in a state of war, imposes a change of course and requires the overcoming of a Mediterranean seen from the North. Only from a cross-referenced look at the Mediterranean societies analysed in their mutual interdependence, can a common strategy emerge that values convergences of political objectives and economic complementarities.

Association between mobility patterns and Covid-19 transmission in the USA: a mathematical modelling study

Authors: Hamada S Badr, Hongru Du, Maximilian Marshall, Ensheng Dong, Marietta M Squire, Lauren M Gardner
Publisher: Elsevier
Publication year: 2020
DOI: 10.1016/S1473-3099(20)30553-3

The Covid-19 pandemic has caused great global disruption with immense economic, environmental, and social impacts throughout the world. The alarming speed of this pandemic has caused millions to be infected and has brought economic activity to a near-standstill as countries imposed tight restrictions on movement to halt the spread of the virus. As the health and human toll rises, the economic damage is already evident and represents the largest economic shock the world has experienced in decades. Unfortunately, we can expect other major disruptions to occur in the future. The intent of this review is to understand the lessons for transportation engineering, which can be learned from the current catastrophe in hopes to better prepare us for future disruptions. The aspects of the pandemic not directly related to transportation, such as development of treatments, test, and vaccines will be ignored.
This study considers the relationship between the emerging dynamics of Covid-19 transmission and mobility in the United States. It looks into several publications that address this issue from a robust, data-driven perspective. The results found

are consistent with Covid-19 transmission research to date. Specifically, that decreased mobility has a significant, positive relationship with reduced case growth. Previous studies have shown that social distancing has positive effects on Covid-19 transmission in China, the work this study extends these results to the United States. The study uses real-world mobility data and reported case counts to empirically estimate the relationship between the two variables in the United States, instead of assumed infection rates, assumed compliance aligned with timing of policies, or modelled or synthetic data. The study concluded that social distancing helps reduce the spread of Covid-19, and should remain part of personal and institutional responses to the pandemic. To quantify the amount of social distancing in each US county, the study defined a mobility ratio for each day and county, which quantified the change in mobility patterns as a proxy for social distancing. The mobility reflects the change in the number of individual trips made in each county per day, relative to ordinary behavioral patterns (i.e., before Covid-19). To compute this measure, the study used daily origin–destination trip matrices at the US county level derived from aggregated and anonymized cell phone, using of aggregated mobility data to monitor the effectiveness of social distancing interventions. The mobility ratio is the sum of the total trips incoming, outgoing, and within each county on a given day, divided by the same measure on a baseline day. This metric is interpreted as a proxy for social distancing on the basis of the assumption that when individuals make fewer trips, they physically interact less. The mobility ratio for the 25 counties with highest number of reported cases at the time of the study ranged from 0.35 in New York City to 0.63 in Harris County, TX, highlighting the varying mobility ratio measures and associated behavioral changes around the country. The statistical analysis revealed that the effect of social distancing on decreasing transmission is not likely to be perceptible for at least 9 –12 days after implementation, and might be longer. This lag time reflects the time for symptoms to manifest after infection, worsen, and be reported. The researchers we hope that the results will motivate both individuals and governments to make safe and data-driven decisions, and acknowledge the effect these choices have on all of our communities.

Author Contributions

The work, although the result of a common reflection, was divided as follows: Carmen Guida, paragraphs 1 and 2, and review box of "Mediterranean Economies 2020"; Jorge Ugan, review boxes of "Reduction in mobility and Covid-19 transmission" and "Association between mobility patterns and Covid-19 transmission in the USA: a mathematical modelling study".

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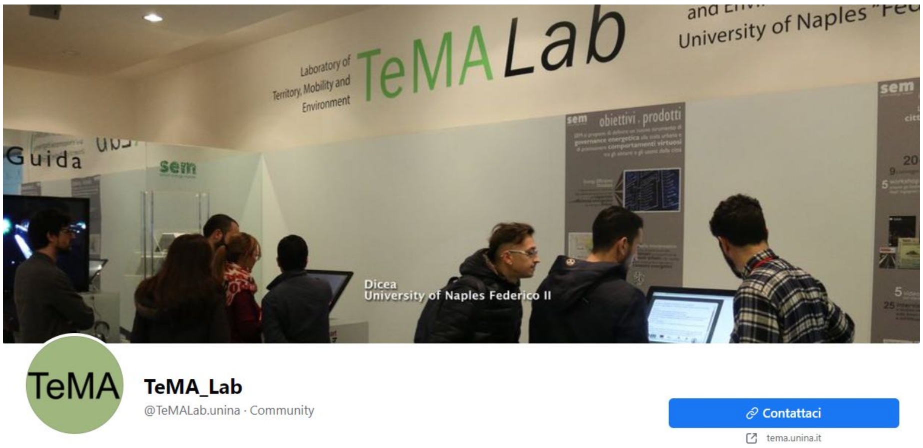

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REVIEW NOTES – Town Planning International Rules and Legislation

Resilience as an urban strategy: The role of green interventions in recovery plans

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Abstract

Starting from the relationship between urban planning and mobility management, TeMA has gradually expanded the view of the covered topics, always 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 Overview section aims at presenting the latest updates in the territorial and urban legislative sphere. The issue of the current recovery and resilience plans and the related reforms envisaged in them aim to give impetus to new forms of organization of urban systems and all its components. In this direction, the content of this review describes the reforms envisaged in the National Recovery and Resilience Plan of Italy and Germany with a focus on the due mission based on the green revolution and ecological transition. Furthermore, this review aims to define the role of these plans for future urban strategies to face the great challenges to which cities are called to respond such as climate change, energy efficiency while also respecting the principles of environmental sustainability.

Keywords

Urban sustainability; Green energy; Resilience plans; Covid-19.

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1 Introduction: EU response

When the WHO declared on the 11th of March 2020, the novel coronavirus out break a global pandemic, majorly spread through air transport (Ania & Joseph, 2021), nations imposed global lock down restrictions on movements and that consequently affected the global economy across all sectors. According to the Congressional Services Report 2020, the pandemic has disrupted lives across all countries and communities and negatively affected global economic growth in 2020 beyond anything experienced in nearly a century. Estimates indicate the virus reduced global economic growth in 2020 to an annualized rate of -3.4% to -7.6%, with a recovery of 4.2% to 5.6% projected for 2021. Global trade is estimated to have fallen by 5.3% in 2020 but is projected to grow by 8.0% in 2021. Accordingly, Regions have had to devise strategies of getting economies back to work to least pre-Covid-19 levels, and so did countries revise their national strategies for growth. For the EU, this pandemic is an opportunity to tilt more towards its net carbon and green growth targets and GHG targets by 2050 and 2030 respectively through its newest strategy, the (European Commission, 2021) to getting out of Covid-19. The EU therefore mandated its member states to adopt national plans ones that sync with the EU broader framework aiming to forge a climate-resilient Europe. In that sense as part of this report, Germany is chosen for study to examine its resilience strategy to the EUs and respectively analyse both under the Paris Agreement of 1.5 °C pre-industrial levels to prevent global warming. In that manner this report examines what exactly the EU strategy is theorizing about or what is not theorizing about underpinned by Paris and net carbonising by 2050 and meeting its immediate 2030 set targets of 55% GHG cut back (European Union, 2020). As such, the EUs, "Forging a climate-resilient Europe - The new EU Strategy on Adaptation to Climate Change" implicitly is a theory of policymaking. The strategy indicates transversal priorities such as: (i) developing solutions based on the improvement of the urban environment, which are wide-ranging, with multi-benefit and multiplier effects in support of various objectives of the European Green deal, such as the protection and restoration of biodiversity, the regularization of the water cycle by mitigating the effects of drought and flood phenomena; (ii) to intervene with local actions, since they represent the basis and the implementation of adaptation actions. This is a big step forward, given the multitude of funding and resources allocated to a city model geared towards mitigating climate change. Cities represent places to organize an effective response to combat climate emergency (Carter et al., 2015; Dodman et al., 2012). Climate change mitigation is a long process whose results are difficult to achieve in a short period of time. Only in recent years has it been understood that the impacts of climate change would increase due to the retarding effects of urban interventions aimed at reducing gas emissions, the scientific community has therefore begun to analyse the relationships between urban characteristics and climate impacts of cities from an adaptation perspective (De Silva et al., 2012). Therefore, the Commission has proposed to strengthen and give more support to existing instruments, such as the Covenant of Mayors in particular, highlighting how achieving resilience in a fair and equitable way is essential so that the benefits of climate adaptation are broadly and shared. However, the Commission considers it increasingly necessary for the support to privilege education, training and requalification initiatives that lead to strategies, actions and interventions that aim on the one hand to improve the sustainability of cities and on the other towards green energy strategies. In accordance with this trend, the issuance of the current recovery and resilience plans and the related reforms envisaged in them aim to give a push towards increasingly sustainable forms of organization of urban systems. Of the six missions in which the plan moves, they are: (i) digitization, innovation, competitiveness, culture and tourism; (ii) green revolution and ecological transition; (iii) infrastructures for sustainable mobility; (iv) education and research; (v) inclusion and cohesion; (vi) health, what has a decisive role on cities is the mission based on the green revolution and ecological transition. Aiming for a green city model and towards an ecological transition means putting in place a coordinated system of strategies, actions and interventions to improve the great challenges that cities today are called to respond to the reduction of the effects of climate change, energy of urban areas as an improvement of sustainable mobility. The multidisciplinary nature of these issues raises several research questions in urban planning practices studied by the relevant scientific community. It also demonstrates that it is necessary to intervene on all the components of the urban system (socioeconomic, physical, functional, and environmental) and on the relationships that exist between them with a view to looking at the city with a holistic-systemic approach (Gargiulo, & Papa; 1993). In particular, the scientific literature for years has focused on developing research on the occurrence of the various phenomena of climate change with the aim of effectively responding to the impacts of climate change on urban systems. A large scientific body has addressed the problem of heat waves and related droughts such as Kleerekoper & Salcedo, 2012; Gago et al. 2013; Rizwan et al. 2008, paying particular attention to the geometry and shape of urban areas with the aim of reducing the intensity of heat islands. Furthermore, the studies questioned what the causes of the occurrence of the phenomenon were as in the materials used in the construction of an urban fabric such as streets, buildings, and squares. Some studies have highlighted how material characteristics such as terminating capacity and conductivity, greater or lesser permeability, reflectivity, and emissivity of materials on buildings affect the thermal comfort of urban areas. At the same time, the materials of the roads, such as, for example, in many Italian historic centres have a paving system (smooth stones, cobblestones, etc.) have good permeability characteristics because they limit the flow and promote the absorption of rainwater and at the same time the high breathability allows to maintain constant heat exchange between the surface and the air. The multidisciplinary nature of the issue highlights how reducing the phenomenon of urban heat islands also leads to an improvement in the energy efficiency of urban settlements. Some studies have examined how compact urban configurations reduce heat exchanges between buildings and the external environment but also reduce solar heat gains by reducing the occurrence of climate change (Xu et al., 2019; Emmanuel & Krüger, 2012). Other studies have focused on the functional mix of urban areas combined with the percentage of jobs and how these variables affect the energy consumption of transport. The push that Covid-19 provided was precisely to encourage different forms of mobility compared to the usual ones such as road and rail transport. Encouraging forms of "soft" mobility such as the use of bicycles, micro mobility services aim to rethink how to implement interventions aimed at improving roads, public spaces and increasing the cycle and pedestrian network (Zecca et al., 2020). This new trend could have a long-term impact on the progress of urban areas towards clean energy, if the positive aspects associated with user behaviour can be sustained thanks to the new reforms in place. In this direction, the content of this review aims to carry out an excursus of the current reforms implemented through the resilience and recovery plans of two European states with a focus on mission two based on the green revolution and ecological transition. Furthermore, this review aims to define the role of these plans for future urban strategies, as climate change, energy efficiency in accordance with the principles of environmental sustainability to which cities must strive.

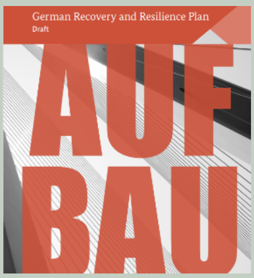
National Recovery and Resilience Plan (PNRR), Italy

The National Recovery and Resilience Plan (PNRR) is part of the Next Generation EU (NGEU) program, the 750-billion-euro package, about half of which is made up of grants, agreed by the European Union in response to the pandemic crisis. The main component of the NGEU program is the Recovery and Resilience Facility (RRF), which has a duration of six years, from 2021 to 2026. The PNRR is a unique opportunity to accelerate and overcome the barriers that they have proved critical in the past.

The Plan is developed around three strategic axes shared at European level: (i) digitization and innovation to which 27% of total resources have been allocated, (ii) ecological transition 40%, social inclusion another 40%. It is an intervention which aims to give a boost after the pandemic crisis and to accompany the country to face the great challenges in the various territorial contexts. In fact, the main objective is to contribute substantially to reducing territorial, generational and gender gaps. The Plan is divided into sixteen Components, grouped into six Missions. In detail, this sheet examines mission 2, or revolution of the green and ecological transition. Mission 2, in turn, is divided into four areas of interest: (i) sustainable agriculture and circular economy; (ii) energy transition and sustainable mobility; (iii) energy efficiency and building renovation; (iv) protection of the territory and of the water resource.

Of the four areas of interest, in turn, the reforms implemented, and which directly affect the components of the urban system that can constitute a starting point for addressing the great challenges that cities are called to respond to are examined. For the mobility system, the aim is to strengthen cycling mobility. The intervention aims to facilitate and further promote the growth of the sector through the creation and maintenance of cycle networks in urban, metropolitan, regional and national contexts, both for tourist or recreational purposes, and to encourage daily travel and intramodality, ensuring safety. The measure also has the objective of improving social cohesion at national level, with 50 per cent of the resources allocated to the Southern Regions. Specifically, the measure provides for the construction of approximately 570 km of urban and metropolitan cycle paths and approximately 1,250 km of tourist cycle paths. Furthermore, the development of mobility based on electric vehicles trying to reduce the vehicular pressure of urban systems representing a significant opportunity for decarbonisation of the sector, but to date it is extremely limited and accounts for 0.1% of the total number of vehicles in compliance with the objectives set within the Green Deal. These measures are aimed at promoting the development of sustainable mobility and accelerating the transition from the traditional model of fuel-based refuelling stations to refuelling points for electric vehicles. In addition, the plan also includes investments for the renewal of the bus fleet with low environmental impact vehicles. This can be accelerated through the implementation of the National Strategic Plan for Sustainable Mobility and provides for the gradual renewal of buses for local public transport and the creation of dedicated charging infrastructures. In particular, the purchase of approximately 3,360 low-emission buses is expected by 2026. About one third of the resources are destined for the main Italian cities. The intervention is consequently aimed at spreading and promoting the technological transformation of the supply chain linked to bus production in Italy, with the main objectives of expanding production capacity and improving the environmental impact.
Regarding, the urban component relating to buildings, the PNRR provides for large investments in the energy efficiency of buildings which represents one of the most relevant and efficient levers for reducing emissions in our country, in line with the European Clean Energy Package and with national emission reduction targets. The current National Integrated Plan for Energy and Climate (PNIEC) already includes ambitious goals in terms of energy efficiency. In detail, the planned reforms relating to buildings move along three axes: (i) introduction of a temporary incentive for energy requalification and anti-seismic adaptation of private real estate and social housing, through deductions tax for the costs incurred for the interventions (ii) development of efficient district heating systems. Therefore, to cope with the long amortization times of building renovations, to stimulate the construction sector, which has been in severe crisis for years, and to achieve the challenging objectives of energy saving and reduction of emissions by 2030. Tax deductions of 110% are envisaged. for interventions aimed at insulation, efficient fixtures, replacement of heating and air conditioning systems and installation of plants for the generation of renewable energy. The admissibility of the interventions is conditioned by an improvement of at least two energy classes of the building, demonstrable by comparison with the energy performance certificate (APE) before and after the intervention. The energy improvement of buildings involves the development of an improvement in the thermal comfort of urban areas. The resources of the PNRR will be used to finance projects related to the construction of new networks or the extension of existing district heating networks. In this regard, priority is given to the development of efficient district heating, i.e., that based on the distribution of heat generated from renewable sources, from waste heat or from congenators in high-performance plants. The investment measure relates to the development of 330 km of efficient district heating networks and the construction of plants or connections for the recovery of waste heat for 360 MW, assuming that 65 percent of the resources are allocated to the networks (cost 1,3 million per km) and approximately 35 per cent is dedicated to the development of new plants (cost 0.65 million per MW).
Furthermore, as regards the urban component relating to open spaces, in accordance with current national and community strategies, it aims to provide a wide-scale quality of life and well-being of citizens through the protection of existing green areas and the creation new ones, also to preserve and enhance biodiversity and ecological processes linked to the full functionality of ecosystems. The plan envisages a series of actions aimed mainly at the 14 metropolitan cities, which are now increasingly exposed to problems related to air pollution, the impact of climate change and the loss of biodiversity, with evident negative effects on the well-being and health of citizens. The measure includes the development of urban and peri-urban forests, planting at least 6.6 million trees (for 6,600 hectares of urban forests).

National Recovery and Resilience Plan (DARP), Germany



Germany's resilience and recovery plan aims to define Italy as a set of measures aimed on the one hand at giving the country an economic recovery and on the other hand to face the great challenges that European countries are called to respond to today. such as climate change and digital transformation. Climate-friendly measures cover a broad spectrum of interventions that affect all components of an urban system: from decarbonisation through renewable hydrogen and climate-friendly mobility to climate-friendly construction. Digitization runs through almost all the measures of the development plan. The plan is divided into 40 measures. The 40 measures are defined in six main axes: (i) climate policy and energy transition; (ii) digitalisation of the economy and infrastructure; (iii) digitization of education; (iv) strengthen social participation; (v) Strengthen a pandemic resilient health system; (vi) modern public administration and dismantling of investment barriers. This sheet examines the measures concerning the first main axis which in turn includes three components. The first component concerns decarbonisation using renewable hydrogen, the second Climate-friendly mobility and finally the third Climate-friendly renovation and construction. The National Hydrogen Strategy describes an important addition to the future energy supply in Germany. an important role in achieving energy and climate goals and in decarbonising the economy and parts of the transport sector. The National Hydrogen Strategy within the recovery plan lays the foundation for making Germany a leading international market for the production and use of green hydrogen technologies. Germany aims to pave the way for production, infrastructure, research and development and logical development technology, as well as about the rapid expansion of renewable energy sources necessary to produce green hydrogen. The emphasis is on the reduction of CO_2 in the atmosphere linked to the emissions process by developing new production processes, in the context of an initially low level of technological maturity. Research approaches consist, for example, to use hydrogen in energy-intensive processes (metal production, glass production) or to partially replace cement in concrete production by developing new input materials, which would allow CO_2 emissions, related to the process. in the production of cement at least partially avoided. The objective pursued within this strategy is to seek solutions for a sustainable future in many metropolitan areas in the context of adaptation to climate change. The funds allocated will allow cities to promote knowledge creation in relation to concrete action options and processes, as well as to increase the effectiveness of measures to adapt to climate change. The second strategy concerns the transition to a climate-friendly environment mobility. It considers country specific recommendations on investments in the ecological transition sector, in particular sustainable transport, and contributes to the implementation of the EU flagship initiative Recharge and Refuel. In particular, the country aims to give subsidies for the construction of filling and charging infrastructure are intended to support the market ramp-up of battery- and hydrogen-based electric vehicles. This requires a comprehensive network of charging infrastructure in line with demand. This is a key element for low-carbon vehicles. In particular, the planned interventions aim on the one hand to develop electric mobility and on the other hand interventions aimed at promoting local public transport with an alternative drive system. In addition, subsidies are also envisaged to finance alternative systems initiatives in rail transport. All these interventions and reforms favour a type of sustainable mobility within cities by reducing vehicular pressure and the related noise pollution and improving the quality of users' movements. The third component aims at the energy efficiency of buildings covered by the research program and EU flagship Renovate. The Confederation reorganizes its financing for energy efficiency in buildings in connection with the implementation of the climate action The 2030 Program and the financing strategy "Energy Efficiency and heat from renewable energies" ("Energieeffizienz und Wärme aus Erneuerbaren Energien"). The aim is to encourage investments that will improve energy efficiency and increase the share of renewables energies in the final energy consumption of buildings. Funding will be provided for the construction and renovation of "efficiency" residential buildings", whose energy needs and CO_2 emissions it will be well below the legal requirements. Funding will be provided for innovative energy-related projects publicly owned renovations or new buildings companies.

The key elements of these subsidies are the introduction of the "EE" classes (e.g. "Efficiency house 55 EE") for the use of renewable energy; higher rates of financing for the efficiency home level EH 40 as a particularly ambitious project; promotion of digitization measures to optimize consumption (e.g. Efficiency Smart Home) with a technologically neutral approach. The development of these interventions improves at the same time the thermal comfort of urban areas making urban environments more liveable and friable for every category of users, in particular vulnerable groups of the population The funding guideline will play a key part in reducing greenhouse gas emissions from buildings to 70 million tonnes of CO2 equivalents by 2030 and thus in achieving both national and European energy and climate targets by 2030.

The coordinated set of interventions and reforms envisaged are aimed, first, at promoting greater harmony and more effective coordination of research policies at European, national, regional level and at strengthening the competitiveness of researchers on the global stage.

In conclusion, the coordinated set of interventions and reforms envisaged in the National Recovery and Resilience Plans aim, first of all, to favour greater harmony and more effective coordination of research policies at European, national, regional level and to strengthen competitiveness. of researchers on the global stage. These plans also represent the synthesis of the lines of action in the field of scientific research carried out by the national system that seek to address the great challenges that cities are called upon to respond to climate change, energy efficiency, soil protection. For example, the improvement of the energy efficiency of buildings, the creation of green infrastructures, the encouragement of sustainable mobility that reduces the pressure and vehicular congestion of our cities, lead to a reduction in the effects of climate change, a greater thermal comfort of the cities, but above all an improvement in the quality of life of our citizens in the various territorial contexts. These interventions implemented by public decision makers with local actions represent the basis and implementation of the adaptation actions of cities.

In addition, the heterogeneous set of interventions (small and medium-sized) will increase the resilience of the territory by adapting and renewing itself, respecting its functions and its identity.

Author Contributions

The work, although the result of a common reflection, was divided as follows: Federica Gaglione, paragraphs 1 and review box of "National Recovery and Resilience Plan (PNRR), Italy"; David Ania Ayiine-Etigo, review box of "National Recovery and Resilience Plan (DARP), Germany".

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REVIEW NOTES – Urban practices

Toward greener and pandemic-proof cities? Policy responses to Covid-19 outbreak in four global cities

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Abstract

Starting from the relationship between urban planning and mobility management, TeMA has gradually expanded the view of the covered topics, always 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 presenting recent advancements on relevant topics that underlie the challenges that the cities have to face. The present note provides an overview of the policies and initiatives undertaken in four global cities in response to the Covid-19 outbreak: New York City (US), Beijing (CN), Paris (FR) and Singapore (SG). A cross-city analysis is used to derive a taxonomy of urban policy measures. The contribution discusses the effectiveness of each measures in providing answers to epidemic threats in urban areas while, at the same time, improving the sustainability and resilience of urban communities.

Keywords

Covid-19; Urban policies; New York, Beijing; Paris; Singapore.

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1. Introduction

In December 2019, in the Wuhan province of China, a new form of Coronavirus (Covid-19) emerged. Since then, the virus has been spreading globally and, as of 05 June 2021, more than 200 Countries around the world have reported 196 million confirmed cases and a death toll of 4.16 million deaths (Template: Covid-19 pandemic data). The Covid-19 pandemic triggered both third and first world economies, causing severe disruption to society and business, especially in urban areas (OECD, 2020a).

2. Toward greener and pandemic-proof urban areas?

Urban areas have been the ground zero of the COVID-19 pandemic, with 90 per cent of reported cases (UN, 2020). They are densely populated places where people live and gather, thus at high risk of spreading the virus due to the close proximity among residents and challenges to implement social distancing (Neiderud, 2015). These conditions have generated a large debate about the future role of cities in the post-Covid scenario. In this respect, some authors have argued that large urban areas are nearly defenseless in times of unprecedented disease outbreaks (Desai, 2020) and that dense urban settlements are not compatible with the needs of social distancing (Megahed and Ghoneim, 2020). These circumstances, coupled with increasing dematerialization of services and pandemic-pushed growing teleworking rates, have prompted some authors to questioning the ever-growing urban concentration model and envisioning a resurgence of rural areas as alternative and safer mode of urbanization in the post-Covid society (Cotella and Brovarone, 2020).
On the contrary, other authors have stressed the pivotal role played by cities in the Covid-19 response in terms of implementing nation-wide measures, but also in terms of providing laboratories for bottom-up and innovative recovery strategies (UN, 2020; OECD, 2020a; UCCN, 2020). Advocates of this second line of argument have seen in the Covid-19 crises an unpredictable opportunity to reshape our cities toward a greener and pandemic-proof urban future (OECD 2020a; Lai et al., 2020; Pierantoni et al., 2020). These optimistic claims are supported by a growing body of interdisciplinary research. Synergies, indeed, has been identified between policies aimed at providing answers to epidemic threats in urban areas and policies aimed at improving the sustainability and resilience of urban settlements (Garcia, 2020; Barbarossa, 2020; Pinheiro et al., 2020). Decentralization of public facilities, prioritization of soft over car-centric mobility, hierarchization of the transport system and public services, and redundancy of public, green and open-space functions have been identified as integrated measures able to achieve both public health and city sustainability targets (Pisano, 2020; Sharifi et al., 2020). Within this context, the present short paper provides an overview of the policies and the initiatives undertaken in four major global cities in response to the Covid outbreak. This is followed, in paragraph 4, by a discussion on whether these measures are (or will) promote a sustainable urban recovery.
Global city definitions are numerous, with one study suggesting as many as 300 (JLL, 2017). This study relies on the definitions and ranking established by GaWC, the Globalization and World Cities Research Network (GaWC, 2020). According to this framework, cities analysed in this short note follow under the categories reported in the table below.

Case Study	GaWC rank	Rank description
New York City	Alpha ++	First-order, world’s leading global centers, most integrated with the global economy.
Paris	Alpha +	Second-order, world’s leading global centers. Highly integrated cities, filling advanced service needs.
Beijing		
Singapore		

Tab1. Classification of the case studies according to GaWC, 2020.

New York City

New York is the most populous city in the United States. With an estimated population of 8,336,817 inhabitants distributed over about 302.6 square miles (784 km²), it is also the most densely populated major city in the United States. The city is considered as the cultural, financial, and media capital of the world, significantly influencing commerce, entertainment, research, technology, education, politics, tourism, art, fashion, and sports. The city has experience a sustained urban growth over the past few decades, characterized by the implementation of large-scale urban projects and the development of an efficient and modern public transportation network, coupled with a well-developed shared-mobility eco-system.

The pandemic has severely hit the city's dynamic economy and social life, reversing the long-standing growth trends that have characterized its economy, with leisure, hospitality, finance, administrative and support services being the most affected economic sectors. As a consequence — only in 2020 — the city lost 750,000 jobs, nearly one out of every six job. This lopsided impact have exacerbated previously existing income inequalities, since the devastating effects have had a concentrated impact on predominantly low-income workers of color, young adults, and women (Parrot, 2021).

During the first year of the pandemic, the city has adopted a number of measures to facilitate social distancing and containing the spread of the virus. For instance, the city expanded its pedestrian walkways and pedestrian-only streets, which has come in handy during social distancing, and has closed down numerous streets in the five boroughs to allow for more pedestrian walkway. As a result, 83 miles of additional car-free streets (also known as *Open Streets*) have been implemented in 2020. In addition to pedestrian walkways, bike lanes, which were once a hotly contested and controversial topic, have been incredibly expanded: the New York City Department of Transportation has indeed constructed a record 28.6 lane miles of new protected bike lanes since the beginning of the pandemic. In addition to pedestrian sidewalks and bike lanes, there has been also an emphasis on the recovery of the leisure activities: bars, restaurant and café have been allowed to expand their terraces onto sidewalks and even close roads in some areas, resulting in 10,800 so-called *Open Restaurants*. Other intervention for the 2020 year included the restoration and the expansion of several public green areas and blue spaces. In January 2021, the city Council adopted an integrated and more structured approach to urban recovery by delivering the *Recovery for All* plan, the Major strategy aimed at creating a stronger, fairer and safer city for all New Yorkers. The strategy is articulated around six main pillars and 33 lines of intervention. Most of them introduce transformations in the built environment as a tool to promote social and economic recovery. For instance, under the *Fight the Climate Crisis* pillar, the plan envisions to make the *Open Streets* initiative (developed during the previous year) a permanent part of the city landscape, while also opens applications for new streets, with a focus on local partner management and support. In addition, New York City will begin the construction on five new *Bike Boulevards*, streets that are designed to give bicycles travel priority and put cyclist safety first. Under the same pillar, the plan also envisions the development of new public spaces (particularly for neighborhoods hardest hit by COVID) that will help support local small businesses, foster community ties and provide space for arts and culture. The *Bend Government to Fight Inequality* pillar focuses on social and spatial inequalities. In this respect, the plan envisions, among other measures, the establishment of a permanent taskforce on racial inclusion and equity, with the aim of identifying the communities hardest hit by COVID-19 and driving new investments and initiatives in these neighborhoods. An important part of the plan concerns with the recovery and diversification of the urban economy. Actions in this domain are grouped under the *Build a New Economy* pillar and include, among others, the revitalization of small businesses by introducing a small-business recovery tax credits, as well as new loans scheme. Finally, particular emphasis is also given to the participation of the population (and especially the marginalized groups) in the decision-making process, as reflected in the *Community Power in Neighborhood* pillar.

Paris

Paris is the capital and most populous city of France, with an estimated population of 2,148,271 residents. Paris is one of Europe's major centers of finance, diplomacy, commerce, fashion, science and arts. While its historic center is one of the most popular destinations in Europe, the recent expansion of its outskirt areas has been characterized by a poorly regulated development, coupled with inadequate infrastructure provision and consequent social and economic exclusion.

Paris has been strongly affected by the virus outbreak, with tourism, leisure and mobility being the economic sectors suffering the most. At the same time, the pandemic was an eye-opener to city administration and an occasion to put forward an ambitious strategy started in 2014 and aimed to decarbonize city's economy and to make Paris a healthier city. Since 2014, the year of the first election of Mayor Hidalgo, 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 and pedestrian space. This process of pedestrianization of the city was fostered during the Hidalgo campaign for re-election 2020, *Paris en Commun*. This campaign manifesto has been relaunched as a post-COVID strategy, introducing the concept of a "15 minutes city", in which citizens' basic needs, such as work, shopping, health, or culture, should be available within 15 minutes of their home. To meet this aim the city has implementing a coordinated mix of land use planning and urban design measures such as the relocation of schools, health centers and other public facilities, the renovation of urban public spaces and the expansion of the city's network of public housing into wealthier areas. This urban design measures have been coupled with soft mobility measures aimed at making cycling and walking an attractive mode of transportation. In this regards, the most evident measure proposed is the extension of the urban bike network that connects the city center to the suburbs. This network was already under examination before the COVID pandemic, but its design has been accelerated and proposed as an emergency measure in order to allow more people to commute using the bike across Greater Paris. In total, more than 50 kilometers of lanes — normally used by cars — have been reserved for bicycles. Among them are the Avenue de la Porte d'Orléans, Avenue du Général-Leclerc (on the southern section), the Étoile tunnel and Porte Maillot. In addition, 30 streets have been designated pedestrian-only, in particular around schools, to avoid large groups of people gathering on sidewalks.

Beside these structural interventions focused on the urban built environment, the city has put in place several measures in the social welfare domain. In this respect, Paris developed a plan to support businesses, low-income families, cultural actors and associations, providing different forms of aids such as direct economic support, rent relief support, food aids, municipal taxes relief programs and discounts on the purchase of public transport subscriptions. The city also acted as "enabler" for private citizens and NGOs that want to help other citizens in need by creating an online platform that is helping people in need to connect with citizens willing to assist them. Particular attention has been devoted to the touristic sector. Whit a drop of tourism in 2020 — one of the main source of income for the city — of approx. 44% compared with the previous year, Paris has devoted a large part of the Covid response to recover this sector. Financial support has been provided to tourism and leisure activities, while the city's Council has approved stringent health-safety measures aimed at increase the confidence in the tourist market by promoting the city as a safe and attractive place to visit and discover. Finally, as for many other EU cities, the Council of Paris has re-designed its city's time-plan, rescheduling the opening hours of public services in order to reduce congestion and mass gathering at public locations.

Beijing

Beijing is the capital of the People's Republic of China and the world's most populous national capital city, with over 21 million residents. It is considered one of the world's leading centres for culture, diplomacy and politics, business and economics, and it is home to the headquarters of most of China's largest state-owned companies as well as private Fortune Global 500 companies.

As the capital city of the first country to experience the coronavirus outbreak, Beijing has been severely affected by the spread of the virus. Furthermore, the pandemic has highlighted the weaknesses of the prevailing Chinese urban developing approaches characterized by lack of green areas, functional mix and a scares engagement of the city population in the decision-making process (Wu and Wang, 2021). At the same time, it has offered the possibility of reorienting urban policies toward more sustainable urban outcomes.

In contrast with the cities analysed in the previous two paragraphs, Beijing policy response to Covid-19 outbreak has been largely "decided" at the national level, with the Central State playing a leading role in issuing and implementing uniform, large-scale policy initiatives. However, especially in sectors such as urban waste management and buildings' technologies, the role of the Beijing local administration has been pivotal.

Short-term emergency policy responses were prioritized during the early months of the pandemic. In particular, priority has been given to environmental management, particularly the management of medical waste in healthcare facilities and household waste in residential areas, and city management, in which digital tools have been used to track and contain the spread of COVID-19. Beside these short-term policies, long-term initiatives have been taken as the next step in the post COVID-19 response, especially in the sector of land-use planning, building design, public facilities planning, and city management. For instance, within the land use-planning domain, Beijing Municipal Government has initiated a land use regulation on strategic spaces, assigning 132 square kilometres of unplanned spaces for responding to future public services or major public safety issues. In addition, the new *Beijing Municipal Master Plan* placed a ban on new large wholesale wet markets and regional wholesale markets, or the extension of existing markets, within its jurisdiction, since these urban environments have played a pivotal role in the spread of the virus. Beside intervention in the land use domain, policies have been also issued in the building design domain. In this respect, different levels of governments have adopted a variety of responses in terms of building design and space use, to contain the spread of the virus. New design guidelines have been put in place for different types of buildings, including medical facilities, hotels for quarantine and treatment, office buildings, residential buildings, schools, shopping malls and supermarkets, and public places, such as transport, elevators, and recreational facilities. All of these responses are focused on regulating air conditioning and ventilation, water supply and drainage systems, waste management, cleaning and sterilization as a tools to contain the spread of the virus. In the public facilities planning domain, the pandemic has showed the importance of accessible green spaces, as well as the importance of easily-accessible public health facilities. In this respect, Beijing has put in place measures to address the unevenly distribution of such facilities, by developing new facilities, especially in rural areas and new urban green space in both rural and congested urban areas.

Finally, an interesting — although isolated — initiative concerns the reframing of the *Xiong* area project*. Xiong* was indeed originally planned as a "new city" aimed at relieving pressure on the over-congested Beijing. The coronavirus outbreak however has seen Beijing's administration reframing the original project to accommodate a pandemic-friendly, self-sufficient urban development, to reflect the lessons learned during the virus outbreak. According to the new plans, the proposal — developed by the Barcelona-based Guallart Architects studio — will include wooden buildings with large balconies and shared 3-D printers that will allow residents to produce resources locally, and provide all amenities even in moments of confinement. This new development will collocate in the same area different urban functions, such as residential buildings, public services and commercial malls, highlighting the importance of proximity and self-sufficiency.

Singapore

Singapore is an island city-state in maritime Southeast Asia. With a population of 5.6 million inhabitant distributed on an area of 728.6 km², Singapore has the second greatest population density in the world. The country's territory is composed of one main island and 63 satellite islands and islets, the combined area of which has increased by 25% since the country's independence as a result of extensive land reclamation projects. Modern Singapore is a gleaming city of the future, a global financial centre, framed by lush and leafy greenery at every turn. It features an urban skyline including astonishing skyscrapers, designed by the most renewed architecture firms, as well as an efficient and modern public transportation network. These impressive urban achievements are the result of a long-term urban planning tradition (Henderson, 2012) that, as described below, is still very relevant in today's city approach to post-Covid recovery. Compared to other Asian economies, impacts of covid-19 have been relatively limited. However, the months-long restrictions resulted in a 5.8% contraction, the worst since independence, in gross domestic product in 2020.

On August 24, 2020, Singapore President Halimah Yacob revealed plans for the country's green recovery, announcing major efforts to foster sustainable growth while improving social safety nets and education. In contrast with the city of New York that has articulated an organic city adaptation response, Singapore response to the Covid-19 has been articulated around a number of sectoral policies regulating different aspect of the city life, including the recent *Singapore Green Plan 2030*. For instance, in the building sector, Singapore has recently released the *Green Building Masterplan*, which encouraged, enabled and engaged industry stakeholders in adopting new green buildings by raising the minimum energy performance requirements for new buildings and existing buildings that undergo major retrofit, to be 50% and 40% more energy efficient compared to 2005 levels respectively. In the transportation sector, Singapore is continuing to pursue alternative energy despite COVID-19. This includes various efforts to develop hydrogen as a fuel source. Furthermore, the city has imposed that new diesel car and taxi registrations will be ceased from 2025, with all new car and taxi registrations to be of cleaner-energy models from 2030. The road tax structure will also be further revised to bring down road tax for mass-market electric cars. In addition, 60,000 electric vehicle-charging points are targeted to be built by 2030. Efforts in supporting the transition to renewable energy are not limited only to the transport sector. Singapore has indeed been moving ahead with the deployment of solar photovoltaic panels in 2020 and 2021. Construction of the 60 MWp floating solar photovoltaic system on the Tengeh Reservoir commence will help the city in securing green energy, while at the same time overcoming land constraints that arise from limited land resources of the city. On the land use side, interventions have been target at strengthening public services with an attention to proximity and a strong focus on the development of new green areas and the decentralization of public facilities. In particular, by 2030, 1 million more trees would be planted, and every household would be within a 10-minute walk from a park. Over 130 ha of new parks will be developed and around 170 ha of existing parks will be enhanced with more lush vegetation and natural landscapes by end-2025, on top of a 1000 ha addition of green spaces by 2035. In terms of public facilities, the city aims at balancing the differences between neighborhoods, enhancing specificities, and trying to reduce inter-district travel. Accordingly, the city has started creating local services, especially in popular neighborhoods, with high population density and characterized by an older population. Finally, on the economic development sector, Singapore has introduced several measures to support businesses hurt by COVID-19. Businesses in green industries such as clean energy and electric vehicles, and businesses pursuing resource efficiency projects, are eligible for these business support measures.

3. Discussion and conclusions

As Covid-19 spreads across the world, cities have become epicenters of the pandemic, amplifying the spread and transmission of infection, with their dense population and transport networks. At the same time, cities have become catalyst of sustainable recovery. Many examples of good practices taking place in cities across the word are captured by dedicated and constantly-updated reports of international organizations such as

WHO (2020), UN (2020) and OECD (2020a) and UCCN (2020). This contribution provided a focus on global cities and examined policy response to the Covid-19 epidemic in a sample of four representative urban areas. A cross-city analysis of measures implemented in the cities under investigation can be a useful exercise to derive a taxonomy of urban policy measures. This is reported below, together with some considerations on the effectiveness of such measures in providing answers to epidemic threats in urban areas while, at the same time, improving the sustainability and resilience of urban communities. Considering the social, the physical and the functional subsystems composing the city, measures could be addressed to:

3.1 Physical subsystem

- *Expansion of cycling infrastructures*. Cycling is promoted by many cities as a recovery strategy since it can reduce pressure on crowded (and often depotentiated) public transport while allowing citizens to respect social distancing, thus lowering the risk of virus transmission. Especially in dense urban settlements, as those exanimated in this article, where commuting distances are compatible with the use of bike, cycling represents an alternatives solution to provide citizens with essential needs, go to work when necessary, and still perform some physical activity, even in times of pandemic outbreaks (Garcia, 2020). At the same time, the promotion of cycling in urban areas represents an essential ingredient to improve cities livability and reduce the externalities of car-oriented urban development (Ison and Shaw, 2012).
- *Improvement of walking paths/ expansion of pedestrian areas*. These measures can be considered effective tools to promote sustainable mobility while, at the same time adapting the city physical environment to the new challenges imposed by the virus outbreak. On the city sustainability side, these measures can contribute to sustainable mobility targets by shifting mobility demand from private cars to active transportation modes (Li et al., 2014). On the health side, ameliorate walkability has been demonstrated an effective tool to improve public health by promoting physical activity (Frank et al., 2006). Furthermore, extension of pedestrian areas and sidewalks can guarantee enough space for safe physical distancing while favoring business reopening by accommodating longer lines deriving for lower business accommodation capabilities (WHO, 2020).
- *Extension of green and open space functions.* Environmental benefit of public, green and open spaces are well-established: they contribute to the purification of water and air climate, to the regulation and mitigation of the urban climate, and support biodiversity conservation (Chiesura, 2004). Following the pandemic outbreak, researchers have found that the virus transmission spreads more easily indoors than outdoors (Morawskaa and Caob, 2020) and that urban green urban spaces have been crucial for exercise and mental wellbeing during the stringent lockdown (Razani et al., 2020). Extension of these areas represents thus a valuable contribution to foster city sustainability while, at the same, time providing concrete spatial planning answers to epidemic threats.

3.2 Functional subsystem

- *Decentralization of public facilities.* Decentralization of public facilities is considered a fundamental property to contain the spread of the virus since it allows people to be able to get the goods and facilities they need within the minimum distance from their houses, thus limiting the interaction with the other sectors of the population (Pinheiro et al., 2020). Furthermore, the decentralization of healthcare services can reduce the response time, and saving operating costs (Pisani, 2020). A balanced juxtaposition of homes and services, is thus not only a well-known urban planning strategy to reduce long-distance trips and promote active transport, but represents also an emerging tool for containing epidemic spreading.

- *Improvement of IT infrastructures and digital services*. These measures can generate positive co-benefits: the digitalization of public services can indeed reduce the need to travel while at the same time contain physical contacts between public servants and city users. Furthermore, IT technologies can also provide a fast and concrete response to citizen's needs. Investments in this domain should be thus certainly encouraged in the context of city's recovery plan.

3.3 Social subsystem

- *Household / small business economic support.* The pandemic crises has exacerbated the existing social inequalities while severely affecting cities economy. Measure aimed at provide households economic, social or rental support as well as measures target at provide relief to most affected economic sectors have been implemented in all cities under investigation. While undoubtedly necessary, these measure, if not integrated in a wider urban economic recovery strategy, can be considered only effective in the short term. Their impacts on cities sustainability and resilience is hard to demonstrate.
- *Human capital development*. According to OECD (2020b), the global pandemic is triggering substantial changes in the labor market. Accordingly, it is essential for governments to help workers transition to the post-Covid 19 economy. These measures are highly recommended by international organizations as they provide the ground for fostering citizens' resilience to current and future disruptive events.

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REVIEW NOTES – Economy, business and land use

Environmental, social and economic sustainability in urban areas: a cool materials' perspective

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Abstract
Starting from the relationship between urban planning and mobility management, TeMA has gradually expanded the view of the covered topics, always 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 tackles the topic of cool materials for urban areas, as a mitigation strategy to counteract climate-change related issues. The most recent developments about cool materials demonstrate how they can boost environmental, social and economic sustainability and resilience in urban areas.

Keywords
Urban areas; Sustainability; Comfort; Cool materials; High-albedo materials.

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1. Introduction

Nowadays, urban areas are subject to increasing challenges, due to different contributing factors, which are all expected to be further exacerbated in the next future.
The first crucial factor is the increase in urban population, as assessed in the United Nations Report "World Urbanization Prospect" (United Nations, 2018). Indeed, as of today, in the entire world, the 55% of the total population lives in cities, while considering only more developed regions, the 78% of population lives in cities – the vast majority of it. Moreover, while today the world urban population is 4.5 billion citizens, projections state that by 2050 such number will be as high as 6.7 billion citizens in urban areas (United Nations, 2018), continuing the unprecedented growth and aggravating the pressure on urban areas. What is even more impressive is the growth of land consumption, which largely outpaces population growth: within 2100 it is expected that 1.1-3.6 million km^2 of land will be added to urban areas and consumed by urban surfaces, depending on different consumptions scenarios (Gao & O'Neill, 2020). The middle scenario assesses 1.6 million km^2 more of land consumption due to cities' growth, a dimension which is almost 5 times the dimension of Germany (Gao & O'Neill, 2020). As of today, cities are responsible for the majority of global energy consumptions and emissions, thus calling decision makers to undertake policies in line with such challenges (Tira, 2020).
Another factor challenging cities is due to climate-change related hazards (Moglia et al., 2018; Moriarty & Honnery, 2015; Shirgir et al., 2019). Climate change leads to more intense and more frequent extreme climate conditions, which are further exacerbated in cities due to the different hygro-thermal equilibrium of urban surfaces with respect to natural land. For example, more intense and frequent heatwaves are expected in the next future and are currently being experienced (Hatvani-Kovacs et al., 2016). In cities, heatwaves are exacerbated by Urban Heat Island (UHI) effect, which entails higher temperatures in cities than in surrounding suburban areas, up to 10°C more (Oke, 1982). Therefore, urban citizens are more at risk of suffering heat-related issues. This factor is considered as one of the main public health threats globally, as it is responsible of increased mortality rates in urban areas, with the 2003 European heatwave resulting in 71,000 excess deaths (Mayrhuber et al., 2018; Xu & Tong, 2017). It also implies higher energy consumptions for cooling and higher costs for energy production and consumptions, as well as a tremendous increase in peak electricity demand, which often leads to interruptions in the service (Hatvani-Kovacs et al.,2016; Santamouris & Kolokotsa, 2015) and thus to environmental problems as well as social and economic ones (Pham et al., 2021).
In this panorama, mitigation strategies that could help to face such issues are analyzed by the scientific community and by policymakers. Some of the strategies are strictly linked to the urban surface and the construction materials composing it. These strategies have the advantage of being "passive" in their functioning, as intrinsic properties of the urban surface itself: indeed, certain materials and construction elements allow modifying the hygro-thermal equilibrium of consumed land due to their intrinsic thermal and optic properties. Such passive strategies have the advantage of not requiring energy or control to work. Some examples are green strategies (AboElata, 2017; Lobaccaro & Acero, 2015), that can be inserted in cities under the form of green patches, parks, trees, vegetation, but also green facades and green roofs. Such measures regards the built environment and entails interventions for housings, firms and infrastructures, (Bianconi et al., 2018; Koppelaar et al., 2021), and may bring benefits both to the environment, society and local economies. In addition to technical factors, indeed, people perceptions towards urban green solutions is positive and may generate virtuous behaviors (Berman et al., 2008). Recently, it has been found that nature-based solutions and green strategies may lead firms to increase their revenues while bringing a positive impact on urban environment (Koppelaar et al., 2021). In the case of hotels, for example, several studies have found that being green increases customers positive feelings, in turn increasing economic performance (Franco et al., 2021; Lee et al., 2010). However, green strategies

generally require higher installation and maintenance costs. In this review note, the focus is on another passive strategy to counteract UHI and heatwaves, namely cool materials (also named high-albedo or high-reflective materials). They are materials with specific thermal and optic properties, that allow to them to maintain cooler temperatures than traditional materials, thus contributing to alleviate extreme heat in cities. Cool materials are generally easy to apply and have low maintenance. While their application on a single building implies a reduction of the energy demand for cooling during the hot season (Rosso et al., 2014), their scaling up to an entire neighborhood and city amplifies their positive effects and mitigation potential, towards environmental, social and economic sustainability and resilience of urban areas.

The aim of this review note is to shed lights on recent advancements in literature about the use of high-albedo materials, their latest developments in cities and their benefits to environment, economy and society. The next section illustrates their functioning, and highlights research and practical cases of cool materials in urban areas. The last section provides discussions and concluding remarks.

2. The application of cool materials in urban contexts

Cool materials come in a wide variety of typologies, and can be composed to form construction elements for both vertical urban surfaces, such as buildings' facades, and horizontal ones, such as buildings' roofs and urban paving (Doya et al., 2012; Santamouris, 2015). Their "coolness" defines the ability to maintain low surface and air temperatures due to their thermal and optic characteristics. Indeed, they have intrinsic high thermal emissivity, meaning their property of re-emitting the absorbed heat, and high solar reflectance and albedo, meaning their property to reflect the majority of the incident solar radiation on their surface (Falasca et al., 2019). On the other hand, conventional materials with low albedo and low solar reflectance absorb solar radiation, thus heating up and contributing to UHI, whilst aggravating heatwaves during the hot season. The lighter and smoother a material is (think about white marble (Rosso et al., 2017)), the cooler (Doulos et al., 2004), while dark and rough materials (for example asphalt (Rosso et al., 2016)) on the contrary absorb solar radiation and heat up during summer.

High-albedo materials can be applied in cities under the form of simple light-colored plaster on facades, or facades' panels (they can be cool stone panels, or light-colored cement-based panels); or as roof finishing material (cool membranes, clay tiles, paving); or else, as urban pavement (cool cement- or asphalt-based paving, tiles, stone paving) (Akbari & Matthews, 2012; C40 Cities, 2016; Kandya & Mohan, 2018; Rosso et al., 2014; Rosso et al., 2018; Synnefa et al., 2006). With reference to the above-cited studies, when such construction elements are applied on a building (as cool façade and roof), they contribute at lowering energy demand for cooling by at least 6%, improving indoor thermal comfort and also contribute to UHI and heatwaves mitigation, by reducing by 20-35°C surface temperatures. Additionally, they help maintaining the façade/roof, as there are lower temperature variations, benefiting the durability of the system.

It is worth considering that urban surfaces are composed by 60% of roof (20%) and pavements (40%) and absorb more than the 80% of incident solar radiation, converting it into heat (C40 Cities, 2016). Therefore, such generally easy-to-apply and non-expensive cool solutions can have a significant effect if extensively applied on the available urban surfaces, at the city-scale. Survey conducted in U.S.A. cities demonstrated that the installation of cool roofs and pavements (together with green strategies such as trees) are able to reduce air temperature by up to 4°C at the city scale during summer (C40 Cities, 2016; Falasca et al., 2019), thus effectively mitigating UHI. Such a large-scale application of cool materials is also able to improve air quality, as ozone-smog is more abundant in hot days. Additionally, the reduction of energy consumptions and related emissions for air conditioning, considering the contribution of many buildings in the city is even more impactful due to the large-scale application of such solutions. A direct consequence of this benefit is the reduced peak electricity demand, which was estimated as 1.6 GW for a reduction of 3°C in Los Angeles, corresponding to $175 million savings each year. Below, in the boxes, some successful cases of cool material strategies applied at the city-scale are reported.

Tokyo - Thermal barriers coating with cool materials on urban paving

Tokyo Metropolitan Government (TMG) promoted cool pavements, by employing high-reflective materials as barriers to solar radiation, defined in the project "thermal barrier coating" (C40 Cities, n.d.; Japan for Sustainability, n.d.). The interventions on streets are part of the construction works for the Olympic Games (2020). 136 km of pavements are implemented, which were able to reduce surface temperatures by 8°C. In this case, the economic burden of converting the paving in cool paving was reduced as the maintenance works were already deemed necessary by the TMG. This case study is relevant to highlight the efficacy and opportunity to include cool strategies during common maintenance works on buildings and other urban surfaces.

New York City - NYC °Cool Roofs Programme

Launched in 2009, the Programme has contributed to implement cool roofs on 530,000 m^2 of rooftops in 625 buildings (C40 Cities, 2016; NYC, n.d.). To-date, it demonstrated to provide a 10 to 30% cost reductions in air conditioning costs. The Programme offers no- or low-cost cool roof installations, depending on the type of buildings. No-cost installations are offered for free to low-income houses, community centers, schools, hospitals museums, while all other buildings can have it at a discounted rate through vendors that participate to the initiative: NYC Cool Roofs will provide the labor and technical assistance at no charge if the building owner pays for the coating. Only determined types of roofs are eligible, in that they have to be flat and in good conditions, accessible and free of dangerous equipment, they should have parapet. The Programme involves local property owners, community partners, workforce training organizations, and volunteers throughout the process. The case study is relevant as it offers financial incentives and provides educational and workforce training to increase population awareness on the topic.

3. Discussion and conclusions

While the above-mentioned benefits clearly demonstrate the contribution of cool materials to environmental sustainability when applied at the city scale, they entail crucial consequences for social and economic sustainability and resilience, too. With respect to social sustainability and resilience, the reduction in temperatures helps mitigating the impact of heatwaves on heat-related death toll, as it was evaluated that a 6% reduction in the number of heat-related deaths during a heatwave could be achieved by increasing the solar reflectance of urban surfaces by 10% at the city-scale. Moreover, the reduction in temperatures aid in safer and more comfortable indoors during the summer months for unprivileged neighborhoods that cannot rely on air conditioning to achieve comfortable conditions during summer (Fuller et al., 2019; Harlan et al., 2006). Indeed, such a solution contributes at reducing energy poverty, as it entails lower expenditures for energy for cooling in the long run. In other words, such kind of materials allow to reduce energy consumptions thus reducing the carbon footprint of the buildings that adopt them (Gargiulo & Russo, 2017). In turn, they bring economic benefits due to two main effects: on one side they cut energy costs, and on the other they allow to implement strategies that may be rewarded by stakeholders. In the case of local businesses, for example, the involvement in green activities signals positive feelings to customers (Koppelaar et al., 2021). Lower expenditures and reduced energy poverty deal also with economic sustainability. As mentioned above, cost savings for citizens and for the operations of large public or commercial buildings can be achieved by means of the application of high-albedo materials. This note tries to shed light on the benefits that such materials can bring to the sustainable development of cities and its components. It adopts a multi-disciplinary perspective embracing engineering and management that is needed to tackle urban grand challenges that involve diverse but interconnected factors. Future studies may further investigate synergies between economy and urban planning in the study of green measures to mitigate climate risks in cities, underlining related benefits and drawbacks.

Author Contributions

The work, although the result of a common reflection, was divided as follows: Federica Rosso, paragraphs 1, 2 and 3; Stefano Franco, paragraphs 1 and 3.

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