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The Special Issue collects six papers that use mobile phone data and spatial analysis techniques to study new urban critical features and social phenomena that arose with the Covid-19 pandemic. The applications of mobile phone data in the three study contexts investigated the potentialities of mobile phone data, as well as their limits. Compared to traditional methods of urban survey mobile phone data provide real-time maps of daily practices.

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Mobile phone data for exploring spatio-temporal transformations in contemporary territories

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MOBILE PHONE DATA FOR EXPLORING SPATIO-TEMPORAL TRANSFORMATIONS IN CONTEMPORARY

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EDITORIAL PREFACE

Special Issue 2.2022

Mobile phone data for exploring spatio-temporal transformations in contemporary territories

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Over the last few years, TeMA Journal has published numerous in-depth scientific-disciplinary Special Issues on the topics of interest to the journal, most of which are closely related to the main purpose of this scientific initiative: to contribute to the construction of new scientific and professional skills on one of the topics of greatest interest to those who study and work in the fields of urban and territorial transformations. The integration between the disciplines which study urban transformations and those which deal with issues of mobility governance makes it possible to overcome the apparent fences between these disciplines, and to build a new body of theoretical-methodological knowledge which provides new solutions to the problems which we continue to face today with the old tools of last century's scientific culture.

These include: the volume 'Transit-Oriented Development in Iran: Challenges and Solutions', published in 2016, in which the experiences of TOD in Iran and Germany were examined, focusing both on the problems which have limited the positive effects, ease of use and good accessibility of public transport systems in Iran and on the state of the art in Germany; in 2018, the volume 'Elderly Mobility' addressed the issues of mobility of the elderly by exploring the supply and demand of Local Public Transport (LPT) in Italian urban areas; finally, in 2018, the volume 'New Scenarios for Safe Mobility in Urban Areas' was dedicated to the relationship between mobility and quality of life in urban areas, with a specific focus on the safety of vulnerable road users.

Other Special Issues, published over the years, have dealt with topics of pressing topical interest: the study, design and implementation of the 'smart city'; the role of new technologies in the organisation of the city of the future; urban resilience as a conceptual approach to urban design aimed at building new awareness among citizens, technicians and administrators to reduce the impacts of climate change and the consequences of natural and man-made disasters; improving the quality of life of the elderly and, finally, the recent implications of the issue of the pandemic which has affected the lives of citizens.

This latest TeMA Journal Special Issue 'Mobile phone data to explore spatio-temporal transformations in contemporary territories' takes up the focus of the journal in a stringent logical-temporal sequence. The volume, in fact, offers the scientific community an in-depth study on the increasingly relevant relationship between new communication technologies and the governance of urban and territorial transformations, and aims to develop a cognitive framework on the evolution of digital communications in the urban and territorial sphere and on their use for the knowledge of settlement phenomena.

The research contained in this volume utilises - a practice which is not very common in our country - a panel of data provided by the use of mobile telephony to gain insight into aspects which are highly relevant to research on

urban phenomena such as metropolitan commuting, distance learning and multi-residentiality. They also testify to the relevance of the availability of mobile telephony data in the investigation of spatial dynamics.
In other words, the articles contained in the volume are oriented towards investigating and interpreting, among others, some highly complex urban phenomena such as 'the variability in the distribution of presences in the neighbourhoods of a large city', 'the seasonality of the use of second homes in a tourist area', 'the use of remote working in sparsely populated areas'.
The availability and reliability of this information, in conjunction with the possibility of using powerful dedicated software, finally makes it possible to investigate issues of great relevance to the study of the city which could not be pursued until now and can be the starting point for various in-depth studies in different disciplines which, like urban planning, study user behaviour (Papa et al., 2016; Carpentieri et al., 2020).
The increasing availability and reliability of mobile data is mainly due to the proliferation of increasingly powerful devices and innovative mobile applications, the use of which recorded a significant spike between 2019 and 2021, straddling the outbreak of the Covid-19 pandemic (Mediobanca, 2022). In fact, mobile data traffic shows an extraordinary increase over this period, reaching 65.5% in France, 74.7% in the UK, 97.9% in Germany, 107.0% in Italy and, finally, 131.9% in Spain (see Fig.1).

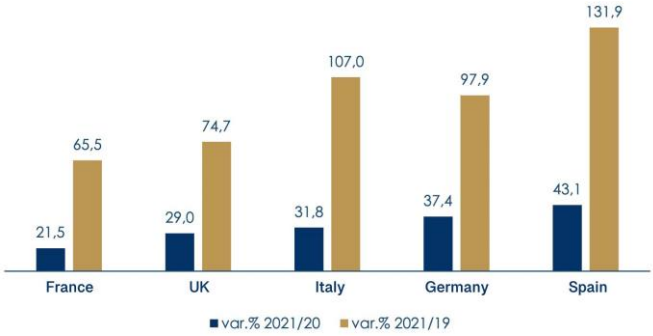

Fig.1 Percentage change in data traffic in European countries (Mediobanca, 2022)

This tumultuous growth trend is self-perpetuating and sees considerable resources committed to the digitalisation sector in 2021 as well: in Spain and Italy, investments have reached EUR 7.6 billion each, in Germany EUR 10.8 billion and in France EUR 15.5 billion. In addition, in order to foster the development of this strategic sector, the EU authorities have invested EUR 49.8 billion of Recovery Fund resources in initiatives of EU countries ranging from the digitisation of public administration to the development of ultra-wide bandwidth, from 5G to satellite networks.
In Italy, access to the mobile telephony network has been steadily increasing over the last decade, as the diagram in Fig.1 shows, with a positive change between 2013 and 2021 of 6.9 million accesses to the total telephone network, accompanied by a positive change of 22.5 million accesses for M2M Sim devices. This diversification in mobile telephony operators highlights a twofold aspect of great scientific relevance: on the one hand, the growing and balanced involvement of public and private companies, which guarantees greater extension and articulation of the available database, and on the other hand, the increasing reliability due to the large number of data sources from devices which allow the exchange of information between devices with limited or no human interaction (M2M Sim).

Fig.2 Number of mobile network accesses (in millions) per human and M2M (machine-to-machine) sim (Mediobanca, 2022)

This exponential increase in mobile telephony activities leads to an equally massive increase in the availability and reliability of data, which can be used in many areas of scientific research, from economics to social research to computer science.

This opens up a fruitful field of research in the knowledge of urban phenomena to which urban scholars do not yet seem to have been devoting the necessary attention. In other words, a 'new' field of research is opening up, of which this volume is intended to be an initial result, requiring innovative approaches, dedicated tools, specific skills and, above all, scientific curiosity.

Mobile phone traffic data have been employed in several applications in urban and territorial research over the last fifteen years. Their application primarily aims to analyse the space-time variability in population distribution in cities (Mobile Landscape Method in Ratti et al., 2006; Ahas & Mark, 2005; Sevtsuk & Ratti, 2010); classify different 'basic' profiles of city users and patterns of consumption (Reades et al., 2007; Soto & Frías-Martínez, 2011; Järv et al., 2014), study trip chaining (Ahas et al., 2010; Srinivasan & Raghavender, 2006; Steenbruggen et al. 2013), update origin/destination matrices and transport models (Noulas et al., 2012; Shoval & Ahas, 2016; Shoval et al., 2014; Yip et al., 2016), detect mobility behaviour for demand analysis (Bayir et al., 2010), and during the COVID-19 pandemic, assist with emergency management (Wang et al., 2020).

These applications make it possible to deal with opportunities and critical issues in the processing of mobile phone records and address the need to integrate these data with other available data sources to investigate complex urban phenomena (Pucci et al., 2015).

In recent years, the availability of mobile phone traffic data in Italy, provided through business services targeted towards public administrations, large companies and research institutions by TIM, Vodafone and Windtre has made it possible to experiment with different uses. In urban research, these data have been increasingly exploited to detect urban practices and complex territorial processes, generating knowledge about their scientific reliability, their limits and the need for a structured integration with other data sources.

In this framework, the special issue aims to reflect on the usability and relevance of mobile phone traffic data for territorial research, on the challenges posed by its treatment in statistical terms and on possible integration with other available datasets, presenting the outcomes of specific empirical experiments on three territorial settings (Milan, Lecce and its coast and the Piacenza Apennines).

These settings represent relevant and challenging study contexts within research on territorial fragilities carried out by the Department of Architecture and Urban Studies, Politecnico di Milano, in the last few years. Processing mobile phone data in these three Italian cases, characterised by different socio-territorial conditions, settlement densities and mobility practices, allows testing the potentialities of mobile phone data and their limitations in exploring unobservable trends and dynamics that may be associated with existing fragility, or on the contrary, signal the presence of opportunities to be exploited to counteract such fragilities.

The data used in the research works presented in this special issue, provided by TIM and characterised by a very high spatial-temporal resolution (15 minutes for 12–16 months in 2019–2020 for three Italian territorial areas) describe two phenomena:

- Human presences: as an estimation of the number of presences detected at the Istat ACE (census areas) level, with socio-demographic details provided by the TIM registry (gender, age groups, foreigners, users' profiles as commuters, inhabitants, tourists, contract typology as business or consumer);
- Human mobility: in terms of displacement with details on origins and destinations at the ACE spatial level for the municipality of Milano.

These data on human presences and mobility, related both to a city's inhabitants and users profiled by age group, gender and nationality and collected over a wide timespan, including a pre-lockdown phase and the pandemic period, have been processed to analyse:

- Space-time variabilities in urban practices, providing information on temporary populations and city usage patterns on a daily, weekly and seasonal basis and considering the impact of holidays, weekdays or specific public events;

- Time variability in the use of urban spaces to detect their over/under-use in some periods of the day/month/season;
- Prevalent mobility flows and their intensity and variability to distinguish systematic from non-systematic mobility, as well as the recurrence of mobility practices at different scales (municipalities and provinces), considering gender issues and nationalities.

Due to the unique characteristics of the three study areas (Milan, Lecce and its coast, the Piacenza Apennines), mobile phone data have been used to investigate different and place-based dynamics, including the variability of presences in the neighbourhoods of Milano during the pandemic; the seasonality of use in coastal areas in the municipality of Lecce, characterised by the presence of second homes, partly unauthorised; and the analysis of practices such as remote working in sparsely populated and low connected territories (Piacenza Appennines), as well near-home tourism, during the pandemic.

Dealing with complex urban phenomena – otherwise difficult to study with conventional data sources – the three case studies led to testing whether and to what extent mobile phone traffic data allow more detailed interpretations of some spatial effects of the pandemic on urban behaviours such as changes in the timing of the use of the cities, rhythms of daily commuting, the impact of remote work and learning and multi-residentiality. Moreover, even though not always representative of the overall population of a territory, case studies illustrate the variability of practices and times of use of urban and rural spaces.

The differences in the study contexts and the related research questions represent a test case for investigating the heuristic potential role of mobile phone data in urban studies, highlighting that mobile phone data do not 'speak for themselves', but instead need interpretative models to guide their use and integration with other data sources. These conditions are relevant in affecting their usability in urban and spatial analysis that remains marginal, despite the availability of a large amount of (digital) data, due also to the level of complexity in the approaches finalised to process and integrate this data (Einav & Levin, 2013; Batini, 2018; Kitchin & Lauriault, 2018; Concilio & Pucci, 2021).

Within this general framework, the six papers of this special issue contribute to the general debate on the use of mobile phone data for urban research, addressing theoretical, methodological and technical issues and presenting three specific case studies. The first paper, 'Mobile phone traffic data for territorial research: opportunities and challenges', reconstructs state of the art in mobile phone research for urban studies in detail, highlighting the potentialities and limitations of mobile phone data. Moreover, the paper introduces the DAStU Department's research on territorial fragilities and the role of mobile phone data in addressing specific topics solicited by this approach. Thus, the paper is intended to guide the reader through theoretical and contextual aspects of urban research based on mobile phone data.

The paper titled 'A glimpse into mobile phone data: characteristics, organization and tools' provides a detailed description of the characteristics of mobile phone data to support their uses and deploy their potential in urban studies. By presenting mobile phone data provided by TIM and its spatial and temporal disaggregation and information related to age groups, gender and classification of behaviours, the paper proposes a baseline for the comparison of the data trends, as well as integration with traditional sources and ad hoc surveys to show how they can facilitate the interpretation of mobile phone data, its validation and its use. Finally, a reference to the operational tools used for data processing and visualisation highlights the need to integrate skills, methodologies and tools for the maximum exploitation of this wealth of information.

The third paper explores 'Exploring the "15-Minute City" and near working in Milan using mobile phone data' and focuses on changes in the attractiveness of Milan neighbourhoods during the COVID-19 pandemic (2020) compared to the year before (2019). The aims of this paper are twofold: it measures the presence of remote workers at the neighbourhood scale and explores which neighbourhoods meet the requirements of the '15 minutes' city paradigm, with specific attention to nearby working. Analysing the change of the city users' presence in the Milan neighbourhoods in 2019–2020 using TIM mobile phone data, the paper performs a correlation of the residents working typologies (e.g. knowledge workers vs. other typologies) and the presence of users at the neighbourhood scale during the day as a proxy of remote working, and it investigates the supply of main services at the neighbourhood scale, including coworking spaces, to understand which Milan neighbourhoods better meet the

requirements of the 15 minutes city, as described in the policy measures promoted by the municipality of Milan (2020) favouring the '15 minutes city'.

Shifting from a central urban area like Milan to the coastal territory of Lecce, the paper titled 'Permanent and seasonal human presence in the coastal settlements of Lecce', tests the effectiveness of mobile phone data in providing an assessment of the permanent and seasonal residents in a coastal area (Marine) characterised by seasonal use and informality. Starting from challenging conditions related to the presence of coastal settlements mainly composed of unauthorised second homes, which are difficult to detect in traditional census and registry statistics, the paper compares TIM mobile phone datasets referring to different slot-times from September 2019 to September 2020 to reveal dissimilarities between the southern *marine* and northern ones, where the former are characterised by the more stable presence of a resident population and fewer environmental risks. In its concluding section, the paper questions, from an urban planning perspective, the usefulness of analysis based on mobile phone data with a high spatial-temporal resolution, with particular attention paid to the many illegal buildings which cannot be legalised and therefore must be demolished.

The third investigation conducted experimentation in the context of a sparsely populated, low-connected and poorly accessible mountain area located in the province of Piacenza (Val Trebbia and Val Nure) characterised by a general process of marginalisation due to the ageing of its population, low occupational rate, low income and a progressive deprivation of local know-how and shrinking of essential services. In this area, the paper titled 'Impacts of the COVID-19 pandemic in inland areas' investigates through the use of mobile phone data if and how, during the Pandemic, remote working and near-home tourism contributed to modifying the marginal conditions of these territories. Comparing the baseline trends of mobile phone data (September 2019) with two weeks in the lockdown (March 2020) and post lockdown (September 2020), the paper highlights the variability of presences at different hours of the day, contributing to profiling the municipalities based on their propensity to be 'stable', 'attractors' or 'generators' of daily presences. By combining mobile phone and socio-spatial data, differentiated trends emerge, and are linked to the intrinsic features of the study area (orography, accessibility, provision of services), supporting the idea that an increase in human presence is often a temporary trend unable to trigger new economies, especially for the most marginal municipalities. Moreover, providing a picture of the changes that have occurred in these marginal areas, the outcomes have shown the great potentiality of mobile phone data, along with some limits which may prejudice their usability, particularly for territorial research in low-density areas.

In the conclusion, 'Mobile phone data: Challenges for spatial research', two perspectives emerge from the experimentation carried out in the three different contexts: on one hand, the relevance of dealing with the features of mobile phone data as a condition for understanding its uses, potentials and limits is considered. On the other, their potentialities as well as their limits are addressed. These data are not always representative of the population of a territory, and above all, interpretative models are needed to guide their use, in combination with the integration with other data sources. These contributions to the Special Issue have addressed specific issues, such as the epistemological value of big data and its necessary interactions with other forms of knowledge, as confirmed by a well-known academic debate (Batty, 2013; Graham & Shelton, 2013; Kitchin, 2014, 2021; Kwan, 2016; Poorthuis & Zook, 2017; Rabari & Storper, 2015; Schwanen, 2015).

References

Ahas, R., Mark, U. (2005). Location based services: new challenges for planning and public administrations? *Futures 37*, 547–561. https://doi.org/10.1016/j.futures.2004.10.012

Ahas, R., Aasa, A., Silm, S., Tiru, M. (2010). Daily rhythms of suburban commuters' movements in the Tallinn metropolitan area: Case study with mobile positioning data. *Transportation Research Part C: Emerging Technologies, 18*(1), 45–54. https://doi.org/10.1016/J.TRC.2009.04.011

Batini, C. (2018) Datacy, perché una scienza per studiare l'impatto dei dati sulla società in "Agenda Digitale". Retrieved from: https://agendadigitale.eu/cittadinanza-digitale/datacy-percheuna-scienza-per-studiare-limpatto-dei-dati-sulla-societa/a.

Batty, M. (2013). Big data, smart cities and city planning. *Dialogues in Human Geography 3* (3), 274–279. https://doi.org/10.1177/2043820613513390

Carpentieri, G., Guida, C., Fevola, O., & Sgambati, S. (2020). The Covid-19 pandemic from the elderly perspective in urban areas: An evaluation of urban green areas in 10 European capitals. *TeMA-Journal of Land Use, Mobility and Environment*, *13* (3), 389-408. https://doi.org/10.6092/1970-9870/7007

Concilio G., Pucci P. (2021). The Data Shake: An Opportunity for Experiment-Driven Policy Making. In: Concilio G., Pucci P., Raes L., Mareels G. (eds) The Data Shake. SpringerBriefs in Applied Sciences and Technology. Springer, Cham. https://doi.org/10.1007/978-3-030-63693-7_1

Graham, M., & Shelton, T. (2013). Geography and the future of big data, big data and the future of geography. *Dialogues in Human geography 3* (3), 255-261. https://doi.org/10.1177/204382061351312

Einav, L., Levin, J. D. (2013). The Data Revolution and Economic Analysis (*NBER Working Paper Series No. 19035*). Cambridge.

Halevy, A., Rajaraman, A., & Ordille, J. (2006) Data Integration: The Teenage Years*. Proceedings of the 32nd International Conference matternson Very Large Data Bases* (VLDB '06), 9-16.

Jarv, O., Ahas, R., Witlox, F. (2014). Understanding monthly variability in human activity spaces: a twelve-month study using mobile phone call detail records. *Transportation Research Part C* 38, 122-135. http://dx.doi.org/10.1016/j.trc.2013.11.003

Kitchin, R. (2014). The real-time city? Big data and smart urbanism. *GeoJournal 79*, 1-14. https://doi.org/10.1007/s10708-013-9516-8

Kitchin, R. (2021). The Data Revolution: A critical analysis of big data, open data and data infrastructures*. Sage.*

Kitchin, R., & Lauriault, T. P. (2018). Toward critical data studies. *Thinking big data in geography*, 320.

Kwan, M. P. (2016). Algorithmic geographies: Big data, algorithmic uncertainty, and the production of geographic knowledge. *Annals of the American Association of Geographers 106* (2), 274-282. http://dx.doi.org/10.1080/00045608.2015.1117937

Kwan, M.P., Dijst, M., Schwanen, T. (2007). The interaction between ICT and human activity-travel behaviour. *Transp Res Part A: Policy Pract 41* (2), 121–124. http://linkinghub.elsevier.com/retrieve/pii/S0965856406000255.

Mediobanca (2022). Le maggiori telco mondiali (2017-2021). Retrieved from: https://www.areastudimediobanca.com

Noulas, A., Scellato, S., Lambiotte, R., Pontil, M., Mascolo, C. (2012). A Tale of Many Cities: Universal Patterns in Human Urban Mobility. *PLoS ONE*, 7(5), e37027. https://doi.org/10.1371/journal.pone.0037027

Papa, R., Gargiulo, C., & Battarra, R. (2016). *Città Metropolitane e Smart Governance: Iniziative di successo e nodi critici verso la Smart City* (Vol. 1). FedOA-Federico II University Press. https://doi.org/10.6093/978-88-6887-005-8

Poorthuis, A., & Zook, M. (2017). Making big data small: strategies to expand urban and geographical research using social media. *Journal of Urban Technology 24* (4), 115-135. https://doi.org/10.1080/10630732.2017.1335153

Pucci, P., Manfredini, F., Tagliolato, P. (2015). Mapping urban practices through mobile phone data. Berlin: Springer. ISBN: 978-3-319-14833-5. https://doi.org/10.1007/978-3-319-14833-5

Rabari, C., and Storper, M. (2015). The digital skin of cities: urban theory and research in the age of the sensored and metered city, ubiquitous computing and big data. *Cambridge Journal of Regions, Economy and Society 8* (1), 27–42. https://doi.org/10.1093/cjres/rsu021

Ratti, C., Frenchman, D., Pulselli, R. M., Williams, S. (2006). Mobile Land-scapes: Using Location Data from Cell Phones for Urban Analysis. *Environment and Planning B: Planning and Design 33* (5), 727–748. https://doi.org/10.1068/b32047

Reades, J., Calabrese, F., Sevtsuk, A., Ratti, C. (2007). Cellular Census: Explo-rations in Urban Data Collection. *IEEE Pervasive Computing 6* (3), 30–38. https://doi.org/10.1109/MPRV.2007.53

Shoval, N., & Ahas, R. (2016). The use of tracking technologies in tourism research: the first decade. *Tourism Geographies, 18* (5), 587–606. https://doi.org/10.1080/14616688.2016.1214977

Shoval, N., Kwan, M.-P., Reinau, K. H., & Harder, H. (2014). The shoemaker"s son always goes barefoot: Implementations of GPS and other tracking technologies for geographic research. *Geoforum*, 51, 1–5. https://doi.org/10.1016/j.geoforum.2013.09.0

Schwanen, T. (2015). Beyond instrument: Smartphone app and sustainable mobility. *European Journal of Transport and Infrastructure Research, 15*(4), 675–690.

Sevtsuk, A., Ratti, C. (2010). Does Urban Mobility Have a Daily Routine? Learning from the Aggregate Data of Mobile Networks. *Journal of Urban Technology 17* (1), 41–60. https://doi.org/10.1080/10630731003597322

Soto, V., Frías-Martínez, E. (2011). Automated land use identification using cell-phone records. *Proceedings of the 3rd ACM international workshop on MobiArch*. https://doi.org/10.1145/2000172.2000179

Srinivasan, K. K., & Raghavender, P. N. (2006). Impact of mobile phones on travel: Empirical analysis of activity chaining, ridesharing, and virtual shopping. *Transportation Research Record, 1977* (1), 258-267. https://doi.org/10.1177/0361198106197
700130

Steenbruggen, J., Borzacchiello, M. T., Nijkamp, P., & Scholten, H. (2013). Mobile phone data from GSM networks for traffic parameter and urban spatial pattern assessment: a review of applications and opportunities. *GeoJournal 78* (2), 223-243. https://doi.org/10.1007/s10708-011-9413-y

Yip, N. M., Forrest, R., & Xian, S. (2016). Exploring segregation and mobilities: Application of an activity tracking app on mobile phone. *Cities, 59*, 156–163. https://doi.org/10.1016/j.cities.2016.02.003

Wang, Y., Li, J., Zhao, X., Feng, G., & Luo, X. R. (2020). Using mobile phone data for emergency management: a systematic literature review. *Information Systems Frontiers*, 1-21. https://doi.org/10.1007/s10796-020-10057-w

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Mobile phone traffic data for territorial research

Opportunities and challenges for urban sensing and territorial fragilities analysis

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Abstract
Mobile phone tracking data collected by telecommunication companies allow recording and reconstructing the practices of mobilities and the presence of users with significant spatial-temporal detail. If properly managed, analysed, and possibly combined with other sources of information, mobile phone data can represent an interesting opportunity for urban research and mobility studies as they shed light on complex socio-territorial dynamics difficult to infer from conventional data analysis. At the same time, reports of numerous experiments using these sources reveal some of the challenges that researchers face in accurately capturing the behaviours of individuals through digital data and translating them into useful research knowledge. Referring both to the direct experience of managing and analysing mobile phone data within the Department of Architecture and Urban Studies of the Politecnico di Milano and to the relevant literature, the paper proposes an overview of the potentialities and limitations of telephone data for urban research and their usability in different territorial contexts characterised by varying socio-spatial and demographic conditions. Besides positioning themselves within and enriching an already lively debate, the issues discussed here will be useful in reading the contributions of the special section that this paper introduces.

Keywords
Mobile phone data; Urban studies; Territorial research; Territorial fragilities.

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1. Introduction

For some years, scientific research has been experimenting with digitally generated data, so-called *big data*, to analyze complex phenomena difficult to detect using more conventional "small" data-based methodologies. These experiments have been particularly significant in the disciplinary fields of urban and territorial studies, mainly due to the versatility of these data and the information they carry about the temporal and spatial evolution of citizens' behaviors and ways of interacting with urban spaces and services. The sensing opportunities offered by the collection and analysis of these data have been exploited both for research purposes and in daily urban management, giving way to the concept of *smart city*, i.e., a city in which the big data produced by information and communication technologies (ICT), in conjunction with social capital and broader policies, contribute to leverage a potentially more sustainable growth and urban development (Caragliu et al. 2009; Papa et al., 2013; Kitchin, 2014a; Papa et al., 2016).

Remaining in the field of urban studies, one of the most promising sources to explore the dynamic mobility practices, human presence, and uses of a territory, its spaces, and its activities, is represented by mobile phone location data collected by telecommunication companies. If properly managed and analysed, mobile phone data can shed light on complex socio-territorial phenomena challenging to infer solely by relying on traditional methodologies typically used in urban and mobility research, such as census data analysis and travel and activity surveys, which suffer from structural limits linked to their low frequency of updating. To this limit is added the fact that census and travel patterns data, at least in the Italian case, describe behaviours, socio-economic, and demographic conditions that concern specific populations (e.g., students and workers in the case of travel surveys) or consider only the inhabitants officially registered in the administrative areas of data collection. Thus, they may overlook phenomena such as multiresidentiality, leisure-related use of the territory, and emerging forms of remote working/learning that are becoming increasingly relevant for research and local policies, especially following the outbreak of the Covid-19 pandemic. Digital data, particularly when sourced from mobile phones, open up new opportunities for the enrichment of more traditional methodologies for territorial analysis thanks to the breadth of collection samples, penetration of the technologies from which they are sourced, and the ability to describe different phenomena without many of the sampling biases of official statistics.

At the same time, reports of numerous experiments using these sources available in the literature reveal some of the challenges that researchers face in accurately capturing the behaviors of individuals through digital data and translating them into helpful research knowledge.

To meet these challenges and test the research opportunities related to the use of mobile phone data, the Department of Architecture and Urban Studies (DAStU) at Politecnico di Milano has conducted several experiments within the framework of the research project on "territorial fragilities" (DAStU-TF project)[1], aimed at investigating specific territorial phenomena overlooked by official statistics and their emergence and evolution since the outbreak of the Covid-19 pandemic. The research works that have developed from this interest, inspired by different research questions and resorting to multiple methodologies of analysis, are the subject of the special issues to which this article acts as an introduction. The paper aims to provide an overview of the DAStU-TF project and the case studies analyzed, framing this experience within the broader research on mobile phone data for urban research and their usability in different territorial contexts.

Thus, the paper opens with a review of the literature (section 2) to define a theoretical framework of reference focusing on the challenges and opportunities of mobile phone data for socio-spatial analysis and planning.

[1] Over the five-year period spanning 2018-2022, the Department of Architecture and Urban Studies has been funded by the Italian Ministry of University and Research ("Departments of Excellence" initiative) to explore the many and complex processes of fragilization in the space-society relationship in terms of exposure to different risk factors: environmental, social, economic, political and institutional.

This review offers some critical insights that explain why focusing on this type of data is relevant to the research on urban phenomena and territorial fragilities conducted within the DAStU-TF project. At the same time, the review pointed out some challenges that, in many cases, precede the definition of specific research questions to be answered through data-driven approaches. In fact, the process of acquiring and managing big digital data is by itself significantly complex and has represented, in the case of the DAStU experimentation, a major challenge answered by building negotiation channels with data providers and adapting research questions to the specific characteristics of the available data. The description of this process, presented in section 3, sheds light on the phases of data acquisition and preparation propaedeutic for the subsequent case study analysis, which research questions and objectives are introduced in section 4. Conclusive remarks close the paper.

As a consequence, each of the mobile phone data-based research experiences conducted in the framework of the DAStU-TF project, introduced in this article and subsequently deepened by the individual papers composing the special issue, moves from an awareness of the opportunities and limitations of mobile phone data to respond to specific research questions in a plurality of territorial contexts characterized by different social and spatial dynamics. In this way, the research provides an original framework for the analysis of urban phenomena that are often hidden or difficult to read, besides positioning itself within and enriching an already lively debate on the role of digital data for research and urban planning purposes.

2. Opportunities and challenges of mobile phone traffic data for territorial research

Thanks to the development and the widespread diffusion of information and communication technologies (ICT), contemporary cities produce an increasing amount of digital "big" data, which unprecedented availability allows researchers and planners to unveil previously hidden dynamics and phenomena. Digitally produced massive, dynamic, varied, detailed, inter-related, low-cost datasets can be exploited to discover and analyse the behaviours, choices, needs, and desires of large samples of individuals on extended time frames (Kitchin, 2014 a,b; Rabari et al. 2015; Hilbert, 2016) and, through correlation, to hypothesize the cause-effect relationships binding them. Moreover, the collection and analysis of this information, which can be aggregated at different temporal and spatial scales, let researchers recognize complex patterns of social interaction and their continuous evolution (Bibri, 2018; Birkin, 2019) in a way that can deeply innovate both the methodologies of urban research and the design, implementation, and evaluation of public policies (Concilio & Pucci, 2021).

Since the early 2000s, many experiments have been conducted to test big-data-based analysis' potential and identify limitations and obstacles to their use in research and policymaking, aspects closely related to the source from which the data are obtained and the algorithms that are used to make it operable. Widely used in such experimentations are the so-called *sensor-generated data* (Thakuriah et al., 2017), passively and automatically collected from personal devices, as in the case of mobile phone data and GPS tracking, or through other monitoring systems often used by public administrations for the management of public services, such as traffic sensors, cameras, or smart cards for public transport. Sensor-generated and other types of big digital data are often subject to hybridization and fusion with data obtained from different sources at different times and for different purposes to produce new information that may not be found by analysing a single data type. As a result, the ability to manage different datasets at the same time by combining those produced by new technologies (*big data*) with others obtained from consolidated techniques such as census and surveys (defined, not by chance, *small data* by Kitchin 2014b), allows obtaining a potential completer and more dynamic picture of what happens in cities and territories.

Most of the experimentations of urban analysis through sensor-generated data available in the literature and implemented by research institutions and public administrations in collaboration with specific data owners, such as transport authorities or telecommunication providers, focus on mobile phone data collection and

analysis. Globally widespread with an extremely high penetration rate, both in developed and developing countries, mobile phones are personal devices that accompany the user throughout the day. For this reason, they are particularly promising in tracking individuals' spatial and temporal activities. When connected to antennas that support the cellular network, mobile phones produce MPR (mobile phone record), timestamped data on users' location, which telephone companies actively or passively collect for billing purposes (Ahas et al., 2010a; Urbanek, 2019). In addition to MPRs, which have been extensively applied in mobility-related research, other kinds of data are produced by the interaction between users and mobile devices, as in the case of positioning data based on GNSS (Global Navigation Satellite System) collected by web-based applications installed on smartphones to offer personalized services to users (Paffumi et al., 2018). Besides, data generated by mobile phones may include data collected through Bluetooth or wi-fi sniffing operations in urban environments (Hasan et al., 2014, Gorrini et al., 2021) and data extracted from the analysis of social media networks (Gadzinski et al., 2018). However, most of the experiences found in the literature use MPRs or, in more recent research, web-based apps.

MPRs are widely experimented with both for research purposes and possible applications in the design of urban policies, particularly in the field of mobility and transport. Indeed, MPRs are structured as chains of location anchor points in which the positioning of a single user is referred to the nearest telephone antenna and collected at even very short time intervals (Ahas et al., 2010b). Measurements are based on large samples of mobile users over geographical areas of flexible extent: being produced following the interaction with the antennas of the mobile network, the data produced can describe patterns of static presence around the single antenna (local scale) and record the mobility behavior of users on larger spatial scales based on subsequent interactions with multiple antennas of the network. This tracking process can also be related to specific spatial areas of interest through resampling algorithms (e.g., administrative boundaries, census tracts). A good density of antennas at the spatial level is thus an essential requirement for reliable tracking (Williams et al., 2015) of everyday life patterns at the individual level – although raw data are generally aggregated for privacy concerns – based on mobility practices and the variation of human presences in different temporalities (Calabrese et al., 2013; Blondel et al., 2015; Jiang et al., 2016), including associating such patterns with the distribution of spatial activities and characteristics of land use (Tu et al., 2017; Ni et al., 2018), transportation systems (Chen et al., 2016), and socio-demographic conditions of users and their interactions with space and other people (Ahas et al., 2010a, 2010b ; Picornell et al., 2015).

Many examples can be found in the literature concerning experiences of the practical application of the opportunities of mobile phone data, especially in recording people's travel patterns and the activities in which they participate by performing the tracked displacements. In the first case, reference is made to the so-defined *trip-based analysis* (Jiang et al., 2016), which involves the application of techniques based on timestamped locations of users to construct origin/destinations (O/D) matrices based on trajectories between positions where users were registered in specific time intervals inferring modal choices and travel times (Chen et al., 2016). More advanced and complex applications concern *activity-based analyses* (ibid.), aimed at recording at different scales and with different levels of aggregation (from the individual to larger populations) the daily area of movement and the activities performed in the anchor locations of measurement (Jarv et al., 2014a, 2014b; Jiang et al., 2016; Bassolas et al., 2019). Different methods can be applied to derive activities. They can be based on time and frequency, thus relying on user presence in prevalent locations at specific time intervals (Alexander et al., 2015), for instance, by considering residential locations as the anchor points in which a person is usually registered during nighttime and working locations as the places visited during the day. Other methods are based on the application of specific models that link the characteristics of the land use surrounding the measurement location using predefined empirical rules (Chen et al., 2016), such as the attractiveness of local points of interest, hourly availability, length of stay, and accessibility to the activity from different origins (Garcia Albertos et al., 2019). The activity-based approach, even if complex to be

implemented, can be helpful in revealing travel behaviors and their relationship with land use characteristics and defining possible correlations with socio-economic conditions when information on user profiling is collected by the telecommunication provider and associated with the data.

The mentioned experiences show how mobile phone data constitute a particularly useful source of information for measuring mobility behaviors, but also the dynamic modes and temporalities of use of a territory and its activities by mobile phone users. The latter group represents a substantial part of the population with a decreasing bias of socio-demographic representativeness thanks to the increasing penetration of ICT technologies in all socio-economic and demographic groups (Deloitte, 2019) and to the development of algorithms allowing extending the tracked sample to larger population based on the market shares of telecommunication providers. For this reason, MPRs are potentially relevant not only in the field of mobility-related planning, policy and research but also promising in a multi-sectoral perspective straddling transportation studies and policy, urban planning, and regional economics by revealing diversified and often unobservable human behaviors in space.

To this extent, at least three aspects make MPRs a source worth relying on for urban and territorial planning and research that distinguish these sources of information from traditionally employed small data in the same fields.

The first aspect concerns the possibility allowed by mobile phone data (and, in general, by other types of big data) of *observing phenomena not recorded by official statistics* (La Rocca, 2014). Compared to conventional census data and travel surveys available in the Italian case, which are generally concerned with recording the characteristics and behaviors of the residents registered in the specific administrative areas of collection, mobile phone data track the activities of users who interact with the telephone network. Consequently, MPRs allow analyzing both the presence of residents, domiciled populations, and territory users not officially counted at the statistical level, unveiling the magnitude of phenomena such as multiresidentiality and temporary presence in specific locations for work, study, or leisure-related reasons or during specific events. This information can be promising in inferring human presence and uses of a territory and its activities that is more adherent to reality, overcoming the limitations of an administrative bias in the collection of socio-demographic information.

The second concerns the opportunities for *user profiling*. In addition to users' location, telecommunication companies collect limited information on the socio-demographic and economic characteristics of all the users interacting with the network (Calabrese et al., 2010), thus allowing the investigation of certain characteristics of resident and non-resident populations by associating behaviors and choices in space and time with specific socio-economic and demographic profiles. In the case of mobility and travel analysis, this means that a limitation inherent in the census-based travel survey (especially in the Italian case) is overcome by broadening the responding sample – not just limiting it to the systematic commuting-related displacements performed by students or workers – and by increasing the possibility of correlation with other conditions recorded by the same digital data.

The third aspect concerns the *temporal granularity and frequency* of updating of mobile phone databases. Unlike census data, which are updated infrequently (e.g., annually, or even every ten years, as in the case of the Italian mobility surveys up to 2011), mobile phone data are collected continuously and at short intervals. Consequently, they can, firstly, record the evolution of specific trends on an hourly or semi-hourly basis. Secondly, they are sensitive to sudden or temporary changes with a level of detail that is unreachable by conventional small data. In this sense, MPRs can be usefully employed to record the effect of specific events circumscribed in time and space (e.g., public events), as well as unexpected sudden changes (e.g., related to the outbreak of the Covid-19 pandemic). This type of information is very relevant not only for urban research but also for the management of public events and states of emergency.

However, it is worth noting that relying on MPR-collected data for research purposes raises important epistemological and operational issues.

From the first point of view, many authors have discussed how big data collected through mobile phones and other sources, whose objectivity may be challenged by the fact that their use requires processing through algorithms that mediate between the observed reality and possible interpretations by the researcher (Kwan, 2016), could subvert the very foundations of the scientific research process. This perspective founds on the idea that big data could support a new paradigm based on data-intensive research and exploration, establishing empiricism based on the observation of datasets and their possible correlations in the search for new problems otherwise unobservable, without therefore needing to base the research on theory. Kitchin (2014a), however, argues that the development of a data-driven science is more likely, in which digital data will support research and analysis of known problems. According to this perspective, the theory will remain a substantial element in the process since not all phenomena can be measured through data analysis (McNeely et al., 2014), and the found cause-effect correlations still need to be verified (Rabari et al., 2015). Therefore, it is interesting to consider what has been argued by Kitchin (2014c), according to which digital data will have different impacts depending on the field of research in which they are employed and will express their value if used in combination with already consolidated research techniques. According to Lazer et al. (2014), and as demonstrated by the approach followed by the research developed under the DAStU-TF project, more than a big data revolution, we are facing an *all data* revolution in which, despite the limitations and challenges described in this paragraph, the availability of digital data will create new opportunities to know the world through a more in-depth and precise analysis of its phenomena.

From an operational perspective, mobile phone data is subject to some critical aspects related to digital innovation, such as data ownership, privacy, and dependence on data and technology providers (Calzada, 2018; Kazmi et al., 2018) which can make accessing this data complex and expensive for research. In addition, mobile phone data have analytical limitations related primarily to the degree of accuracy of the measurements that depends on the potentially uneven spatial density and distribution of the antennas in different study contexts and the fact that raw data must be processed through complex algorithms to translate the recorded tracks in punctual locations (Chen et al., 2014; Alexander et al., 2015; Semanjski et al., 2016). Moreover, the reliability of the information may be influenced by the unequal penetration of technologies, which can lead to biased survey samples (Calabrese et al., 2013) and may produce inaccurate insights (Hasan et al., 2014). Also, if used to infer users' modal choices and activity patterns, the statistical error at the individual level is likely to be particularly significant (Chen et al., 2014). Other known issues are the scarce information they provide on users' socio-demographic characteristics and the limited potential to infer non-commuting activities (for instance, after-work or leisure activities) that travellers participate in (Jestico et al., 2016). As a consequence, and to overcome these limitations, numerous experiments put in place specific strategies of hybridisation between different types of data aimed at better interpreting users' behaviour and relating them to land use, transport-related and socio-economic characteristics of the context of analysis, for example, by combining data from MPRs with traditional small data from census and identify potential relationships between user activity spaces and the socio-economic status of the places they usually frequent (Calabrese et al., 2013; Jarv et al., 2014a).

Therefore, it seems necessary for researchers to develop the proper ability to understand what information mobile phone data can provide compared to or in combination with other data and what are the inherent limitations to its use; build negotiation processes with private data providers and owners to acquire high-quality, reliable data; manage and analyse data establishing interdisciplinary research teams that can address the complex challenge of extracting value and insights. As described in the next section of the article, these challenges were addressed by the DAStU-TF project in the preliminary management of data provider relationships and subsequent data preparation operations. These steps are essential to carry out big data-

driven research because the choice of the type of data and its preparation affect the definition of research questions and objectives, orienting them according to the potential and limitations of the data itself.

3. Mobile phone data as a component of the DAStU project on "Fragile Territories"

Within this general context, the DAStU developed a complex and ambitious research program aimed at testing the potential of mobile phone data for urban research in the field of *territorial fragilities*, which is the research theme that DAStU embodies within the "Departments of Excellence" initiative (2018-2022) launched and funded by the Ministry of University and Research (MIUR). This ministerial action rewards departments with high-quality research and funds their development projects on specific themes. In this perspective, the DAStU aims to become an essential node of an international network of researchers and institutions that work on the various declinations of socio-spatial fragility. The ultimate goal is to set up a transdisciplinary competence center on "fragile territories" that can become a permanent point of reference both for the academic and non-academic realm and among all the institutional, professional, and social actors involved in "anti-fragile" policies and projects. The issue of *fragility* has led many researchers of the DAStU to explore different territories, from the most urban to the most rural, to interpret their variegated weaknesses and, in particular, all the forms of risk and uncertainty that characterize their present condition. The concept of fragility is linked to radical uncertainty (Chiffi & Curci, 2021), and the Covid-19 pandemic has increased the general interest in this issue.
The resources mobilized by the project have been an opportunity to start a discussion within the Department on the ongoing research and on the possibility of acquiring innovative data to enrich the empirical analysis of the Italian territories. Through the skills of the Mapping and Urban Data Lab (MAUD)[2] of the DAStU, which has long been engaged in research on mobile phone data, the scientific direction of the project has oriented the choice towards mobile phone tracking data to extend their use also to research groups that had not yet tested their potential.
As explained in section 2, mobile phone data were chosen due to the specific analytical opportunities compared to conventional data sources. What was particularly relevant for the purposes of the DAStU-TF project was having access to mobile phone data characterized by high spatial resolution and available for different Italian contexts. In addition, a high temporal resolution was required to ensure the availability of information for a continuous period from 2019 to 2020 on a sub-hourly basis to detect from yearly to daily trends.
Therefore, a preliminary step concerned the identification of a provider capable of delivering adequate mobile phone data for different Italian contexts characterized by specific conditions of territorial fragility. The issue required engaging with private data owners among Italian telecommunication companies to select the most suitable provider according to the mentioned criteria. This first phase ended with the selection of the TIM company[3].
The negotiation process between the DAStU research team and TIM had two major challenges. Firstly, the definition of suitable research questions according to the availability and features of the data (XXXX in this special issue). Secondly, the implementation of procedures for managing, cleaning, and tailoring the data for the research teams. This time-consuming process was necessary to uncover the main issues related to the collaboration between academia and a private company characterized by specific economic, technological, and data accessibility constraints. For example, the initial interest of the research teams in analyzing the data even

[2] The Mapping and Urban Data Lab – MAUD is an experimental laboratory that focuses scientific, technical and methodological skills on the analysis, on the mapping and on the visualization for urban and regional studies.

[3] TIM is an Italian telecommunications company. Founded as a mobile telephony company in 1995, since 2015 it has become a brand that provides mobile, fixed telephony, and Internet services. TIM customers in Italy were 30.5 million (September 2021).

at a very high level of spatial detail was redefined during the process due to the available data resolution only at the municipal level for most territorial case studies.

Other technical requirements concerned the possibility of accessing the data through an online service and the opportunity to customize the spatial units of analysis to acquire patterns of mobile phone activity in different spatial contexts. An agreement was made with TIM, which already had a specific program named "City Forecast" available for public administrations: through a web platform, TIM allows visualizing and downloading raw data on human presence and mobility practices (at the municipal or sub-municipal scale, the latter being available also for major cities) at a very high temporal resolution (15 minutes). To have access to this already implemented infrastructure for research purpose, a specific arrangement has been made with TIM for the provision of several datasets accessible through the proprietary web platform named Data Visual Insight (DVI), falling in the following geographical categories:

a) The municipality of Milan, chosen considering the observatory role played by DAStU as a research actor in the geographical area of belonging;
b) Other single Italian municipalities with around 100.000 inhabitants;
c) Multiple contiguous Italian municipalities which aggregate around 100.000 inhabitants.

The selection of the research areas required a phase of internal presentation and discussion inside the Department about the characteristics of mobile phone data available, also to prompt interest about the possibility to experiment with the use of mobile phone data among those who were already researching territorial fragilities. An internal call open to different research groups was launched which led to the selection of several research ideas based on their relevance to the DAStU-TF project, the type of application proposed, and the ability of the groups to conduct research with a significant level of complexity due to the amount of data to be managed and analysed. Eight different research groups participated in the call of interest and proposed a research activity based on the analysis of TIM mobile phone data. Some of the proposals were developed in the framework of the territorial fragility project. Others were directly related to the ongoing research activities of Ph.D. students or research fellows. The variety of proposals made by the groups that participated in the call demonstrates, as described in section 2, how mobile phone data can offer multiple insights for urban and spatial research. Among the proposed topics it is worth mentioning the following research themes that were suggested: community behaviours in the Milan city parks before and during the pandemic; mobility in Milan and its relationship with the heat islands affecting the city; human presence and activity participation in marginal territories; seasonality of human presences in Apulian informal coastal settlements; mobility practices in a low-density mountain area in Emilia-Romagna; mobility of younger students around selected high schools within the metropolitan area of Milan; mobility of older people in some selected municipalities in northern Italy regions.

The MAUD Lab managed the call and the dialogue with the research groups to evaluate the feasibility of the proposal concerning the available data, their scale, reliability, and the actual capability of the different groups to carry out data-driven research, which is characterized by the need for strong analytical and methodological skills. At the end of the selection process, in addition to the case study of Milan on which several proposals have converged, two other territorial cases study have been selected, covering different research issues and experimenting with different possibilities offered by the data as will be described in the following paragraph and deeply depicted in the papers of the special issue.

Following this preliminary phase for the selection of a data provider and the territorial contexts of analysis, an uninterrupted dialogue has been opened with TIM to define the requisites of the data needed for the research (time interval, spatial resolution), the testing of the spatial platform and finally the opening of the access to the data itself through the DVI platform.

Date	Activity
September 2018	First contact with TIM
July 2019	TIM Commercial proposal
July 2019	Acceptance of proposal and start of administrative procedures
April 2020	Presentation to DAStU of the data available and of the DVI platform
June 2020	DAStU call for project proposals
July 2020	Opening of the DVI platform and data access
September 2020	DAStU research teams constitution and starting of the research activities
March 2021	Seminar at DAStU on research progress
October 2021	Closing of DVI platform
October 2022	Tema Journal Special Issue

Tab.1 Timeline of the project

4. Research questions and their applications to three specific Italian contexts

The data acquisition process lasted over two years when the world faced the first phase of the Covid-19 emergency, a condition that was not foreseeable when the decision was made to acquire these data, but it turned out to be an opportunity to compare urban phenomena occurring in the absence of restrictions with other months in which a series of measures have severely limited the mobility of people for work, study or leisure (lockdown, closure of schools, massive use of remote working to cite some). The analysis and comparison of people's behaviors and their relationship with land use make it possible to determine the response of territories to the pandemic concerning daily, weekly, or seasonal mobility practices.

The works of research presented in the following chapters are aimed to test whether and to what extent the mobile phone traffic data allow detailed interpretations of complex urban phenomena related to the different dimensions of territorial fragilities otherwise challenging to study with conventional data sources. Among these, we can also mention the spatial effects of the pandemic on urban behaviors influencing changes in the timing of the cities' use, the rhythms of daily commuting, the impact of remote working and learning, and the multi-residentiality practices. The pandemic has therefore reoriented the research proposals, which, however, already intended to evaluate the specificities of the territories concerning a series of relevant urban phenomena. In particular, the possibility to use and process mobile phone data in three selected Italian contexts proposed by DAStU researchers and characterized by different socio-territorial conditions, settlement density, and mobility practices (Milan, the Piacenza Apennines, Lecce and its coast) allowed us to test their potentialities as well their limitations, investigating the following issues:

- The changes in the attractiveness of Milan's neighbourhoods during the Covid-19 pandemic;
- The analysis of remote working and remote learning practices on sparsely populated, marginal, and low-connected territories (Piacenza Apennines) and near-home tourism before and during the pandemic;
- The seasonality of use in the coastal areas in the municipality of the city of Lecce, characterized by the presence of second homes, mainly unauthorized.

Therefore, the three research works seek to answer complex questions for which no conventional data exists, being them scarcely updated or unavailable. Thus, mobile phone data have been tested to evaluate their potential in covering emergent issues in urban studies related to the time variation patterns of presence during the pandemic in a major Italian city (Milan), the variability in the use of coastal areas during summer months, and the mobility practices in low-density marginal mountain areas. These three study cases cover situations that represent territorial trends occurring in Italy, both in cities and in "inner" peripheral contexts. At the same

time, their relevance is expressed by the possibility of extending the methodology of analysis and the main outcomes to other contexts.
Mobile phone data were then specifically exploited to highlight their potential for urban studies and to contribute to a discussion on the value of a data-driven approach for a new research agenda while dealing with significant challenges related to the role of big data in urban research and their integration with conventional data, the ability of these data to bring out temporal and spatial behaviours difficult to intercept through conventional data, the relevance of these data for urban and mobility policies even in fragile territories. Within this general framework, the three research works that are deepened in the papers composing this special issue are relevant in that they attempt to answer these challenges.

4.1 Human presence and mobility patterns in urban contexts

In highly urbanized contexts, mobile phone data have been widely used to analyze and map large events, highlighting the overall attractivity of cities for visitors and tourists. In the current research, the focus was on exploring the potential of these data in describing human mobility patterns and evaluating the different temporal behaviors connected to the presence of urban populations in Milan.
These data also make it possible to characterize the amount of presence in space and in time based on specific categories of TIM users (gender, class age, type of contract) and based on their personal behaviors (commuters, inhabitants, visitors, and tourists) as will be explained in the next paper.
The idea was to use these data for the analysis of the variation of human presences within the different neighborhoods of Milan during a long period (16 months), including four months in 2019, the total lockdown period during the first phase of Covid -19 pandemic and two more months of partial activity reopening in 2020. The availability of data covering the whole lockdown period guaranteed the possibility of building general figures about the overall number of displacements and human presence per hour at the city level and in the different neighborhoods, both in a period where most of the activities were closed and in the pre-lockdown period when Milan's attractiveness was at its best. The spatial and temporal differences in mobile phone activity and, therefore, human presences highlighted specific behaviors in the neighborhoods and their responses to the lockdown measures that differently impacted the areas with a high concentration of activities such as service companies, universities, and shops compared to most residential areas.
Within this general context, the change in the city users' presence in the Milan neighborhoods in 2019-2020 is analyzed using TIM mobile phone data. This analysis allows investigating which neighborhoods lost city users during the day, and which have gained them, thus providing an overview of the social and spatial impacts of Covid-19 lockdown pandemic in Milan that put in discussion the competitivity of the city (Deponte et al., 2020) and, as a reaction, pushed the local administration to propose ambitious strategies to reorient mobility patterns and reconsider the role and qualities of public spaces with a longer term perspective extended beyond the pandemic emergency (Pucci et al., 2021; Ravagnan et al., 2022).
A specific paper in this issue (Mariotti et al., 2022) investigates the change in the attractiveness of the Milan neighborhoods during the Covid-19 pandemic (2020) compared to the year before it (2019) with a specific focus on the issue of remote working and near working. The paper has twofold aim: (i) measure the presence of remote workers at the neighborhood level, and (ii) explore which neighborhoods meet the requirements of the "15 minutes city" paradigm, with specific attention to near working.

4.2 New home/work and tourism-related mobility practices in low-density mountain areas during the Covid-19 pandemic

If Mobile phone data represent a promising resource for the analysis of mobility and presence that has been extensively experimented in densely urbanized areas, the contribution they can offer in low-density, rural, and mountain territories is less explored. As introduced in section 2, in these geographical contexts digital data

could reveal dynamics and rhythms that cannot always be deduced from the analysis of traditional sources of information. Moreover, the information inferable from sensor-generated data concerns not only the registered residents of a specific geographical context of study but also other types of territory-users who, for various reasons, frequent it, use its services, and contribute to increasing its liveliness and well-being.

In this perspective, mobile phone data have been analyzed in a paper proposed in this issue (Lanza et al., 2022) to deepen the knowledge of the living rhythms of a low-density mountain area between Piacenza and Parma provinces. This territorial context is characterized by some conditions typically associated with forms of marginality and territorial fragility found in the Italian Apennines and alpine regions, such as progressive depopulation, aging, and poor availability and accessibility to essential services and networks. However, at the same time, it represents a context of environmental and landscape value strategically located between the metropolitan area of Milan and the axis of the Via Emilia. Because of its geographical position and intrinsic qualities, this territory can potentially attract near-home tourist flows and be a place to experiment with new forms of remote living and working, made increasingly flexible and possible by the development of information and communication technologies. This theme has become particularly relevant and discussed, in the field of urban planning, following the outbreak of the Pandemic Covid-19, an event that has prompted questions about the role and livability of large urban centers considering the restrictions and the need for social distancing and has simultaneously shift the attention to smaller settlements and the possibilities of re-inhabiting them as quality places (Cotella & Vitale Brovarone, 2019). Provided that specific assets and infrastructure are available (i.e., high-speed internet connection), a similar perception can generate significant opportunities to make inner areas attractive and generate new forms of economic development and repopulation (De Luca et al., 2020). The availability of mobile phone data recorded between July 2019 and September 2020 made it possible to observe the presence variations before the pandemic outbreak and during the different phases of the total lockdown and explore if and how these changes could be explained according to the spatial and functional peculiarities of the different parts of the territory. Thanks to an analytical approach that exploits the updated and temporally exhaustive information inferable from the analysis of mobile phone data and the evaluation of the results obtained, the research questions the extent of the repopulation processes induced by the Covid-19 pandemic and how the presence of new territory users can create unprecedented development opportunities, enrich the territory, and contribute to reversing the dynamics of abandonment and fragility.

4.3 Multiresidentiality in coastal areas marked by second homes and unauthorized construction

Mobile phone traffic data allows for the integration of official statistics and registry data, especially in those contexts which by their nature escape systematic analyses on an administrative and census basis. In this sense, second homes settlements and informally urbanized coasts represent fields of particular interest for mobile phone data utilization: they provide spatially and temporally detailed information on residential and recreational mobility (inter-weekly and inter-seasonal comparisons, between high and low bathing season, between weekdays and holidays); their spatial detail, free from administrative constraints and limits, enables the analysis of the effective use of the coastal space in all its components: beaches, backdunal spaces, wetlands, coastal roads, protected areas, state-owned soils. A more specific aspect is related to the phenomenon of unauthorized construction since mobile phone data can help establish orders of priority in demolishing non-condonable illegal buildings. Accordingly, analysis based on mobile phone data can offer helpful information for the public administrations in preparing urban plans and the programming and maintenance of public facilities.

In a paper proposed in this issue (Curci et al., 2022), the first results of an analysis conducted on the coast of the Municipality of Lecce are reported. The dedicated article primarily aims at understanding the relationship between permanent and temporary human presence, questioning: the differences between adjacent coastal

settlements in terms of seasonal/recreational and residential/permanent presences; the effectiveness of the 2011 Census in detecting the resident population; the correlation between the seasonal-recreative vocation of the settlements and the existence of environmental risks.
The analysis confirms substantial seasonality and permanence differences between adjacent and similar coastal settlements. Moreover, it reveals that Census data may be effective in some areas and less effective in others. Concerning the specific geographical context, the elaborated maps show that the area most exposed to environmental risks is also the most seasonal and intermitting.
Regarding the pandemic period, the analysis conducted between September 2019 and September 2020 seems to confirm the impression of wider and more prolonged use of second homes even after the end of the summer with a general increase in the human presence (temporary and permanent).

5. Conclusion

This article serves as an introduction to the entire special issue and has the main objective of discussing the meaning and importance of acquiring and elaborating mobile phone data in the context of the DAStU research project on "territorial fragilities" within a broader discussion on the role of big digital data for urban studies.
In the first two paragraphs, we introduced the topic and examined in depth what are the main characteristics of mobile phone data compared to traditional ones and how they are gaining ground in socio-territorial research. We explained that, however, mobile phone data often need to be associated with other types of data to express their maximum potential, and this represents one of the main methodological challenges. We further explained that this type of data requires a great deal of negotiation with private data providers and owners to acquire high-quality reliable data.
In paragraph 3, we retraced the entire process that led the DAStU to acquire TIM data to use them in different research scopes and on different territories, but with the theme of territorial fragilities as a common denominator.
Finally, in paragraph 4, we went into more detail about the specific research questions that have been built around the three thematic case studies that are dealt with in the other articles composing this special issue. In this way, the article laid the foundation for framing the goals, methodologies and experimental purposes of the works conducted under the DAStU-FT project into the broader data-driven urban research that are presented in this special issue.

References

Alexander, L., Jiang, S., Murga, M., González, M. C. (2015). Origin–destination trips by purpose and time of day inferred from mobile phone data. *Transportation Research Part C: Emerging Technologies*, 58, 240-250. Part C: Emerging Technologies, 58, 240-25.

Ahas, R., Silm, S., Järv, O., Saluveer, E., Tiru, M. (2010a). Using Mobile Positioning Data to Model Locations Meaningful to Users of Mobile Phones*. Journal of Urban Technology*, Vol.17, N. 1, 3-27. http://dx.doi.org/10.1080/10630731003597306

Ahas, R., Aasa, A., Silm, S., Tiru, M. (2010b). Daily rhythms of suburban commuters' movements in the Tallinn metropolitan area: Case study with mobile positioning data. *Transportation Research Part C*, 18, 45-54. https://doi.org/ 10.1016/j.trc.2009.04.011

Bassolas, A., Ramasco, J.J., Herranz, R., Cantù-Ros, O.G. (2019). Mobile phone records to feed activity-based travel demand models: MATSim for studying a cordon toll policy in Barcelona. *Transportation Research Part A*, 121, 56-74. https://doi.org/10.1016/j.tra.2018.12.024

Bibri, S.E. (2018). *Smart sustainable cities of the future: the untapped potential of big data analytics and context-aware computing for advancing sustainability*. Cham: Springer.

Birkin, M. (2019). Spatial data analytics of mobility with consumer data. *Journal of Transport Geography*, 76, 245-253. https://doi.org/10.1016/j.jtrangeo.2018.04.012

Blondel, V.D., Decuyper, A. & Krings, G. (2015). A survey of results on mobile phone datasets analysis. *EPJ Data Science*, 4

Calzada, I. (2018). (smart) citizens from data providers to decision makers? The case study of Barcelona. *Sustainability*, 10, 3252. https://doi.org/10.3390/su10093252

Calabrese, F., Di Lorenzo, G., & Ratti, C. (2010). Human mobility prediction based on individual and collective geographical preferences. IEEE Conference on Intelligent Transportation Systems, Proceedings, ITSC, 312–317. https://doi.org/10.1109/ITSC.2010.5625119

Calabrese, F., Diao, M., Di Lorenzo, G., Ferreira Jr., J., Ratti, C. (2013). Understanding individual mobility patterns from urban sensing data: a mobile phone trace example. *Transportation Research Part C*, 26, 301-313, https://doi.org/10.1016/j.trc.2012.09.009

Caragliu, A., Del Bo, C., Nijkamp, P. (2009). Smart cities in Europe. *Journal of Urban Technology* n.18

Chen, C., Jingtao, M., Susilo, Y, Liu, Y.,Wang, M. (2016). The promises of big data and small data for travel behavior (aka human mobility) analysis. *Transportation Research Part C* 68, pp. 285–299. http://dx.doi.org/10.1016/j.trc.2016.04.005

Chen, C.L.P., Zhang, C-Y (2014). Data-intensive applications, challenges, techniques and technologies: A survey on Big Data. *Information Science*, 275, 314–347. http://dx.doi.org/10.1016/j.ins.2014.01.015

Chiffi, D., & Curci, F. (2019). Fragility: concept and related notions. *TERRITORIO*

Concilio G., Pucci P. (2021). *The Data Shake: An Opportunity for Experiment-Driven Policy Making*. In: Concilio G., Pucci P., Raes L., Mareels G. (eds) The Data Shake. SpringerBriefs in Applied Sciences and Technology. Springer, Cham. https://doi.org/10.1007/978-3-030-63693-7_1

Cotella, G. & Vitale Brovarone, E. (2020). Questioning urbanisation models in the face of Covid-19. *Tema. Journal of Land Use, Mobility and Environment*, 105-118. http://dx.doi.org/10.6092/1970-9870/6869

Curci, F., Kercuku, A., Zanfi, F. & Novak, C. (2022). Permanent and Seasonal Human Presence in the Coastal Settlements of Lecce. An Analysis Using Mobile Phone Tracking Data. *Tema. Journal of Land Use, Mobility and Environment.* http://dx.doi.org/10.6092/1970-9870/8914

Deloitte (2019). Global mobile consumer 2019, Italy. Retrieved from: https://www2.deloitte.com/it/it/pages/technology-media-and-telecommunications/articles/global-mobile-consumer-survey-2019---deloitte-italy---tmt.html

De Luca, C., Tondelli, S., & Åberg, H.E. (2020). The Covid-19 pandemic effects in rural areas. *Tema. Journal of Land Use, Mobility and Environment, Special Issue Covid-19 vs City-20*, 119-132. http://dx.doi.org/10.6092/1970-9870/6844

Deponte, D., Fossa, G. & Gorrini, A. (2020). Shaping space for ever-changing mobility. *Tema. Journal of Land Use, Mobility and Environment*, 133-149. http://dx.doi.org/10.6092/1970-9870/6857

Gadzinski, J. (2018) Perspective of the use of smartphones in travel behavior studies: findings from a literature review and a pilot study. *Transportation Research Part C*, 88, 74-86. https://doi.org/10.1016/j.trc.2018.01.011

García-Albertos, P., Picornell, M., Salas-Olmedo, M.H., Gutiérrez, J. (2019). Exploring the potential of mobile phone records and online route planners for dynamic accessibility analysis. *Transportation Research Part A: Policy and Practice*, vol. 125(C), pages 294-307. https://doi.org/10.1016/j.tra.2018.02.008

Gorrini, A., Messa, F., Ceccarelli, G. & Choubassi, R. (2021). Covid-19 pandemic and activity patterns in Milan. Wi-Fi sensors and location-based data. *Tema. Journal of Land Use, Mobility and Environment, 14*(2), 211-226. http://dx.doi.org/10.6092/1970-9870/7886

Hasan, S., Ukksuri, S.V. (2014). Urban activity pattern classification using topic models from online geo-location data. *Transportation Research Part C*, 44, 363 – 381. http://dx.doi.org/10.1016/j.trc.2014.04.003

Hilbert, M. (2016). Big Data for development: A review of promises and challenges. *Development Policy Review n.34* (1) 135-174

Jarv, O., Ahas, R., Witlox, F. (2014a). Understanding monthly variability in human activity spaces: a twelve-month study using mobile phone call detail records. *Transportation Research Part C* 38, 122-135. http://dx.doi.org/10.1016/j.trc.2013.11.003

Jarv, O., Muurisepp, K., Ahas, R., Derudder, B., Witlox, F. (2014b). Ethnic differences in activity spaces as a characteristics of segregation: a study based on mobile phone usage in Tallinn, Estonia. *Urban Studies*, 1-19. https://doi.org/10.1177/0042098014550459

Jestico, B., Nelson, T., Winters, M. (2016). Mapping ridership using crowdsourced cycling data. *Journal of Transport Geography*, 52, 90-97. http://dx.doi.org/10.1016/j.jtrangeo.2016.03.006

Jiang, S., Ferreira Jr., J., Gonzalez, M.C. (2016). Activity based human mobility patterns inferred from mobile data: a case study of Singapore in: IEEE Transactions on Big Data.

Kazmi, A., Serrano, M., Lenis, A., (2018). Smart governance of heterogeneous internet of things for smart cities. *Twelfth International Conference on Sensing Technology (ICST).*

Kitchin, R. (2014a). The real-time city? Big data and smart urbanism. *GeoJournal* 79, 1-14. https://doi.org/10.1007/s10708-013-9516-8

Kitchin, R. (2014b). *The data revolution,* London: SAGE publications.

Kitchin, R. (2014c). Big Data, new epistemologies and paradigm shifts. *Big Data and Society* 1:1, https://doi.org/10.1177/2053951714528481

Kwan, M-P (2016). Algorithmic Geographies: Big Data, Algorithmic Uncertainty, and the Production of Geographic Knowledge. *Annals of the American Association of Geographers, 106* (2) 2016, 274–282.

Lanza, G., Pucci, P., Vendemmia, B. & Carboni, L. (2022). Impacts of the Covid 19 pandemic in inner areas. Remote work and near-home tourism through mobile phone data in Piacenza Apennine. *Tema. Journal of Land Use, Mobility and Environment.*

La Rocca, R. A. (2014). The Role of Tourism in Planning the Smart City. *Tema. Journal of Land Use, Mobility and Environment, 7* (3), 269-283. http://dx.doi.org/10.6092/1970-9870/2814

Lazer, D., Kennedy, R., King, G., Vespignani, A. (2014). The parable of Google Flu: Traps in big data analysis. *Science*, Vol.343, pp. 1203-1205.

Mariotti, I., Giavarini, V., Rossi, F. & Akhavan, M. (2022). Exploring the "15-Minute City" and near working in Milan using mobile phone data. *Tema. Journal of Land Use, Mobility and Environment.* http://10.6092/1970-9870/9309

McNeely, C.L., Hahm, J-o, (2014). The Big (data) Bang: Policy, prospects, and challenges. *Review of Policy Research*, vol.31, n.4. https://doi.org/10.1111/ropr.12082

Ni, L., Wang, X. (Cara), & Chen, X. (Michael). (2018). A spatial econometric model for travel flow analysis and real-world applications with massive mobile phone data. *Transportation Research Part C: Emerging Technologies, 86* (April 2017), 510–526. https://doi.org/10.1016/j.trc.2017.12.002

Paffumi, E., De Gennaro, M., Martini, G. (2018). European-wide study on big data for supporting road transport policy. *Case studies on Transport Policy* 6, 785-802, https://doi.org/10.1016/j.cstp.2018.10.001

Papa, R., Gargiulo, C., Battarra, R. (Eds), 2016, Città Metropolitane e Smart Governance: Iniziative di successo e nodi critici verso la Smart City, *FedOA Press* (Federico II Open Access University Press): Napoli, https://doi.org/10.6093/978-88-6887-005-8

Papa R., Gargiulo C., Galderisi A. (2013) Towards an urban planner's perspective on smart city. *Tema. Journal of Land Use, Mobility and Environment*, 5-17. https://doi.org/10.6092/1970-9870/1536

Picornell, M., Ruiz, T., Lenormand, M., Ramasco, J. J., Dubernet, T., & Frías-Martínez, E. (2015). Exploring the potential of phone call data to characterize the relationship between social network and travel behavior. *Transportation, 42* (4), 647–668. https://doi.org/10.1007/s11116-015-9594-1

Pucci P., Lanza G., Vendemmia B. (2021). Distributing, De synchronizing, Digititalizing. Dealing with transport inequalities in Milan in post- coronavirus society in B.Doucet, R. van Melik, P. Filion (eds.) *Global Reflections on COVID-19 and Cities: Urban inequalities and the pandemic*, Bristol University Press.

Rabari, C., Storper, M. (2015). The digital skin of cities: urban theory and research in the age of the sensored and metered city, ubiquitous computing and big data. *Cambridge Journal of Regions, Economy and Society*, 8, 27-42, https://doi.org/10.1093/cjres/rsu021

Ravagnan, C., Cerasoli, M., & Amato, C. (2022). Post-Covid cities and mobility. *Tema. Journal of Land Use, Mobility and Environment,* 87-100. http://dx.doi.org/10.6092/1970-9870/8652

Semanjski, I., Gautama, S., (2016). Sensing Human activity for smart cities mobility management. *Smart City Technology*, IntechOpen. https://doi.org/10.5772/65252

Thakuriah, P., Tilahun, N.Y., Zellner, M. (2017). *Big Data and Urban Informatics: Innovations and Challenges to Urban Planning and Knowledge Discovery* in P. Thakuriah et al. (Eds.) Seeing Cities Through Big Data, Springer Geography.

Tu, W., Cao, J., Yue, Y., Shaw, S-H., Zhou, M., Wang, Z., Chang, X., Xu, Y., Li, Q. (2017) Coupling mobile phone and social media data: a new approach to understanding urban functions and diurnal patterns. *International Journal of Geographical Information Science.* https://doi.org/10.1080/13658816.2017.1356464

Urbanek, A. (2019). Data-Driven Transport Policy in Cities: A Literature Review and Implications for Future Developments in Integration as Solution for Advanced Smart Urban Transport Systems. TSTP 2018. Advances in Intelligent Systems and Computing, Publisher: Springer, 61-74.

Williams N.E., Thomas T.A., Dunbar M., Eagle N., Dobra A. (2015) Measures of Human Mobility Using Mobile Phone Records Enhanced with GIS Data. PLOS ONE 10(7): e0133630. https://doi.org/10.1371/journal.pone.0133630

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

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A glimpse into mobile phone data: characteristics, organization, tools

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Abstract
This paper aims to present the presence and mobility data provided by TIM, highlighting the acquisition methodology, the levels of spatial and temporal disaggregation, as well as the additional information related to age groups, gender, and classification of behaviours, which are directly supplied by TIM. The construction of a baseline based on mobile phone data for the comparison of temporal trends in the presence of people is also discussed.
At the same time, the supporting data obtained from traditional sources or ad hoc surveys will be presented to show how they can facilitate the interpretation of telephone data, its validation, and its use. Finally, a reference on the operational tools used for their processing and visualization will highlight the need to integrate skills, methodologies, and tools for the maximum exploitation of this wealth of information.

Keywords
Mobile phone data; Data manipulation; Presence.

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1. The generation of mobile phone data

In mobile phone research, the data on the users' activity acquired by the telephone network cells are provided as spatial and temporal data on the overall number of people and on their fluxes based on complex methodologies that the telephone operators define to attribute the data to comparable spatial areas.

The understanding of the general principles on the generation of telephone data together with the detailed description of the characteristics of the data is two fundamental conditions to use this data and to determine its potential in the context of urban studies. The intensity of mobile phone activity in a cell (i.e. the area covered around an antenna) is proportional to the presence of mobile phone users (Sevtsuk and Ratti, 2010; Reades et al., 2007; Ratti et al., 2006; Ahas and Mark, 2005). Most of the research in the last decade focused on the Erlang data provided at the time by mobile phone companies. Erlang[1] is the average number of concurrent contacts in a time unit and has been used to describe the correlation between mobile phone data and people's daily activities (Ratti et al., 2006; Sevtsuk and Ratti, 2010). In more recent years, mobile phone companies started to provide data about the overall number of users' presence and mobility. This made it possible to obtain a more directly usable figure as it is expressed as the number of active users instead of Erlang which is a measure not directly attributable to individuals but their activity. Moreover, TIM, like other telephone companies offering data analytics services, has developed a proprietary model for extracting, analysing, and providing data acquired from telephone cells, for small portions of territory such as 250x250 pixels or statistical aggregations such as municipalities or Census Areas (ACE). The model takes into consideration the land cover by assigning the probability of finding a person to the different land covers. According to this model, urban areas will therefore have a major weight than agricultural or forestry areas.

The value of mobile phone data for urban studies is widely recognized since the last decade (Steenbruggen et al., 2015; Blondel et al., 2015; Manfredini et al., 2013) mostly because of their spatial and temporal resolution which can be significantly higher than that of conventional data. In fact, while mobile phone data are available at a very fine temporal scale (hourly or sub hourly), conventional data have considerable limitations with respect to time dimension as they are updated on an annual or multi-year scale. Moreover, in order to intercept urban phenomena related to temporary populations and mobility issues, there is a need to acquire information that goes beyond administrative boundaries usually used in conventional data surveys. Mobile phone data as they are acquired from the activities of individual users, can be aggregated at different spatial scales (for istance square cells, customized areas, neighbourhoods) and can therefore describe complex urban phenomena very effectively and at the correct geographical scale.

Among the main applications of mobile phone data in urban studies, it is possible to cite:

- mobility behaviors of individuals at a global scale (Gonzalez et al., 2008);
- spatial structure of cities based on average distance between mobile phone users (Louail et al., 2014);
- emergency management (Gething et al., 2011; Dobra et al., 2015);
- mobility practices and travel behaviors (Pucci et al., 2015; Wang et al., 2018);
- land use classification and identification (Soto et al., 2011; Toole et al., 2012);
- temporary uses of urban spaces and tourism analysis (Manfredini et al., 2011; Ahas et al., 2008);
- improving quality of official statistics (Barcaroli et al., 2014; Vanhoof et al., 2018);

This rich but still partial list of mobile phone data applications for urban studies defines a possible urban agenda for improving the knowledge of urban phenomena that are difficult to intercept through conventional

[1] One erlang is the equivalent of one call in a specific channel for 3600 seconds in an hour. there are many ways in which a channel can carry a certain number of erlangs. For example, a traffic density of 3 erlangs can consist of three simultaneous calls, each lasting for an hour or of six calls, each of which are allocated 30 minutes or 180 calls, each of which occupy one minute.

data. The current research experience based on TIM data aims at investigating some emergent urban issues in the broad field of territorial fragilities in three different Italian contexts (Curci et al., 2022).

2. TIM mobile phone data

In recent years, TIM has developed a platform called DVI (Data Visual Insight), which makes it possible to view and download mobile phone data in text format (CSV) with a very high temporal resolution (available every 15 minutes for a while no longer than 2 years before the current date) on a spatial resolution of the ACE (Census Area).

Census Areas (ACE) are provided by ISTAT (National Statistics Italian Institution) and correspond to an aggregation of contiguous census tracts, the smallest Italian statistical unit consistent to the building block in urban areas. Census areas have been defined only for the Italian cities with an overall population of around 100.000 inhabitants. Every ACE has many inhabitants between 13,000 and 18,000, with some exceptions.

This data is collected through the network from the mobile phone activity of standard Sim cards[2] by TIM customers representing a market share of about 26% on a national basis (AGCOM, 2022[3]) at different levels of aggregation: Regions, Provinces, Municipalities, and ACEs.

Through the DVI platform, it is possible to access two different data categories at the ACE level: Presences and Mobility for the three active study areas selected, named by TIM "Scenario".

Case study	Spatial data available	Research topic
Milano	85 ACE	Near working during the pandemic in the Milano districts[4]
Piacenza	33 municipalities with the distinction of the main urban settlements	New home/work and tourism-related mobility practices in low-density mountain area during the Covid-19 pandemic[5]
Lecce	1 municipality with 9 coastal areas	Multiresidentiality in coastal areas marked by second homes and unauthorised construction[6]

Tab.1 Active TIM scenario available in the DVI platform

In two case study (Milano and Piacenza), new disaggregated areas have been selected to obtain data on the human presence for the analysis of specific urban phenomena. In particular, for the Piacenza case study, the main urban settlements of the area have been acquired in order to produce a detailed figure of the principal mobility patterns. For Lecce, some coastal areas have been isolated in order to analyse the seasonal patterns of presences in contexts characterized by a huge amount of second homes and unauthorised constructions.

2 Standard SIM cards are mainly used in consumer devices for human communication (voice, text or data).

3 AGCOM is the national Authority for Communications Guarantees and is the regulator and competition authority for the communication industries in Italy. AGCOM publishes quarterly the Communication Markets Monitoring System which provides, among other information, national data on mobile subscribers and mobile market shares

4 Mariotti, I., Giavarini, V., Rossi, F. & Akhavan, M. (2022). Exploring the "15-Minute City" and near working in Milan using mobile phone data. Tema. Journal of Land Use, Mobility and Environment

5 Curci, F., Kercuku, A., Zanfi, F. & Novak, C. (2022). Permanent and Seasonal Human Presence in the Coastal Settlements of Lecce. An Analysis Using Mobile Phone Tracking Data. Tema. Journal of Land Use, Mobility and Environment

6 Lanza, G., Pucci, P., Vendemmia, B. & Carboni, L. (2022). Impacts of the Covid 19 outbreak on two Apennine valleys. Remote-working and near-home tourism through mobile phone data. Tema. Journal of Land Use, Mobility and Environment

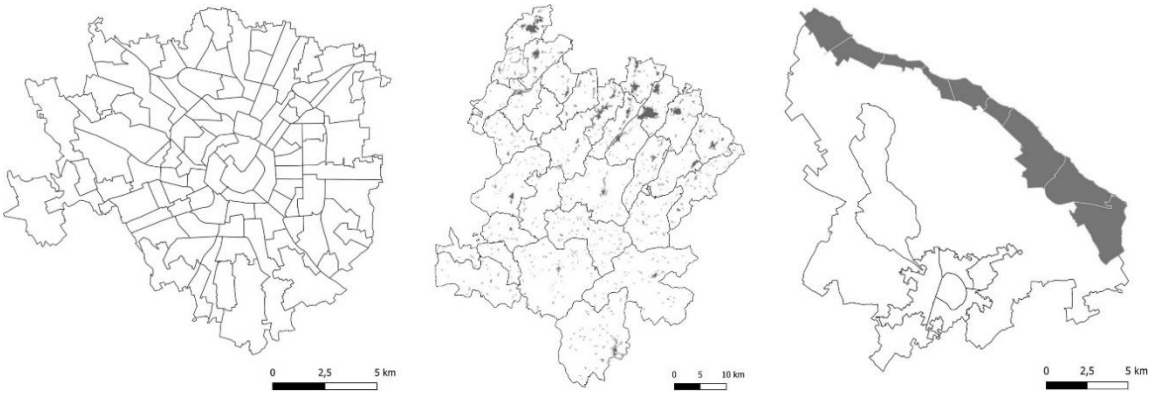

Fig.1 Maps of the three active scenarios (Milano - left, Piacenza - centre, Lecce - right). In grey colour are depicted the custom areas (urban settlements in Piacenza and coastal areas in Lecce)

2.1 Human Presence

The service provides presence data as an estimation of the number of people detected in the geographical area of interest (ACE basis), with socio-demographic details (gender, type of contract, age classes, nationality of the users, clusters category).

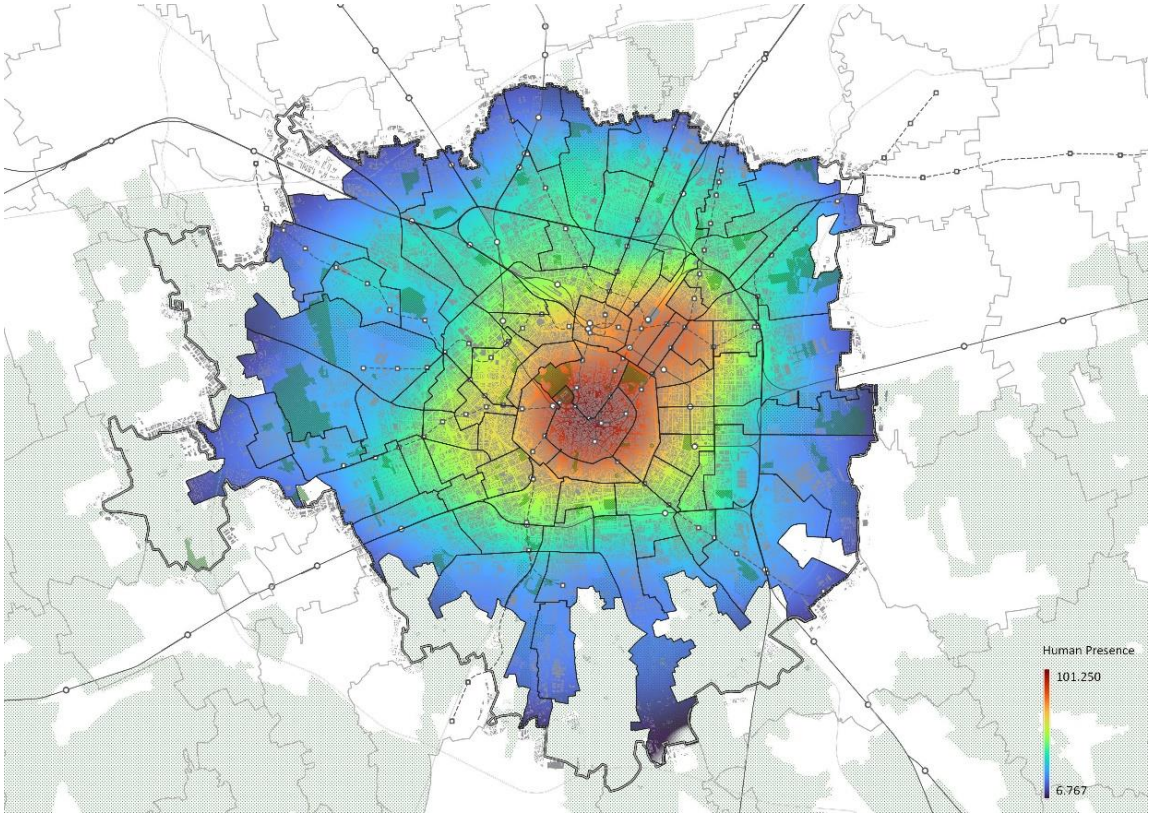

Fig.2 Presence map of Milan (date/time) available from DVI Insight

Fig.2 for example depicts the average number of overall human presence within a typical working day in April 2019 in Milano. The map shows through a heat map representation the amount of population calculated according to TIM market share, in every Census Area It is possible to observe the Milano districts which attract more population (the city centre, the area near the Milano Central station but also some suburban neighbourhoods in the south western side of the city where the overall number of presence is very high.

The type of contract can be business or customer and reflects the use of a mobile phone for personal or for business activity, according to the mobile plan subscriptions. Typically, a business contract is subscripted by companies for their employees who use corporate phones for job purposes.

The class ages (< 18 years old, 18-30 years old, 31-40 years old, 41-50 years old, 51-60 years old, and over 60 years old) together with the other variables, are directly extracted from the registry of TIM clients. The data for the youngest class is certainly underestimated compared to the real phenomenon because parents are used to purchasing a sim card and giving it to their children. Obviously, in these cases, the demographic data provides information on the owner of the sim and not on who is using it at that moment. For the other age groups, this issue is very small if not non-existent.

Field name	Field description
id	Unique ID counter
cluster	Description of TIM data
data_da	Beginning date and hour of the interval for which the data is provided
data_a	Ending date and hour of the interval for which the data is provided
numero_presenze	The number of people counted
layer_id	Spatial data code (Region + Province + Municipality + ACE)
layer_nome	Spatial data code
dettaglio(secondi)	Time interval (second)

Tab.1 Record layout for the human presences dataset

To define the presence data clusters category, it is necessary to define 2 types of TIM user ACE: Living ACE and Working ACE.

The Living ACE is derived from a set of events made by the user in the last 30 working days (Monday, Tuesday, Wednesday, and Thursday from 00:00 to 06:00 and from 22:00 to 24:00; Friday from 00:00 to 06:00). The 'residence' cell is calculated from the events during these periods. The idea beyond this Living ACE definition is that the residence is the ACE where a user spent most of the time in the last 30 days during the night.

The working ACE is derived from a set of events carried out by the user during the last 30 working days from 9:00 to 12:00 and from 14:00 to 18:00. The 'work' cell is calculated from the events during these periods. The idea beyond this ACE Work definition is that the work area is the ACE where a user spent most of the time in the last 30 days during the classical working hours.

These two definitions are directly provided by TIM and can lead to some misunderstandings concerning some categories of users who have different behaviours in terms of working hours or mobility practices.

Given the above definitions, it is possible to define the classes of travellers as follows:

- residents: counting of the Italian users of the TIM network, for each pixel of the map, who are (at the time selected in the timeline) in their ACE of residence;
- commuters: counting of the Italian users of TIM network, for each pixel of the map, who are (at the time selected in a timeline) in their ACE of work;
- intra-regional visitors: counting of the Italian users of TIM network, for each pixel of the map, who are (at the time selected in a timeline) outside their ACE of work or residence but in the region of residence;
- extra-regional visitors: counting of the Italian users of TIM network, for each pixel of the map, who are (at the time selected in a timeline) outside their ACE of work or residence and the region of residence;
- foreign visitors: counting of users with a foreign SIM card detected on the TIM network.

This classification can be used for the identification of particular patterns of the different categories of users related to the time variability of the presence in the different hours of the day for job, study, or leisure reasons, days of the week, and season for holidays and festivities.

For foreigners, the Presence dataset provides information on the number of users with a foreign SIM connected to the TIM network disaggregated by single nationality. This information therefore probably covers mostly tourists or temporary visitors and not immigrants living in Italy who have a TIM sim.

In research based on the use of mobile phone data, is worth noting that the technological constraints associated with how data is acquired and delivered are significant and greatly determine the development of the research itself.

This highlights a new role for researchers who must define research questions and methodologies that are strongly conditioned by the characteristics of the data source.

For all the three case studies, the human Presence dataset was available.

Fields	Categories
Gender	Male, Female
Type of contract	Business, Consumer
Class age	< 18 years, 18-30 years, 31-40 years, 41-50 years, 51-60 years, > 60 years
Traveller class	Intra-regional traveller, Extra-regional traveller, Residents, Commuters, Foreign visitors
Nationality	Italians, Foreigners (according to SIM)

Tab.2 Filters available in the human presences Scenarios

2.2 Mobility

The DVI platform also provides mobility data defined as the estimate of trips in the area of interest on an ACE basis, with details of where people come from or where they go.

The destination data is the analysis of movements from the territory of interest on an ACE basis. Displacement is considered to be detected when two consecutive events occur in the same cell.

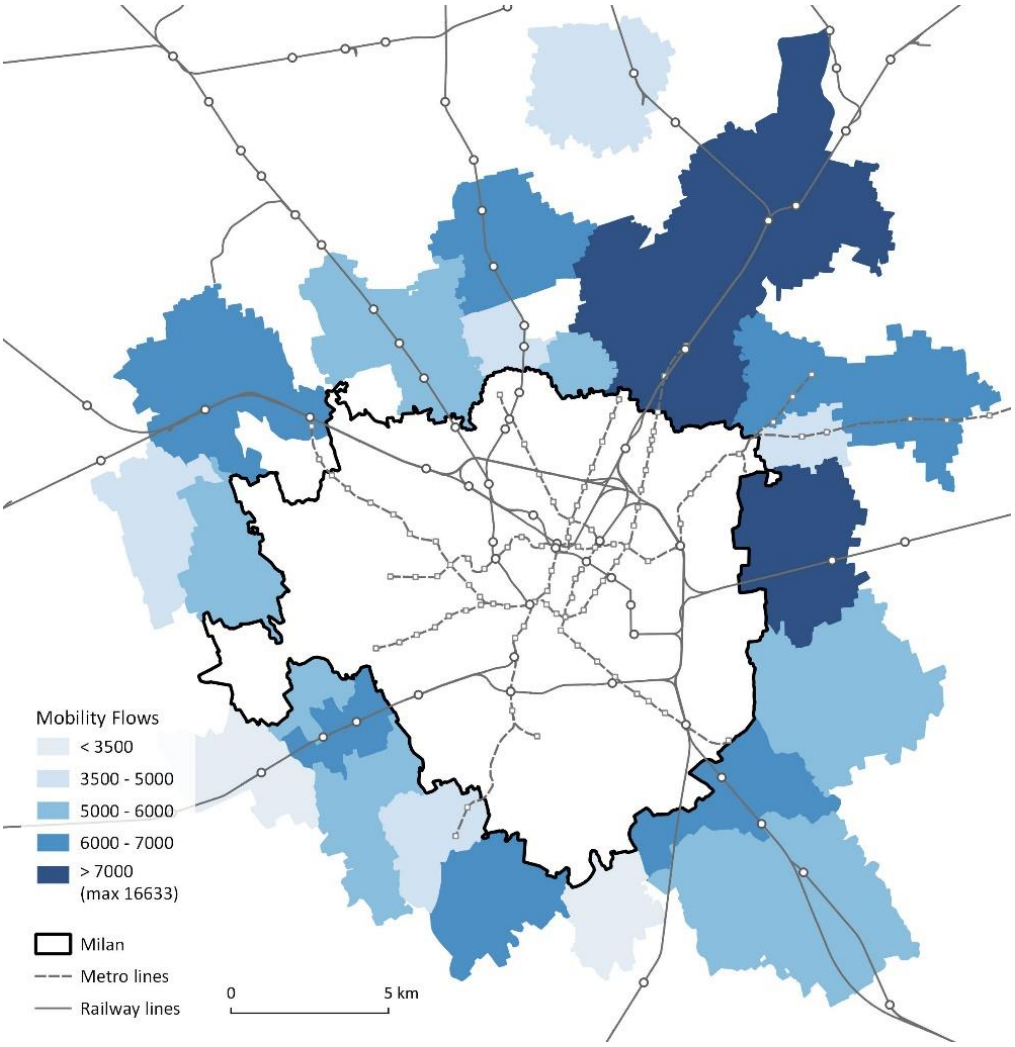

Fig.3 Mobility flow to Milano (3/4/2019)

In Fig.3 for example the overall amount of movement between some municipalities around Milano and the main city in a specific working day in April 2019 (3/4/2019) is depicted showing the mobility relationships at the metropolitan scale as detected from mobile phone data.
The origin data is the analysis of movements toward the territory of interest on an ACE basis, where the area of origin is based on the location of the users in the previous night. Provenances are a subset of Presences.
The tracking of mobile phone users' movements within the network is made possible by the passive location platform (PLS) that allows the estimation of the users' geographical position within an area whenever there is an interaction with the network. PLS keeps only the last available position and the instant when the update occurred.
The interactions with the network that are used by PLS define an event and can be:

- phone power on/off;
- return to coverage;
- call initiation (made and received);
- SMS (sent or received);
- location Update (periodic and non-periodic update app).

Mobility data is commonly represented by Origin-Destination data which is the most widely used tool to analyze and map mobility demand.
An Origin-Destination matrix represents the movements that affect the study area in a given period, subdivided by the zone of origin and destination. For each time interval, the trips between each pair of zones are available.
The data on the movements of individual users are processed during the day of analysis and are therefore aggregated and provided in an anonymous form the following day.
The positions of the users are associated with the zones and, for each user, a movement is derived from the Origin Zone (which contains the cell used by the user in the time interval in which the origin is calculated) to the Destination Zone (which contains the cell used by the user in the time interval in which the destination is calculated).
Long-range movement is defined as a movement from location L1 to location L3 via Ln. In case the SIM does not generate events in the Ln location, only the movement from L1 to L3 will be recorded.
Further consideration of mobility data provided by TIM concerns the degree of complexity of the phenomena that can be detected.
If we take into account that mobility data is available at the ACE spatial aggregation both for Origin and Destination, we can easily conclude that the level of detail of the information is very high since it permits the detection of hourly Origin-Destination matrices at the ACE scale. This allows to analyse and map spatial relationships between a relatively small portion of territory with a temporal detail that cannot be achieved with other sources. It is possible to analyse mobility practices at night, at weekends, or at different times of the year. Mobility data is available only for the Milan scenario.

3. Elaboration of TIM data: from raw to usable data

The DVI Insight platform is useful for visualizing data but has proved to be ineffective for data extraction and elaboration. For this reason, we have obtained the raw data, which allows greater flexibility of use and ensures greater integration with the spatial analysis tools at our disposal. The complexity and the amount of raw data made it necessary to develop some preliminary elaborations to transform, clean, and finally, use the human Presences data. The following considerations and methodologies refer specifically to Milano which is the most complex and articulated case but can also be applied in general to other scenarios as they refer to the same types of data.

3.1 Pre-processing and preliminary elaborations

For the processing described below, in particular the preliminary cleaning and rearranging, given the amount of data, its organization, and type, Python programming language is used, and in particular the Pandas libraries (version 1.3.2) for the data frame management. Pandas is an open-source library providing high-performance, easy-to-use data structures and data analysis tools for the Python programming language.

Python is one of the most widely used languages for Data Analysis and Data Science.

The TIM data on human Presences in the municipality of Milan are also provided in CSV format, each file containing data for an entire week. Each file contains the following fields: cluster; date_from; date_to; attendance_number; layer_id; layer_name; detail (seconds).

The first operation performed by a script developed specifically for the project is to open the compressed CSV files and merge them into a single data frame containing all the human Presences data. In this way, the data for the entire period can be analyzed together:

- the year 2019: March, April, May | September, October, November;
- the year 2020: March, April, May, June, July, August, September, October, November, December.

The fields are also reorganized, keeping only those that are essential for further analysis and the result is as follows:

For the available period, the TIM data of Milan Presences consists of 18,971,793 records. The "cluster" field contains all TIM categories (Presences, Males, Females, Business, Consumer, Italians, Foreigners, <18 years, 18-30 years, 31-40 years, 41-50 years, 51-60 years, >60 years, Intra-regional Visitors, Extraregional Visitors, Commuters, Residents, Foreign Visitors) - (Total Attendances, Gender, Age Classes, Traveller Classes). If we consider only total human Presences, the number of records is reduced to 1,077,412. This number refers to the ACE of Milan with an hourly time interval between records. The available hours are 11,711 (almost 490 days analyzed).

Another preliminary operation to be performed is the conversion of the date-time format that TIM provides in UTC, into the local date and time format of Milan (Europe/Rome). The UTC format, which corresponds to Greenwich, differs by one or two hours from Milan (summertime and solar time) depending on the period of the year selected. To analyze presences with a time interval, it is therefore essential to convert the UTC format to the correct timezone (UTC+1). Another Pandas Python script has been used to perform this complex operation.

Once the correct time for Milan has been obtained, other information regarding the time range is added, which will be useful in the following steps of the analysis and which will facilitate further extractions and elaboration:

- day_name: Name of the day of the week;
- day_num: Number of the day of the week (Monday=0; Tuesday =1; Wednesday=2; Thursday=3; Friday=4; Saturday=5; Sunday=6);
- hour: Time of the day;
- date: Date without time reference in format yy:mm:hh;
- n_day: Progressive number identifying in ascending order the day within the period (first day = 0; second = 1; third = 2; etc);
- week: Number of the week within the year;
- n_week: Progressive number identifying in ascending order the week within the period.

This reorganization of the temporal aspect of the data greatly increases the amount of elaboration and complexity that can be carried out. For example, it is possible to compare the behaviours of the same day during the whole period or to calculate the average number of people per day or compare different weeks between them.

Finally, the presence of TIM users is recalibrated to obtain a reliable projection of the total presence of people (real number) according to the Tim market share in the municipality of Milan.
The final Milan database contains the estimated overall number of people on an hourly basis for the ACE for the whole period.

3.2 Baseline calculation

To facilitate the comparison between different periods we decided to build a reference trend for the presences in Milan, named baseline.
By baseline we mean the value we expect to find in a certain area, day, and time, in a 'standard' week, i.e. a week without any significant events that can be used to highlight specific behaviours or out-of-average trends during other periods. For the calculation of the baseline, we have used a methodology developed by Maas et colleagues for the calculation of presence data in Facebook 'disaster maps' (Maas et al., 2019).
The big difference is that Facebook calculates the baseline in the period before a critical event (for example a flooding event or an earthquake or the starting period of the pandemic). In our case, since we have data for the whole year, the baseline was calculated by selecting "standard" weeks, those with normal values (no major events, holidays, working week, open schools).
It is necessary to select the weeks that have the chosen characteristics for the baseline calculation.
By selecting standard weeks, it is possible to compare the attendance of any other period of the year against the baseline, at events, holidays, holiday periods, or periods where covid 19 measures were active to detect spatial and temporal patterns that diverge from the mean.
The values of the standard week (baseline) are calculated for each geographical area (ACE), for each time interval (hour) of each day of the week, and possibly for each TIM category.
Therefore, for a given location and time interval, the baseline dataset is composed of a set of counts from the same location over the same time interval on the same day of the week for multiple weeks preceding the crisis.
Once the period is selected, a dataset that contains only the data of the selected period is extracted. In our case, 6 weeks of 2019 are considered: the first three weeks of March, the second week of May, and the third and fourth weeks of October. i.e. working weeks with no major holidays, schools open.
The procedure for the construction of the baseline is the following:

- extraction of the baseline Dataset for each ACE, for each time interval, and possibly TIM category;
- calculation of the mean and the standard deviation for each Dataset;
- Winsorisation procedure by excluding extreme values beyond the determined thresholds: 'lower bound' and 'upper bound' (2.5 and 97.5 percentile) using a normal distribution (+ and - 2std from the mean = 95% values).

The winsorization is a process through which it is possible to eliminate extreme values by computing the mean and standard deviation of the pre-winsorization distribution, identifying the 2.5th and 97.5th percentiles of a Gaussian with that mean and standard deviation, and setting values outside those bounds to the lower and upper bound values if they are anomalously low or high, respectively.
The final baseline acts as a reference for the further analysis carried out to the Milano case as will be shown in the following paper.

4. Integration with conventional data

One of the findings of previous research based on the analysis of telephone traffic data is that integration with conventional data is needed to enhance both the capacity to interpret phenomena emerging from user-generated data and to build a better understanding of urban usages, in time and spaces (Pucci et al., 2015).

There is an ongoing debate over the potential of mobile phone data for official statistics (Daas et al., 2015; Struijs et al., 2014; Barcaroli et al. 2014). Some general issues are related to the nature of the data itself or the differences in terms of the dimension of the samples because conventional data refer to the universe of the population while mobile phone data refer to a subsample of the overall mobile phone subscriptions (i.e. active users). Mobile phone data are provided by private companies and in general, there are no common definitions about the format and the methodology used for data collection and there is no clarity on their costs. Moreover, some privacy issues must be taken into consideration according to national laws (De Montjoye et al., 2019).

For all these reasons we decided to integrate our mobile phone dataset with some other ancillary data acquired from conventional data sources and to provide researchers with some additional information useful for improving the interpretation of mobile phone data patterns both in the spatial and in the temporal dimension. Concerning the spatial dimension, we organized a database of variables and indicators on socio-demographic issues at the ACE level based on conventional or spatial data sources that can be easily integrated with mobile phone data. In particular, we covered the main socio-demographic issues (overall number of inhabitants, foreigners, class ages) from the Milano official registry and the main big attractors available through multiple spatial data sources available aggregated at the ACE level (distribution of schools, economic activities, university buildings, main residential areas, public parks, etc) that can help in determining the causes of variations in the presence of people during the different hours of the day.

Concerning the temporal dimension, we developed a calendar of events for Milano and official regulations about the different restrictions taken during the pandemic for the interpretation of mobile phone trends which are strongly influenced by these external factors. In the calendar is possible to distinguish weekend vs working days, holidays and festivities, big events occurring in the city, lockdown measures.

These indications pertain to institutional, recreational, and socio-cultural activities of particular relevance with differentiations for dates of national interest and those of local level, but also in general related to the calendar with the identification of holidays and weekdays.

In particular, since the period examined partially coincided with the emergence of the pandemic and subsequent containment measures, we identified and took into consideration the different dates when governmental limitations of activities and movements of the population have been active. These phenomena were some of the major factors of change in the use of the city and greatly impacted the behaviours of people in terms of daily, weekly and seasonal mobility.

Date	Activity
1 March 2020	Lockdown starts for some regions
4 March 2020	Schools and universities are closed
10 March 2020	Lockdown starts for Italy
21 March 2020	Prohibition of all travel
10 April 2020	Extension of lockdown until May 3rd
3 May 2020	End of Lockdown
4 May 2020	Reopening of activities
17 May 2020	Transfers between regions are permitted
12 June 2020	Reopening of the event without the public
15 June 2020	Reopening of cinemas and theatres, summer centres
29 July 2020	Extension of state of emergency

Tab.3 Extraction from the calendar of events database

Another information available concerns the school system calendar with the identification of the dates of the beginning and end of the school year and holidays for the various Italian regions. Attention was paid to some

territorial differences, such as local festivities, to be able to monitor and adequately define the presences within the different territories.

Being Milano a large municipality with many events taking place there, it was necessary to make a selection of those with a significant impact in terms of the number of people involved. The dates of the Salone del Mobile fair, the Fashion Weeks, and the main football events at the San Siro stadium have been collected and identified.

All the information has been reported in a spreadsheet that can be easily consulted to provide consistent help for the present and future analyses based on mobile phone data.

The complexity of the telephone data requires the use of supporting information that can be integrated into the research design for an appropriate elaboration and understanding of the dynamics highlighted by it.

5. Tools and competences

Working with mobile phone data means processing a huge amount of data in the form of hundreds of tables with spatial and temporal information. To better exploit the potential of this source new tools are needed for data storage, elaboration, and visualization. In our workflow, we acquired competencies and developed integrated methodological frameworks based on Python scripting, Database Management System, Geographical Information, System, and visualization tools. Due to their complexity, an intersection between different competencies is needed to fully benefit from the opportunities offered by this kind of data. Computation and quantitative analytical skills are therefore required, together with the capacity to read temporal and spatial dynamics deriving from the analysis of big data.

References

AGCOM (2022) Osservatorio sulle comunicazioni n. 4/2021

Ahas, R., Aasa, A., Roose, A., Mark, Ü., & Silm, S. (2008). Evaluating passive mobile positioning data for tourism surveys: An Estonian case study. *Tourism Management*, *29* (3), 469-486. https://doi.org/10.1016/j.tourman.2007.05.014

Barcaroli G, De Francisci S, Scannapieco M, Summa D (2014) Dealing with big data for official statistics: IT issues. *Meeting on the management of statistical information systems*, Dublin, Ireland and Manila, Philippines, 14–16

Blondel, V. D., Decuyper, A., & Krings, G. (2015). A survey of results on mobile phone datasets analysis. *EPJ data science*, *4* (1), 10. https://doi.org/10.1140/epjds/s13688-015-0046-0

Curci, F., Lanza, G. & Manfredini, F. (2022). Mobile phone traffic data for territorial research. Opportunities and challenges for urban sensing and territorial fragilities analysis. *Tema. Journal of Land Use, Mobility and Environment.* http://10.6092/1970-9870/8892

Curci, F., Kercuku, A., Zanfi, F. & Novak, C. (2022). Permanent and Seasonal Human Presence in the Coastal Settlements of Lecce. An Analysis Using Mobile Phone Tracking Data. *Tema. Journal of Land Use, Mobility and Environment.* http://10.6092/1970-9870/8914

Daas, P. J., Puts, M. J., Buelens, B., & van den Hurk, P. A. (2015). Big data as a source for official statistics. *Journal of Official Statistics*, *31* (2), 249. http://dx.doi.org/10.1515/JOS-2015-0016

De Montjoye, Y. A., Gambs, S., Blondel, V., Canright, G., De Cordes, N., Deletaille, S., ... & Bengtsson, L. (2018). On the privacy-conscientious use of mobile phone data. *Scientific data*, *5* (1), 1-6. https://doi.org/10.1038/sdata.2018.286

Dobra, A., Williams, N. E., & Eagle, N. (2015). Spatiotemporal detection of unusual human population behavior using mobile phone data. *PloS one*, *10* (3), e0120449. https://doi.org/10.1371/journal.pone.0120449

Gething, P. W., & Tatem, A. J. (2011). Can mobile phone data improve emergency response to natural disasters?. *PLoS medicine*, *8* (8), e1001085. https://doi.org/10.1371/journal.pmed.1001085

Gonzalez, M. C., Hidalgo, C. A., & Barabasi, A. L. (2008). Understanding individual human mobility patterns. *nature*, *453* (7196), 779-782. https://doi.org/10.1038/nature06958

Lanza, G., Pucci, P., Vendemmia, B. & Carboni, L. (2022). Impacts of the Covid 19 outbreak on two Apennine valleys. Remote-working and near-home tourism through mobile phone data. *Tema. Journal of Land Use, Mobility and Environment.* http://10.6092/1970-9870/8915

Louail, T., Lenormand, M., Cantu Ros, O. G., Picornell, M., Herranz, R., Frias-Martinez, E., ... & Barthelemy, M. (2014). From mobile phone data to the spatial structure of cities. *Scientific reports*, *4* (1), 1-12. https://doi.org/10.1038/srep05276

Maas, P., Iyer, S., Gros, A., Park, W., McGorman, L., Nayak, C., & Dow, P. A. (2019, May). Facebook Disaster Maps: Aggregate Insights for Crisis Response & Recovery. In KDD (Vol. 19, p. 3173). Shmelev, S.E. (2019). *Sustainable cities reimagined: multidimensional assessment and smart solutions*. New York: Routledge.

Manfredini, F., Pucci, P., & Tagliolato, P. (2013). Mobile phone network data: new sources for urban studies?. In *Geographic information analysis for sustainable development and economic planning: New technologies*, 115-128. IGI Global. https://doi.org/10.4018/978-1-4666-1924-1.ch008

Manfredini, F., Tagliolato, P., & Rosa, C. D. (2011, June). Monitoring temporary populations through cellular core network data. In *International Conference on Computational Science and Its Applications*, 151-161. Springer, Berlin, Heidelberg. https://doi.org/10.1007/978-3-642-21887-3_12

Mariotti, I., Giavarini, V., Rossi, F. & Akhavan, M. (2022). Exploring the "15-Minute City" and near working in Milan using mobile phone data. *Tema. Journal of Land Use, Mobility and Environment.* http://10.6092/1970-9870/9309

Pucci, P., Manfredini, F., & Tagliolato, P. (2015). *Mapping urban practices through mobile phone data, 3* (4). Heidelberg, New York, Dordrecht, London: Springer. https://doi.org/10.1007/978-3-319-14833-5

Soto, V., & Frías-Martínez, E. (2011, June). Automated land use identification using cell-phone records. In *Proceedings of the 3rd ACM international workshop on MobiArch*, 17-22. https://doi.org/10.1145/2000172.2000179

Steenbruggen, J., Tranos, E., & Nijkamp, P. (2015). Data from mobile phone operators: A tool for smarter cities?. *Telecommunications Policy*, *39* (3-4), 335-346. https://doi.org/10.1016/j.telpol.2014.04.001

Struijs, P., Braaksma, B., & Daas, P. J. (2014). Official statistics and big data. *Big Data & Society*, *1* (1), 2053951714538417. https://doi.org/10.1177/2053951714538417

Toole, J. L., Ulm, M., González, M. C., & Bauer, D. (2012, August). Inferring land use from mobile phone activity. In *Proceedings of the ACM SIGKDD international workshop on urban computing*, 1-8. https://doi.org/10.1145/2346496.2346498

Vanhoof, M., Reis, F., Ploetz, T., & Smoreda, Z. (2018). Assessing the quality of home detection from mobile phone data for official statistics. *arXiv preprint arXiv:1809.07567*. https://doi.org/10.48550/arXiv.1809.07567

Wang, Z., He, S. Y., & Leung, Y. (2018). Applying mobile phone data to travel behaviour research: A literature review. *Travel Behaviour and Society*, *11*, 141-155. https://doi.org/10.1016/j.tbs.2017.02.005

Image Sources

Fig.1: Authors' elaboration;

Fig.2: Authors' elaboration;

Fig.3: Authors' elaboration.

Table Sources

Tab.1: Authors' elaboration;

Tab.2: Authors' elaboration;

Tab.3: Authors' elaboration.

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TeMA Journal of Land Use, Mobility and Environment

Call for papers – Special Issues 2023

BURN OR SINK.
THE PLANNING AND MANAGEMENT OF THE LAND

Throughout the summer of 2022, several alarming episodes related to the growing climate and energy crises have exposed vulnerabilities in the social and economic organization of the territories. While the appropriate regenerative, adaptative, and mitigative actions must be carried out for cities, other approaches should be pursued simultaneously regarding the natural resources present in the territory. In particular, water, food (hence, soil), and energy, which are often exchanged with other territories. Natural resources are one of the bases of the economy of a territory and can come to represent its identity, especially when they can be used to obtain high value-added goods which are recognized outside their place of origin. Furthermore, they represent an indicator of the equilibrium between environment and man in a territory. Natural resources are the focus of global attention, as indicated in the UN Sustainable Development Goals and the environmental action programs of the European Community.
For this reason, natural resources must be protected from climate change and from excessive use that causes destructive and dispersive effects. Furthermore, they must be considered as strategic resources to be fully included in the processes of territorial planning.

This Special Issue wants to deepen the topic through articles that investigate the following points:

- The first is scientific. The research in progress (see, for example, that on ecosystem services, on natural capital and on FEW Nexus) should be further deepened and addressed towards the identification of theoretical principles deepening the relationships between resources and territory, to be developed through models and quantitative or qualitative/quantitative techniques (scenario techniques, and others).
- The second point is related to the research effects. Theoretical results must be the building blocks of real action systems that can enhance the broader planning actions. Deepening case studies is relevant for this second point.
- The third point is social. The papers should explore what changes in individual and collective behaviour are required to steer society towards the greater collective well-being. This point could be investigated using case studies centred on particularly problematic areas, such as, for example, inland areas or urban and metropolitan peripheries. Case studies, in parallel with the regeneration actions, can be the starting point to build new social relationships and behaviours.
- The fourth point concerns the decision-making systems and the evolution of the legislation. The research and applications could significantly contribute to the process of simplifying and updating the legislation, becoming an authoritative source for the new rules regarding the management and sustainable regulation of land use processes.

The Special Issue of TeMA is mainly addressed to urban and planning scholars interested in deepening the topic's evolutionary aspects which the processes of climate change have made necessary. In consideration of the aforementioned points, the call is open to contributions of scholars of other research sectors too, with the objective of cultivating a healthy exchange of knowledge with the urban planning field.
Papers must deepen the analysis of ongoing processes and workable solutions, focusing on the development and utilization of quantitative and/or qualitative techniques and models highlighting the acceleration of the processes occurring in recent decades and building scenarios for the future.

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Exploring the "15-Minute City" and near working in Milan using mobile phone data

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Abstract
This paper investigates the changes in neighbourhood attractiveness during the Covid-19 pandemic (2020) compared to the year before in 2019 in the city of Milan. Central neighbourhoods recorded a drop in users from -63% to -47%, while the peripheral areas showed a relatively steady presence during the day. Indeed, remote working and the fear of public transport led to rethinking commuting and re-value working close to home. Semi-peripheral and peripheral neighbourhoods have gained a renewed role in attracting remote workers, and coworking spaces represent a valuable alternative for those willing to improve work-life balance through near working. Within this context, the paper aims to:(i) measure the presence of remote workers at the neighbourhood level; (ii) explore the accessibility to coworking spaces within 15 minutes of walking and cycling distance; (iii) focus on three peripheral neighbourhoods which show the lowest number of city users loss, do not host CSs, and present different levels of essential services and access to subway stations. The three cases are explored to understand whether they are considered feasible locations for hosting a neighbourhood coworking space. The change of the city users' presence in the Milan neighbourhoods in 2019-2020 is analysed using «TIM Big Data – Data Visual Insight», which includes the presence and mobility of the TIM mobile network's users.

Keywords
Remote working; Covid-19 pandemic; 15-minute city; Coworking spaces; Near working; Milan; TIM mobile phone data.

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1. Introduction

The health emergency caused by the spread of the Covid-19 pandemic transformed the way we live and work. The needs and functions of companies' spaces for commercial or office use were redefined, and the need to guarantee social distancing emptied the offices, forcing the employees to work from home (Florida et al., 2021). It is estimated that this remote working trend will continue after the health emergency, therefore, many companies are redefining their spaces: rather than single offices or individual workstations, open, shared, or hybrid spaces are designed. Besides, companies are opening new offices/hubs in dispersed locations closer to their employees' homes (Mariotti, 2021)[1].

The geography of occupation is expected to change since suburban and peripheral areas will likely become more attractive places to live and work. Commuting to central areas will decrease, and walking and cycling will become predominant for the city's mobility, to help people maintain physical distance (Zecca et a., 2020; Fenu, 2021; Cirianni et al., 2022).

Thus, the suburban areas of cities will gain attractiveness (Mariotti et al., 2022b) and real estate values are expected to rise (Mariotti, 2021). Moreover, as argued by Florida et al. (2021), the pattern of urbanisation is unlikely to be changed. However, the pandemic could lead to significant intra-metropolitan, neighbourhood-level, and daily life changes in cities. Indeed, cities might increasingly become cultural and civic gathering places, rather than shopping destinations or office hubs, with fewer people commuting five days a week at peak hours.

A new demand for coworking spaces (CSs) to host remote workers, and favour near working (Tajani, 2021; Pais et al., 2021), has arisen. By using such spaces, workers can combine their professional and personal needs and reduce commuting trips, which positively impact environmental sustainability in terms of traffic congestion and pollution reduction, and contribute to improve work-life balance (Manzini Ceinar & Mariotti, 2021; Mariotti et al. 2022a). A new demand for "neighbourhood coworking space" (Pais et al., 2021; Mainieri et al., 2021; Mariotti et al., 2021b) offering freelancers, employees, employers, remote workers, etc., the chance to work closer to home, has arisen. The neigbourhood CS represents a proximity based service to inhabitants promoted by the 15-minute city strategy (Moreno et al., 2021), and suggested by the Municipality of Milan with the "Milano Strategia di Adattamento 2020" (Milan 2020 Adaptation strategy) to cope with the Covid-19 restrictions (see also Pinto & Akhavan, 2022).

According to the Eurofound Covid-19 survey (2020), during the pandemic, Italy climbed the European ranking of working from home frequency; indeed, in 2019, only about 8% of employees worked from home, while during the lockdown in 2020, about 40% started working from home (Sostero et al., 2020). However, home-working is not suitable for all occupations. Based on the remote working index of the National Institute for Public Policy Analysis (INAPP; Barbieri et al., 2021), the economic activities characterised by greater ease of working remotely are professional, scientific, and technical activities; finance and insurance; ICT; real estate and public administration.

In Italy, the number of remote workers rose from 570,000 in 2019 to 6.58 million in March 2020 (during the strictest lockdown), decreasing to 5.06 million in September 2020 (Osservatorio Smart Working, 2021). The Osservatorio Smart Working (2021) showed that the home is not always considered the ideal workplace. Indeed, workers complain about technology as not being adequate (29%), having a sense of isolation (29%), difficulty in work-life balance (27%) and feeling of being constantly connected (26%). In this context, the new workplaces (first, coworking spaces -CSs-) represent a valid alternative by offering support services, flexible

[1] This is the case of Assolombarda, the association of companies operating in the Metropolitan City of Milan, and in the provinces of Lodi, Monza and Brianza, and Pavia which has offered its employees working in the head quarter in Milan to work near their homes in the Assolombarda offices outside the city (www.assolombarda.it). Besides, other companies which headquarter is in Milan have offered their employees to work closer to their homes in decentralized offices (i.e., Price Waterhouse Cooper which head quarter is in the skyscraper Torre Libeskind in City Life neighborhood has opened an office in Monza because most of its employees live in Brianza area, where Monza is located).

spaces, and carefully managing hosted professionals' well-being and health. Moreover, CSs are spread over the territory, also in Italy, and, therefore, more accessible for workers living far away from the companies' premises (Mariotti et al., 2021b; Lo Russo & Mariotti, 2022).

The paper discusses the case study of Milan, which has a polycentric urban structure, with dense historic cores and a comprehensive functional system with human-scale dimensions (Deponte et al., 2020). It is the Italian economic capital city, characterised by huge commuting and tourist flows, alongside with crowding and congestion problems on local public transports, roads and public spaces (e.g., Navigli waterfronts, Parco Sempione, etc.) (Balducci et al., 2017). The city of Milan and Lombardy NUTS2 region were hitten by the Covid-19 pandemic, especially during the first wave in March-May 2020, from a public health and economic point of view. Thousand business meetings were cancelled, leisure and cultural activities stopped, and iconic events were postponed (e.g., Milan Design Week, etc.).

Since the first Prime Minister Decree of 4 March 2020 (Gazzetta Ufficiale Serie Generale n. 55/2020), Italy progressively closed non-essential economic and institutional activities to face the pandemic. The most restrictive period was from March to May 2020 (the first strict lockdown), when only "essential activities", such as health and personal care, specific manufacturing activities, and agriculture involved in food provision and retail, were allowed to operate. Then, during the summertime, the previous restrictions and containment measures were gradually eased, and economic activities reopened. Finally, from November 2020 to March 2021, Italy lived through a second lockdown.

There was a progressive closure of specific activities, differentiated across the Italian regions depending on the number of infection cases (Mariotti et al., 2022b).

Within this context, the present paper investigates the changes in the neighbourhood attractiveness in Milan during the Covid-19 pandemic compared to 2019, using TIM mobile phone data and Piano dei Servizi di Milano (PGT) data, and analyses whether and how peripheral neighbourhoods satisfy the "15-minute city" paradigm. Specifically, the aim is threefold: (i) measure the presence of remote workers at the neighbourhood level; (ii) explore the accessibility to CSs within 15 minutes of walking and cycling distance; (iii) focus on three peripheral neighbourhoods which show the lowest number of city users loss, do not host CSs, and present different levels of essential services and access to subway stations. The three cases are explored to understand whether they are considered feasible locations for hosting a neighbourhood CS, thus improving the level of essential services.

The paper is organised into six sections. The Introduction is followed by a brief review of the studies on the 15-minute city paradigm. Section 3 presents the analysis of the leave of people from the Milanese central neighbourhoods during the Covid-19 pandemic, and the attractiveness of the peripheral areas to remote workers. Section 4 focuses on the CSs in Milan, exploring their dynamics and location patterns, and briefly describes the "Milano 2020 Strategia di Adattamento" promoting the 15-minutes and near-working concepts. Section 5 presents three peripheral neighbourhoods (Niguarda-Parco Nord, Gallaratese, Baggio) not hosting CSs, characterised by different levels of essential services and access to subway stations, and registering a steady presence of people during the pandemic compared to the year before. Specifically, it is investigated whether they are considered feasible locations for a neighbourhood CS hosting remote workers. The concluding section discusses the results of the analysis of the three neighbourhoods, and puts forward further research.

2. The 15-minute city concept: origins and characteristics

In light of the Covid-19 pandemic, one of the urban planning approaches that immediately caught public attention is the 15-minute city concept, coined by the French scientist and university professor Carlos Moreno in 2016 and then applied by the mayor of Paris, Anne Hidalgo, in 2020 (Reid, 2020). One should note that this idea is not entirely new. The origins of this concept can be traced back to several neighbourhood schemes and ideas about proximity and walkability starting from the early 20th century. Sharifi (2016) studied the

evolution of planning and design at the neighbourhood scale, which is essential for achieving sustainable development. He recognised five planning movements in the past century to mitigate the issues caused by unregulated urbanisation: Garden City, Neighborhood Unit, Modernism, Neo-traditionalism, and Eco-urbanism. In particular, the 15-minute city can be associated with the movements such as New Urbanism, Transit-Oriented Development and Smart growth, for long been used as schemes related to Neo-traditional principles (Furuseth, 1997).

All the past movements are rooted in the Neighborhood Unit concept introduced by the American planner Clarence Perry in the early 1900s (Perry, 1929). He proposed design principles for a neighbourhood's functional and structural organization for public services and urban amenities (e.g. school, library, retail store, community centre, etc.), a hierarchical street network, green and public open spaces and a residential area. In the early 2000s, Farr (2007) updated Perry's Neighborhood Unit and presented the 'sustainable neighborhood unit', where he added elements such as car-free housing, neighbourhood retails, third places (where people meet, develop trust and form associations), car-sharing, etc.

Moreover, Smith (2011) discussed the importance of neighbourhoods as the spatial context that frames people's lives, where residents meet their basic needs, interact and communicate. Yet, policymakers have neglected critical aspects of a prosperous neighbourhood, and there is a need to understand further the services and spaces that cities currently provide and future functions that can contribute to developing sustainable neighbourhoods (Di Marino et al., 2022).

Moreover, long car-dependent urban planning goes hand in hand with rising social and economic inequalities, leading to unsustainable practices (Newman, 2017).

Alongside this literature, planners reflect on the compact city models and the characteristics of urban developments in suburban areas. In particular, Mouratidis (2018) examined the impact of the compact city on neighbourhood liveability, finding that essential components of the compact city (such as LPT, accessibility to city centre and land use mix) show a positive association with neighbourhood satisfaction. Moreover, our cities are increasingly characterized by mixed-use locations (Batty, 2021), where "more than one activity or function exists in the same location and/or at the same time" (Batty et al., 2004). However, this concept holds only if we consider a neighbourhood or time interval in which these activities exist together. Indeed, multi-functionalism is a relative concept, dependent upon the spatial and temporal scale. In this sense, the current paper focuses on three specific Milanese neighbourhoods before and during the Covid-19 pandemic.

During the pandemic and due to health measures, periodic lockdowns, and mobility restrictions, neighbourhoods have acquired new dynamics. Moreno et al. (2021) introduced the 15-Minute City model (also known as "la ville du quart d'heure") as an alternative planning approach to confronting the aftermath of the Covid-19 pandemic, to respond to the city's need for a radical re-thinking and the necessity to provide proximity-based services to inhabitants. The authors refer to similar approaches for modern cities, such as the 15-minute walkable neighbourhood proposed by Weng et al. (2019) and the 20-minute model by Da Silva et al. (2020), who follow the principles of the "chrono-urbanism".

Moreno's 15-Minute City model insists on the importance of urban rhythms and the quality of life in cities and calls for increased proximity, social interaction, digitalisation, and diversity pillars which may reinforce community ties.

The original concept supports a spatial layout where residents can access all of their essential needs at distances reachable within 15-minute by foot or by bicycle. Moreno defines six essential urban social functions to sustain a decent urban life: (1) living, (2) working, (3) commerce, (4) healthcare, (5) education and (6) entertainment (Moreno et al., 2021, p.100).

To embrace the 'new normal' brought by the pandemic, Moreno's 'modified 15-minute city' framework revisited the four main dimensions of (a) density, (b) proximity, (c) diversity and (d) digitalization. His original model was tested in Paris. It has been considered a successful urban planning concept to boost the economy,

enhance social cohesion and create sustainable ecosystems in cities. Following the 15-Minute City model's popularity, other cities have replicated some of the features of this idea.

Recently, Abdelfattah et al. (2021) discussed the potential of Milan to become a 15-minute city with sufficiently walkable neighbourhoods, by investigating the relationship between neighbourhood walkability and population distribution as a way to gauge distributional inequalities between levels of walkability across the city. Moreover, Bocca (2021) evaluate how urban transformations can be elements in support of the 15-minute city and how transformative placemaking can be part of the strategy.

Until today, only two studies have combined the concepts of a 15-minute city and the new working spaces, in particular CSs. The first, published in 2021, is the project Milan Collabora (Mariotti et al., 2021c), which has explored the case of near working and CSs in Milan as enhanced by the Milan "2020 Adaptation Strategy". The second, recently published, is carried out by Mina di Marino et al. (2022) focusing on the cases of Oslo and Lisbon. The authors based their discussion on chrono-urbanism and the current planning debate on new urban models for sustainable neighbourhoods.

3. Potential remote workers in Milan: an estimation

The present section aims to measure the presence of remote workers at the neighbourhood level before and during the pandemic. To reach this goal, an experimental methodology based on TIM mobile phone data was applied to investigate the Milan neighbourhoods that have lost city users during the pandemic and to identify those that have not lost and/or have gained users. These data show the presence and mobility of TIM mobile phone users in a definite territory and time[2].

Specifically, data are analysed at the neighbourhood level, identified by one census area (ACE, as defined by ISTAT), which groups adjacent census sections with 13-18 thousand inhabitants. Since data are available for a few months before the pandemic spread and some months after the limitations imposed by the health emergency, specific neighbourhood dynamics can be identified.

A similar approach based on big data was applied by Gorrini et al. (2021).

They gathered data for seven months (January to July 2020) through a network of 55 Wi-Fi sensors distributed in several department stores, shops and public services in Milan. Their results show a significant decrease between the daily average number of mobile devices detected before the Covid-19 spread and those witnessed during the lockdown phase. Fig.1 and 2 show the difference (in absolute terms and percentage, respectively) between April 2020 and April 2019 in the people's presence within Milan neighbourhoods.

The central neighbourhoods (in purple) have the highest loss of people (about -63,000 people / -63%), but the decreased numbers are observed in a large area of the city. Since, by definition, the ACE average population is equal to 15,000 inhabitants, a loss of more than 10,000 people represents a substantial impact on the neighbourhood. This phenomenon is related to the urban distribution of significant attractors (e.g., railway stations, universities, etc.) in specific areas, which suffered the highest decrease in the number of users due to the movement restrictions imposed by the health emergency. Instead, the neighbourhoods coloured in yellow showed variation between -5% e + 5%, suggesting that the more peripheral areas suffered less from the effects of the first lockdown.

The spatial structure of these trends may suggest development policies promoting proximity services and coworking spaces in areas closer to people's residences, rather than only in the central or more attractive ones. In this way, reducing congestion and crowding on local public transport (LPT) and public spaces would be indirectly supported. Moreover, spreading local services represents an important opportunity for developing and revitalising peripheral areas, reducing existing inequalities.

[2] TIM mobile network users represent about 30% of the national mobile-phone users (AGCOM, 2022). These data are weighted to be representative of the entire population using mobile phones.

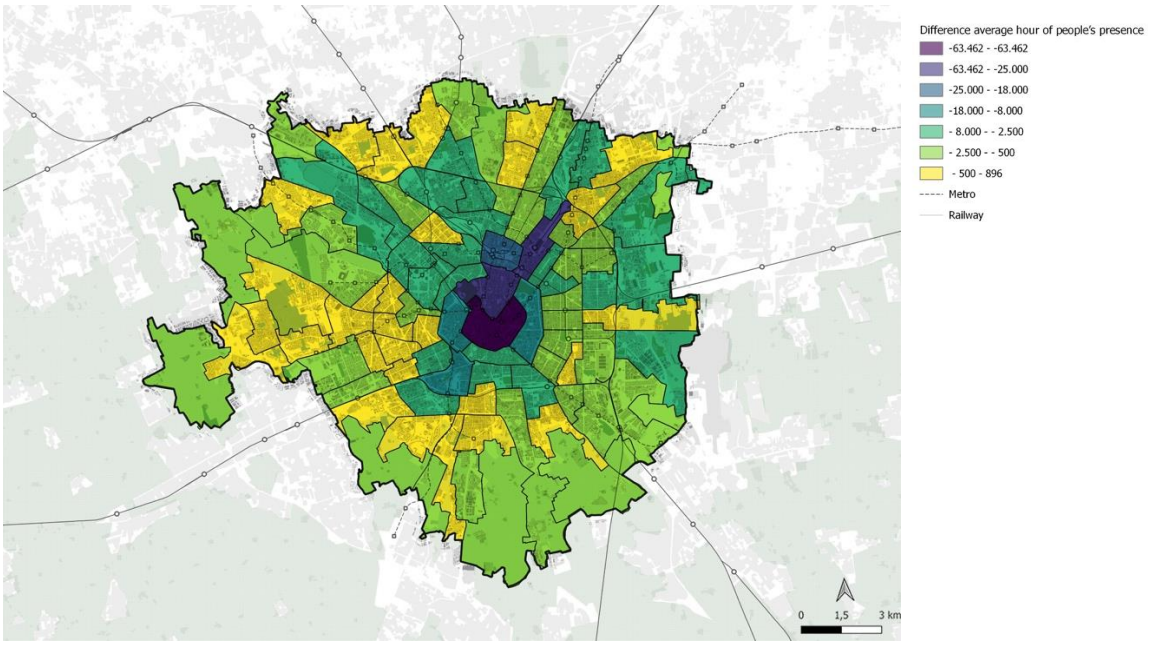


Fig.1 Difference (in absolute terms) of the monthly average hour of people's presence in Milan (April 2020 and April 2019 by neighbourhoods)

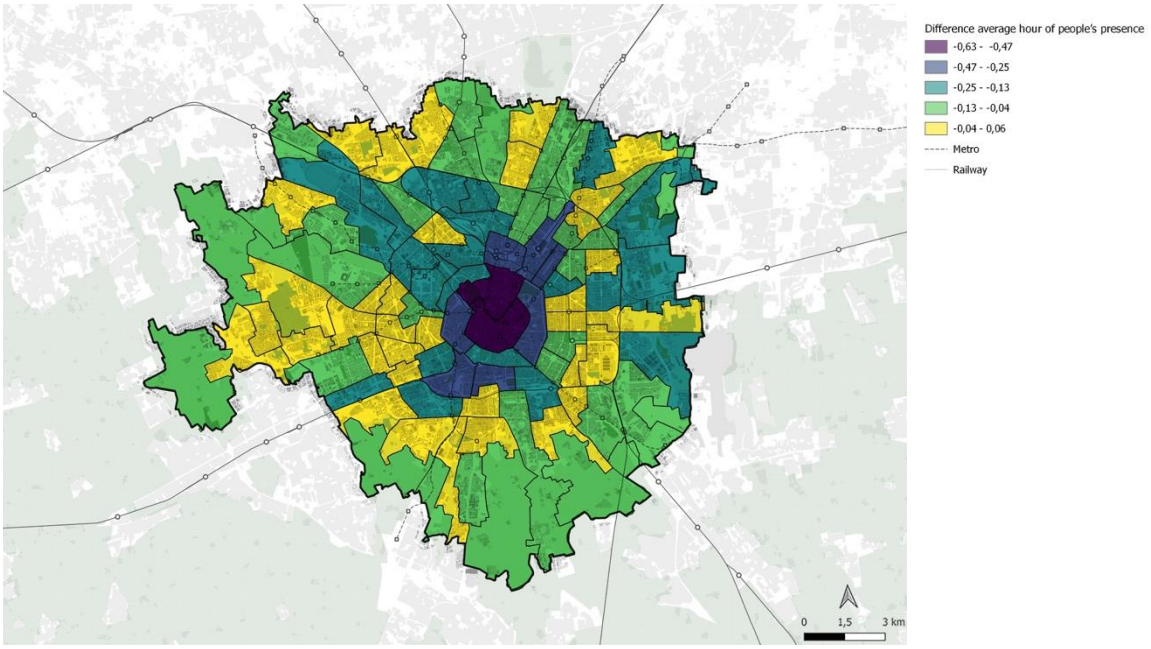


Fig.2 Difference (in percentage) of the monthly average hour of people's presence in Milan (April 2020 and April 2019 by neighbourhoods)

4. Coworking spaces and near working in Milan

This paragraph and the next one are dedicated to the exploration of the peripheral neighbourhoods that may host a coworking space that can satisfy the local demand for remote workers. Moreover, the essential services these neighbourhoods offer within the "15-minute city" paradigm are analysed through the calculation of proper accessibility indicators and mapping methods.

The Covid-19 pandemic has reduced people's mobility and the fear of contagion, favouring the re-discovery of the neighbourhood. Among the public policies adopted in the last year at an urban level, there is the "15-

minute city" paradigm, described in section 2, allowing residents and city users to reach the primary services in 15 minutes of walking and cycling distance by reorganising functions and spaces (green spaces, services, workplaces, etc.).

This issue was recently mentioned in the "Milano 2020 Strategia di Adattamento"[3] ("Milan 2020 Adaptation strategy") to cope with the Covid-19 restrictions (see also Pinto & Akhavan, 2022). This strategy, indeed, promotes the neighbourhood dimension, guaranteeing the primary services within that distance, hybrid spaces for the community (shopping, facilities for the community) and tactical urbanism to improve the use of public spaces. Besides, it supports mobility based on LPT with a reduced capacity, smart working and reorganising the timetable for several activities to avoid gatherings during peak hours. Specifically, it focuses on strengthening remote working as an ordinary system to carry out at home or in third places (coworking spaces), thus ensuring work-life balance. Finally, it aims to improve air quality through slow and sustainable mobility (bikes, push scooters, electric motorvehicles, also in sharing). These transformations could represent an opportunity to re-imagine the neighbourhoods and to rethink the centre-peripheries relationship (Mariotti, 2021). Within this context, the Municipality of Milan has promoted the "near working" strategy by offering its employees a place to work close to their home, thus reducing the sense of isolation and improving their work-life balance. The employees could work in decentralised branches owned by the municipality, disused offices of large local companies belonging to Assolombarda[4], and in private coworking spaces (Tajani, 2021).

But what is a coworking space, how many are they, and where are located in Milan? Coworking spaces (CSs) are shared-collaborative-flexible workplaces, which are becoming popular among freelancers, startups, employees, and self-employed workers, from diverse professional profiles and competencies, ranging from the creative industry (such as architects, designers, journalists, etc.) to engineering and digital sectors (namely IT, software developers, consultants, etc.) (Akhavan & Mariotti, 2018; Gandini, 2015; Spinuzzi, 2012; Mariotti et al., 2021a). CSs usually apply a membership-based model that allows coworkers to have temporal access to the facilities and services offered by the space.

The first Italian CSs were born in 2008 during the economic recession, and they started growing significantly only in 2013/2014. According to Italiancoworking (2021), 660 CSs were recorded in January 2019 and 779 in January 2021 (Figure 3). Likewise other countries, the Italian CS is mainly an urban phenomenon: in 2021, about 51% were concentrated in the 14 metropolitan areas, with Milan in the lead, hosting 119 CSs (Italiancoworking, 2021).

Among the factors influencing the CSs location choice are the density of activities (urbanisation and localisation economies), the size of the current and potential market, and the presence of productive amenities (e.g., good access to customers, availability of specialised services, presence of universities and research centres, good accessibility to transport networks), as well as non-productive amenities (e.g., presence of bars and restaurants, shops, cultural and entertainment activities, good urban quality) (Mariotti et al., 2017).

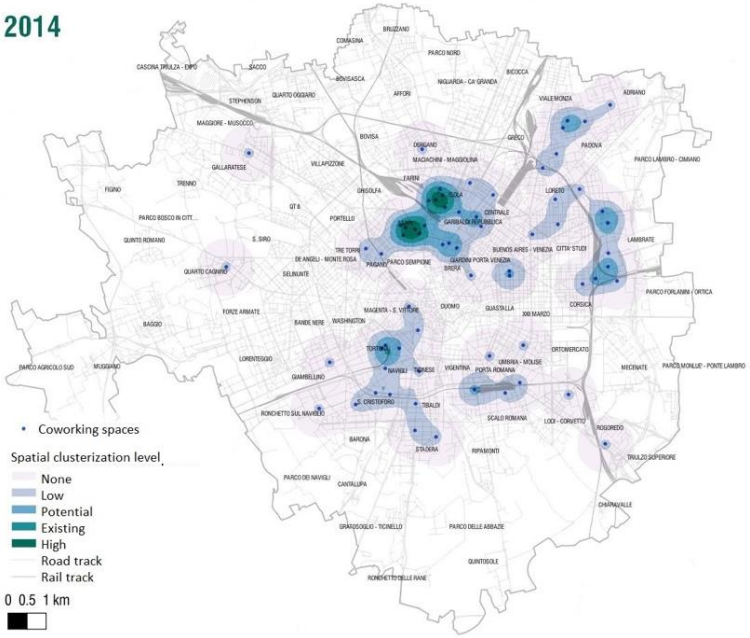
Since 2008, the number of CSs in Milan has grown significantly more than in any other Italian city. The diffusion of CSs was also promoted by the Municipality, which has actively supported CSs and their coworkers since 2013.

Between 2014 and 2021, the number of CSs in Milan rose from 68 to 119 units (+75%), with some agglomerations strengthening and the emergence of new CSs in peripheral neighbourhoods (Fig.3). In both years, it was confirmed the attractiveness of the central and semi-central areas with good accessibility (i.e., Garibaldi-Repubblica-Centrale) and the areas characterised by gentrification processes (i.e., Porta Romana).

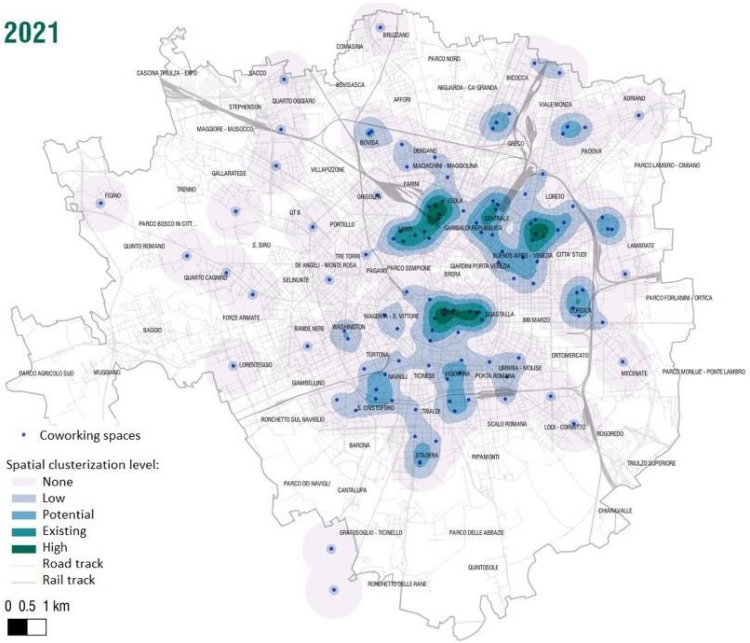
[3] https://www.comune.milano.it/documents/20126/95930101/Milano+2020.++Strategia+di+adattamento.pdf/c96c1297-f8ad-5482-859c-90de1d2b76cb?t=1587723749501

[4] Assolombarda is an association of companies operating in the Metropolitan City of Milan and in the provinces of Lodi, Monza and Brianza, and Pavia (www.assolombarda.it).

In contrast, other peripheral areas (i.e., Bruzzano, Mecenate, Figino, Quarto Cagnino, Quarto Oggiaro) became new attractors.



(a)



(b)

Fig.3 Agglomeration dynamics of coworking spaces in Milan (2014-2021)

In a survey on coworking managers in 2020, Pais et al. (2021) found that 35% of CSs in Milan had new customers or requests from the neighbourhood inhabitants; 25% of the spaces wanted to invest in the neighbourhood potential demand in the future, and 20% started or planned to start new partnerships with neighbourhood's commercial activities and cultural associations. Within this context, the 'neighbourhood coworking' can contribute to the "15-minute city" logic.

To establish if the current 119 coworking spaces in Milan can be seen as 'neighbourhood coworking', the 15-minute accessibility by foot and bike was calculated (see Fig.4 and 5). This analysis allows us to map, at the urban scale, the level of accessibility to CSs and highlight the city's grey areas from which CSs are inaccessible

through sustainable means. Accessibility was measured by means of isochrones to CS (for further details on the methodology, see Manfredini and Di Rosa, 2018).

Fig.4 shows the pedestrian access to the CSs in Milan, using an isochronous[5] representation. Dark green highlights areas where CSs can be reached in less than 5 minutes by foot. The decreasing green colour intensities indicate, respectively, a travel time between 5 and 10 minutes and a travel time between 10 and 15 minutes. The map shows heterogeneous pedestrian accessibility within the city. Specifically, a poor level of accessibility is observed in the urban fringes.

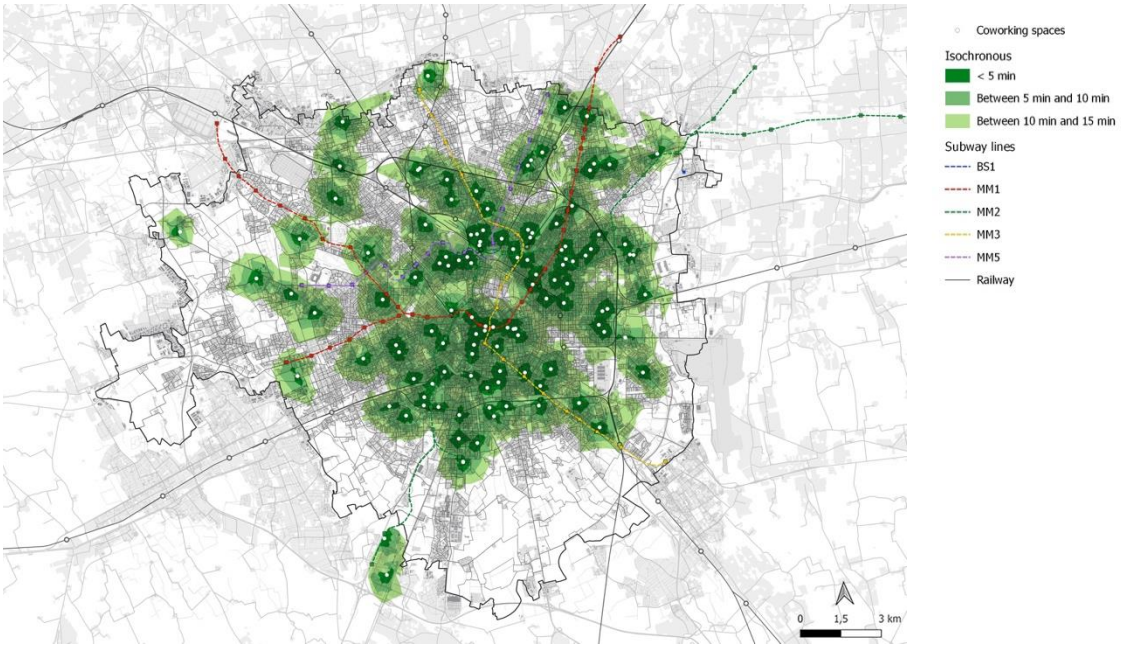


Fig.4 Pedestrian access to coworking spaces within 15 minutes in Milan

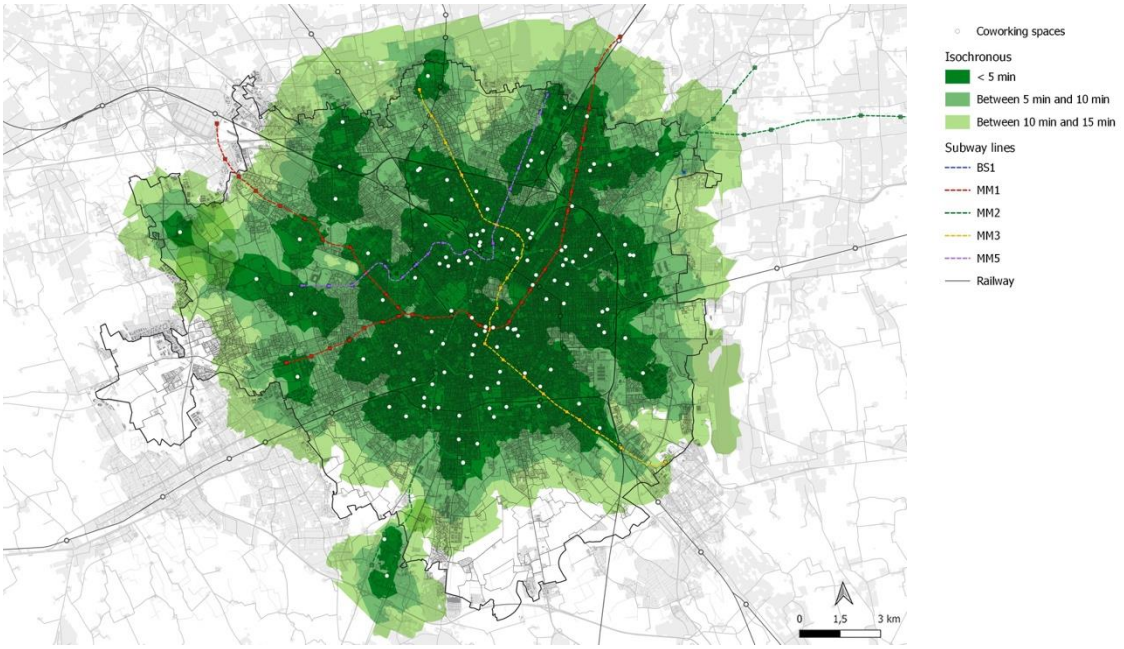


Fig.5 Access to coworking spaces by bike within 15 minutes in Milan

[5] Average walking speed of an adult in good health: 1 m/second equal to about 4 km/hour.

Accessibility by bike was calculated analogously, using a speed of about 3.3 m/second equal to 12 km/hour. In this case, the overall level of access to CSs is higher: it is possible to reach one CS in less than 15 minutes from almost all the city areas (Fig.5). However, CSs agglomeration phenomena in some neighbourhoods should be reconsidered as some areas are served by only one space, while others, especially around the city centre, host a significant variety of spaces, even close to each other. In conclusion, this analysis provides a complex and integrated framework of services and mobility and can guide policymakers towards relevant actions or projects.

5. A focus on three Milanese neighbourhoods: Niguarda-Parco Nord, Gallaratese, and Baggio

This section focuses on three peripheral neighbourhoods in Milan: Niguarda- Parco Nord, Gallaratese, and Baggio, which have been chosen because during the pandemic: (i) have lost the lowest number of city users; (ii) are peripheral neighbourhoods with different levels of essential services and access to subway stations (Tab.1, Fig.6); (iii) do not host CSs. Specifically, Gallaratese has high accessibility to subway stations, Niguarda-Parco Nord has medium accessibility, and Baggio has low accessibility.

For each neighbourhood, TIM mobile phone data are analysed to map the outflows between 9:00 a.m. and 10:00 a.m. in three working days: one before Covid-19 spread (April 3, 2019), one in the first lockdown (April 1, 2020) and one in the period of coexistence with the virus (October 14, 2020). Mobile data show that during the Covid 19 pandemic, the number of human presences has been steady, probably because people live and work in these areas.

	1. Niguarda-Parco Nord	**2.Gallaratese**	**3.Baggio**
Population (31/12/2020)	13,579	17,478	18,687
School Educational Services	11	10	13
Crèche	4	2	0
Nursery school	3	4	4
Primary	2	3	2
Secondary I level	2	1	1
Secondary II level	0	0	1
Family time-space	0	0	1
Sport and leisure	11	17	12
Playground	10	14	8
Oratory	1	3	4
Culture and training	7	2	5
Associations	4	0	3
Italian schools for foreigners	0	1	1
Library	0	0	1
BikeMI	2	1	0
Show	1	0	0

Tab.1 Essential services by neighbourhood

The aim is to identify specific areas where new neighbourhood CSs can settle to satisfy the local demand for remote workers. The approach can be replicated to study other neighbourhoods and help identify the mobility flows. Some of these flows could be intercepted by the neighbourhood CSs, as alternative workplaces to the traditional work premises and private homes. Niguarda-Parco Nord hosts all school levels up to the first-grade secondary school, associations, a theatre, and playgrounds. There is also a Milano sports structure, and the neighbourhood services are spread all over the area. Gallaratese supplies all schools to the secondary level

and has no associations. The neighbourhood shops are clustered along an axis to the north and from the centre to the south. Finally, in Baggio, all school orders are up to grade II (vocational school). There are a family time space and a library; however, the territorial distribution of services is very concentrated in the centre. The analysis of the supply of the services shows that the three areas are somewhat similar but with the following exceptions (Tab.1, Fig.s 7,9,11). Niguarda-Parco Nord services are more distributed, while in Baggio and Gallaratese, they are mainly located along the main arteries. Gallaratese does not host any association except for an Italian school for foreigners, and there are only two crèches compared to 4 in the other two neighbourhoods. Baggio hosts all school types, including family time space and a vocational school. Therefore, Gallaratese has a lower level of accessibility to services than the other two having high endowments only in playgrounds. Baggio, instead, is the one with a higher school coverage.

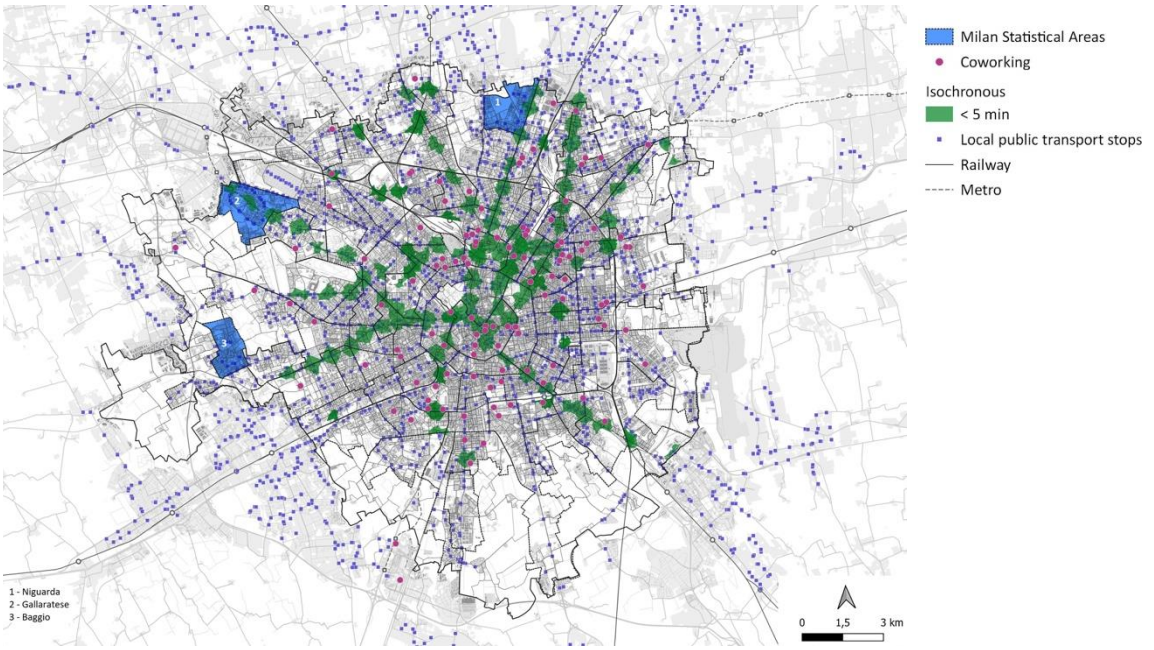


Fig.6 Access to subway stations

Niguarda- Parco Nord

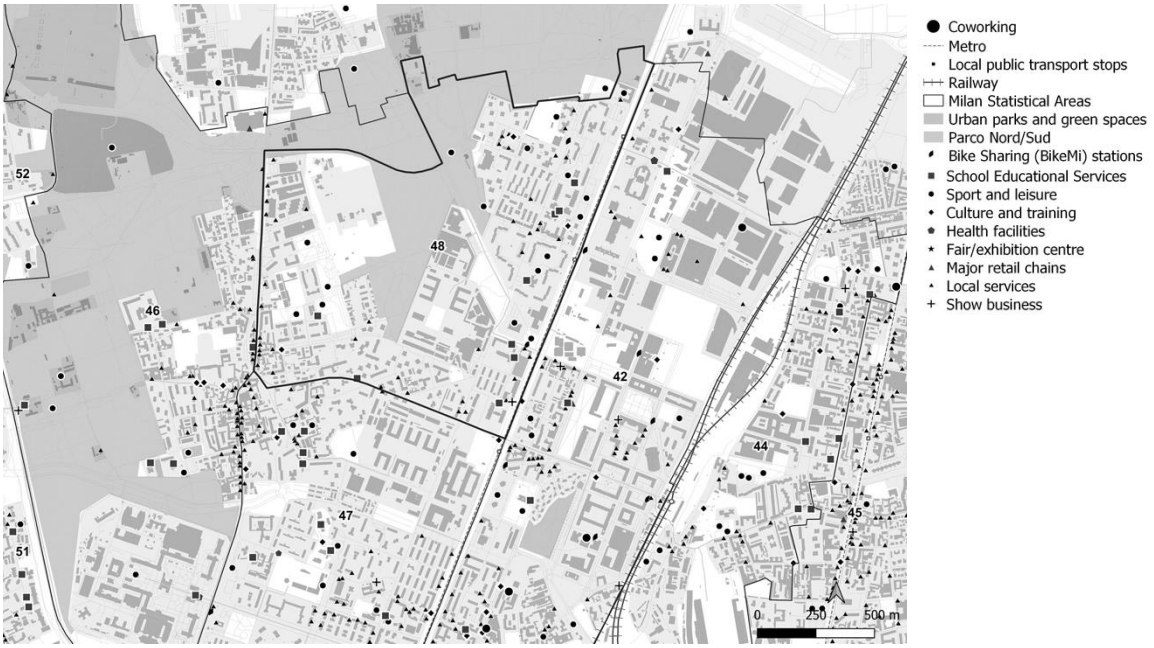


Fig.7 Essential services in Niguarda- Parco Nord neighbourhood (48)

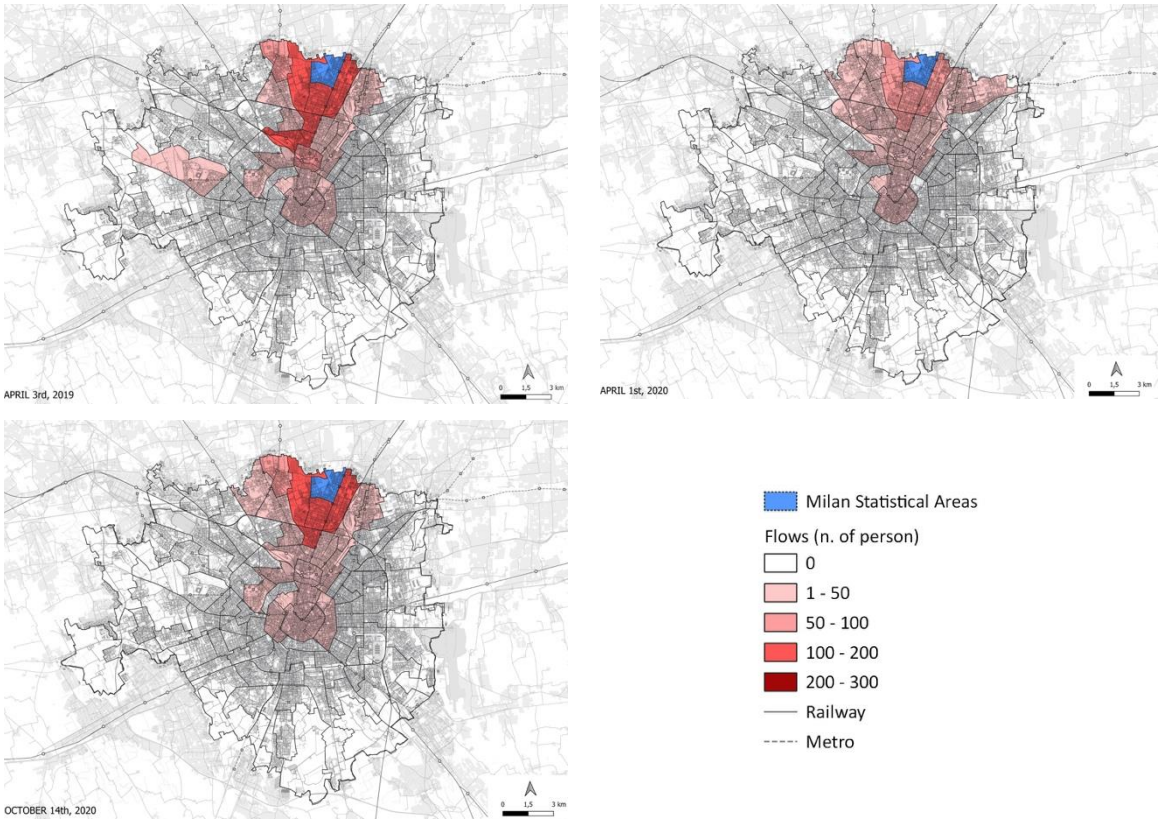


Fig.8 People outflows from Niguarda-Parco Nord between 9 am, and 10 am on three working days before and during the Covid-19 pandemic

The neighbourhood Niguarda-Parco Nord is located in Milan's northern area, at the border with the municipalities of Bresso and Sesto San Giovanni. It has a medium accessibility level, taking advantage of metro line 5, whose stops are located in the eastern portion of the area. Figure 9 shows that, in this case, the flows are mainly concentrated in the northern part. Data also highlights some mobility patterns in the morning, indicating a potential user pool for a CS.

Gallaratese

Fig.9 Essential services in Gallaratese neighbourhood (72)

Fig.10 People outflows from Gallaratese between 9 a.m., and 10 a.m. on three working days before and during the Covid-19 pandemic

Gallaratese has a high level of accessibility, with two subway stops. As shown in Fig.7, a strong connection between the city centre and the north-western quadrant emerges, also maintained during the lockdown period. The good accessibility level to the subway stops and the proximity to park and ride facilities make this area appealing for a CS. During the pandemic, there has been an increasing demand for peripheral working spaces with good accessibility to the city centre.

Baggio

Fig.11 Essential services in Baggio (78)

Fig.12 People outflows from Baggio between 9 am and 10 am on three working days before and during the Covid-19 pandemic

Baggio had less intense flows than the other two neighbourhoods (Fig.11), probably due to its limited accessibility to the subway stops. Before the Covid-19 spread, outflows were directed towards adjacent areas, the city centre, and some transport hubs. However, these flows substantially disappeared during the pandemic, highlighting a significant presence of remote workers in this neighbourhood, which are potential users of a CS.

6. Discussion, conclusions and further research

The analysis of TIM mobile phone data highlighted a decrease during the Covid-19 pandemic in the people's presence within central areas of the city. This phenomenon implies the existence of a pool of remote workers and other users of the city centre, which might be searching for solutions closer to their homes to work and entertain. CSs could intercept part of this demand since they are alternative workplaces.

The exploration of the three peripheral neighbourhoods of Niguarda- Parco Nord, Gallaratese, and Baggio, which do not host a CS, underlined that they present a potential demand for a coworking space. Before the pandemic, Niguarda-Parco Nord and Baggio experienced an outflow of people – although with different intensity – which substantially disappeared during the pandemic. This trend highlights the presence of remote workers in these neighbourhoods, which might work in neighbourhood CSs.

The case of Gallaratese is different because it has a good accessibility level to the subway stops and offers park-and-ride facilities, thus attracting users from outside the neighbourhood and the neighbouring municipalities. During the pandemic and beyond, there has been an increasing demand for geographically dispersed hubs like CSs with good accessibility to the centre of large cities. For remote workers living outside Milan, choosing to work in a CS in the peripheral neighbourhood of Gallaratese allow them to reach the workplace by car, park it in the parking nearby, and reach the city center by underground when needed.

The structural adoption of a decentralised working model requires a comprehensive rethinking of service distribution within the city. The "Milano 2020 Strategia di Adattamento" (Milan 2020 Adaptation Strategies)

has promoted this, and the Municipality of Milan has offered their employees to work in a third-place close to their homes (i.e. decentralised branches owned by the Municipality, disused offices of large local companies, and private coworking spaces). The near working strategy produces positive externalities such as vehicle traffic reduction, transports' congestion, better work-life balance, and stimulates knowledge exchange. The neigbhourhood CS should offer several social services (e.g., babysitting services, training, workshops) to improve the users' work–life-balance (Mariotti et al., 2021b; Mainieri et al., 2021).

The matching between supply (of CS) and demand (of users) can be supported by offering vouchers for working in a CS, thus covering the CS's fees to rent a desk and use its facilities. These vouchers can be provided by either the employer (justified by space and cost reduction for traditional offices) or by public institutions (compensation for lower environmental costs linked to the decrease in mobility or public policies aiming to support peripheral areas).

Future research could focus on implementing a synthetic index of available public and private services in the neighbourhoods, differentiating by the relevance of each type of service. The analysis for all Milan neighbourhoods will be able to measure the "15-minute city" goal, offering a valuable tool to policy makers and official planners to promote new local services – including new working spaces such as neighbourhood coworking spaces (Mainieri et al., 2021; Mariotti et al., 2021b), and hybrid spaces –, thus contributing to the revitalisation of peripheral areas, and reducing existing inequalities.

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References

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

AGCOM (2022). Communication Markets Monitoring System, www.agcom.it.

Akhavan, M., & Mariotti, I. (2018). The effects of coworking spaces on local communities in the Italian context. *Territorio*, (87), 85–92. https://doi.org/10.3280/TR2018-087014

Balducci, A., Fedeli, V., & Curci, F. (2017). Milan beyond the metropolis. In A. Balducci, V. Fedeli, & F. Curci (Eds.), Post-metropolitan territories: Looking for a new urbanity (pp. 27–52). New York: Routledge.

Barbieri T., Basso G., & Scicchitano S. (2021). Italian Workers at Risk During the COVID-19 Epidemic. *Italian Economic Journal.*

Batty, M. (2021). Science and Design in the age of COVID-19. *Environment and Planning B: Urban Analytics and City Science* 48 (1), 3–8. https://doi:10.1177/2399808321989131.

Batty, M., E. Besussi, K. Maat, & J. J. Harts (2004). Representing Multifunctional Cities: Density and Diversity in Space and Time. *Built Environment* 30 (4), 324–337. https://doi:10.2148/benv.30.4.324.57156.

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

Capasso Da Silva, D.; King, D.A.; & Lemar, S. (2020). Accessibility in practice: 20-minute city as a sustainability planning goal. *Sustainability*, 12, 129.

Cirianni, F.M.M., Comi, A. & Luongo, A.S. (2022). A sustainable approach for planning of urban pedestrian routes and footpaths in a pandemic scenario. Evidence from Italian cities. *Tema. Journal of Land Use, Mobility and Environment*, 15 (1), 125-140. http://dx.doi.org/10.6092/1970-9870/8629

Deponte, D., Fossa, G. & Gorrini, A. (2020) Shaping space for ever-changing mobility. *Tema. Journal of Land Use, Mobility and Environment*, 133-149. http://dx.doi.org/10.6092/1970-9870/6857

Di Marino M, Tomaz E., Henriques C. & Chavoshi S.H. (2022). The 15-minute city concept and new working spaces: a planning perspective from Oslo and Lisbon, *European Planning Studies*, http://dx.doi.org/10.1080/09654313.2022.2082837

Farr, D. (2007). Sustainable Urbanism: Urban Design with Nature, John Wiley & Sons Inc, Hoboken, New Jersey.

Fenu, N. (2021). Bicycle and urban design. A lesson from Covid-19. *Tema. Journal of Land Use, Mobility and Environment*, *14* (1), 69-92. http://dx.doi.org/10.6092/1970-9870/7716

Florida R., Rodríguez-Pose A., & Storper M. (2021). Cities in a post-COVID world. *Urban Studies,* 1-23.

Gorrini, A., Messa, F., Ceccarelli, G. & Choubassi, R. (2021). Covid-19 pandemic and activity patterns in Milan. Wi-Fi sensors and location-based data. *Tema. Journal of Land Use, Mobility and Environment*, 14 (2), 211-226. https://doi.org/ 10.6093/1970-9870/7886

Italiancoworking (2021). Italian coworking survey 2021, I numeri del coworking in Italia, 30 gennaio 2021, https://www.italiancoworking.it/i-numeri-del-coworking-in-italia

Lo Russo M., & Mariotti I. (2022). L'impatto della pandemia Covid-19 sulla sostenibilità e resilienza degli spazi di coworking, in Montanari F., a cura di, Spazi collaborativi in azione. Creatività, innovazione e impatto sociale, Franco Angeli, Milano, in corso di pubblicazione.

Mainieri M., Saturno E., Selloni D. (2021). Coworking di prossimità: nuovi modelli per una città dei 15 minuti. Un percorso di co-design con i coworking milanesi, Milano Collabora, Comune di Milano, https://collaboriamo.org/media/ 2021/07/Coworking_a_Milano.pdf

Manfredini, F. & Di Rosa, C. (2018). Measuring Spatial Accessibility for Elderly. An Application to Subway Station in Milan. *Tema. Journal of Land Use, Mobility and Environment*, 85-94. doi: http://dx.doi.org/10.6092/1970-9870/5800

Manzini Ceinar, I., & Mariotti, I. (2021). Teleworking in post-pandemic times: may local coworking spaces be the future trend? *Romanian Journal of Regional Science*, *15* (1), 52-76.

Mariotti I., Di Vita S., & Akhavan M. (2021a), eds., New workplaces: Location patterns, urban effects and development trajectories. A worldwide investigation, Springer.

Mariotti, I., Di Marino, M., & Akhavan, M. (2021b). The emergence of coworking models in the face of pandemic. In J.R. Bryson, A. Lauren, L. Reardon, A. Ersoy, eds., Living with Pandemics: People, Place and Policy, Edward Elgar, 129-139.

Mariotti I., Manfredini F., & Giavarini V. (2021c). La geografia degli spazi di coworking a Milano. Una analisi territoriale, Milano Collabora, Comune di Milano, https://collaboriamo.org/media/2021/07/Coworking_a_Milano.pdf

Mariotti I., Di Marino M., & Bednar P. (2022a). The COVID-19 pandemic and Future of Working Spaces. Routledge, https://doi.org/10.4324/9781003181163

Mariotti I., Di Matteo D., & Rossi F. (2022b). Who were the losers and winners during the COVID-19 pandemic? The rise of remote working in suburban areas. *Regional Studies, Regional Science*, forthcoming.

Mariotti I. (2021). Il lavoro a distanza svuota le città? In Bellandi M., Mariotti I., Nisticò R., eds, Città e periferie alla prova del Covid-19: dinamiche territoriali, nuovi bisogni, politiche, Donzelli Editore, Roma, pp.25-35.

Mariotti I., Pacchi C., & Di Vita S. (2017). Coworking Spaces in Milan: Location Patterns and Urban Effects, *Journal of Urban Technology*, 24 (3), 1-.21.

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

Mouratidis, K. (2018). Is Compact City Livable? The Impact of Compact Versus Sprawled Neighbourhoods on Neighbourhood Satisfaction. *Urban Studies* 55 (11), 2408–2430 https://doi:10.1177/0042098017729109

Newman, P. Beatley, T., & Boyer, H. (2017). Resilient Cities: Overcoming Fossil Fuel Dependence, 2nd ed.; Island Press: Washington, DC, USA.

Osservatorio Smart Working (2021). Politecnico di Milano: https://www.osservatori.net/it/ricerche/osservatori-attivi/smart-working

Pais, I., Manzo, C., & Gerosa, A. (2021). La trasformazione dei coworking di Milano nell'emergenza pandemica. Le interviste ai coworking manager. Report, Comune di Milano, Milano Collabora, https://collaboriamo.org/media/2021/07/ Coworking_a_Milano_cattolica.pdf

Perry, C.A. (1929) "The Neighborhood Unit", "Regional Plan of New York and its Environs", vol. VII, New York.

Reid, C. (2020). Anne Hidalgo Reelected as Mayor of Paris Vowing to Remove Cars and Boost Bicycling and Walking. Available online: https://www.forbes.com/sites/carltonreid/2020/06/28/anne-hidalgo-reelected-as-mayor-of-paris-vowing-toremove-cars-and-boost-bicycling-and-walking/?sh=7aa9e961c852

Pinto, F., & Akhavan, M. (2022). Scenarios for a Post-Pandemic City: urban planning strategies and challenges of making "Milan 15-minutes city." *Transportation Research Procedia*, 60 (2021), 370–377. https://doi.org/10.1016/j.trpro.2021.12.048

Smith, Mark K. (2011). 'Neighborhoods and regeneration. Theory, practice, issues', The encyclopedia of pedagogy and informal education. [www.infed.org/community/neighborhoods_and_regeneration.htm].

Sostero, M., Milasi, S., Hurley, J., Fernandez-Marcias, E., & Bisello, M. (2020), Teleworkability and the COVID-19 crisis: a new digital divide? Seville, European Commission JRC and Eurofound.

Spinuzzi, C. (2012). Working Alone, Together: Coworking as Emergent Collaborative Activity. *Journal of Business and Technical Communication, 26* (4), 399–441. https://doi.org/10.1177/1050651912444070

Tajani C. (2021), Città prossime. Dal quartiere al mondo: Milano e le metropoli globali, Guerini e Associati editore.

Zecca, C., Gaglione F., Laing, R., & Gargiulo C., (2020) Pedestrian routes and accessibility to urban services. rhythmic analysis on people's behaviour before and during the Covid-19. *Tema. Journal of Land Use, Mobility and Environment* 13 (2), 241-256. http://dx.doi.org/10.6092/1970-9870/7051

Weng, M.; Ding, N.; Li, J.; Jin, X.; Xiao, H.; He, Z.; & Su, S. (2019). The 15-minute walkable neighbourhoods: Measurement, social inequalities and implications for building healthy communities in urban China. *Journal of Transport & Health*, 13, 259–273.

Image Sources

Fig.1: Mariotti et al. (2021c, p.33);

Fig.2: Mariotti et al. (2021c, p.34);

Fig.3: Mariotti et al. (2021c, p.24);

Fig.4: Mariotti et al. (2021c, p.29);

Fig.5: Mariotti et al. (2021c, p.30);

Fig.6: authors' elaboration on Piano dei Servizi di Milano (PGT);

Fig.7: authors' elaboration on Piano dei Servizi di Milano (PGT);

Fig.8: Mariotti et al. (2021c, p.39);

Fig.9: authors' elaboration on Piano dei Servizi di Milano (PGT);

Fig.10: Mariotti et al. (2021c, p.38);

Fig.11: authors' elaboration on Piano dei Servizi di Milano (PGT);

Fig.12: Mariotti et al. (2021c, p.40).

Table Sources

Tab.1: authors' elaboration on Piano dei Servizi di Milano (PGT).

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Permanent and seasonal human presence in the coastal settlements of Lecce

An analysis using mobile phone tracking data

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Abstract
This paper presents the first results of analyses carried out using mobile phone data on human presence (residents, commuters, visitors) in the coastal territory of Lecce (Italy). The aim of the research, conducted in the framework of the DAStU Project 'Department of Excellence on Fragile Territories' in collaboration with the Municipality of Lecce, is to provide precise feedback on the actual use of a coastal territory which is mostly inhabited temporarily, marked by unauthorised building, and threatened by various environmental and climate risks. Starting with an acknowledgement of the limits that traditional census and registry data have in detecting the use of territories characterised by seasonal use and informality, the paper analyses the variations in anthropic presence over multiple years and the incidence of permanent residents. The analyses were carried out using mobile positioning data extracted from the TIM Data Visual Insight (DVI) platform and refer to the period between September 2019 and September 2020. The results show evident heterogeneity among the different coastal settlements. In particular, there are substantial differences between the southern *marine* (San Cataldo, Torre Veneri, Frigole, Montegrappa) and northern ones (Torre Chianca, Spiaggiabella, Torre Rinalda), where the former show a greater presence of stable residents and a less pronounced seasonal fluctuation. These differences are fundamental for urban planning policies to determine in which areas the retreat of the building from the coast could cause more difficulties and inconveniences.

Keywords
Coastal settlement; Second homes; Unauthorised construction; Human presence; Seasonality.

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1. Introduction

This paper aims to analyse the seasonal fluctuations of human presence in the coastal settlements (*marine*) of Lecce and to evaluate the specific contribution of mobile phone data compared to census data. This analysis can importantly support public policies to evaluate the actual use of the housing stock to delimit areas with greater exposure to environmental risks or underutilization phenomena. The way these data can help local authorities and land-use policies to promote retreat or regeneration strategies along the coast is also discussed.
The *marine* of Lecce is characterized by unauthorized building and other informal practices in the use of the littoral.[1] This case is not sufficiently known in the literature, thus much of the information reported in this paper is the result of fieldwork activities carried out by the authors between 2018 and 2022 in dialogue with the municipal administration and local actors.
The paper is structured in 5 paragraphs. Since the study area has very peculiar weaknesses, before proceeding with a more methodological and statistical treatment, the Paragraph 1 provides a synthetic and qualitative portrait of the area under study, also from a landscape point of view, and tries to explain its main frailty. Paragraph 2 provides a general framework of the observed phenomenon in Southern Italy. Paragraph 3 introduces the potential and criticalities of mobile phone data in the analysis of human presence.[2] Paragraph 4 presents and discusses the analysis of mobile phone data carried out for the *marine* of Lecce. In the concluding section (Paragraph 5), we summarise and raise further questions that may be addressed in the future.

2. A fragile territory, and difficult to interpret: the *Marine* of Lecce

The coastal settlements of the Municipality of Lecce (Apulia Region, Italy) consist mainly of second homes. They encompass seven coastal hamlets known as *marine*[3], distributed along a 22-km-long stretch of the Adriatic coast with shallow, sandy beaches.
In terms of urban morphology, the *marine* are non-homogeneous settlements. This is also true of their relationship with the main roads, historical evolution, and distance from the urban centre of Lecce. Moreover, along the same stretch of coast, we also find protected natural areas, agricultural areas, military areas, wetlands, water basins, and a variety of hydraulic infrastructure. These bear witness to the enormous efforts made since the beginning of the twentieth century to reclaim land for agricultural use through the construction of reservoirs, canals, irrigation systems, and water pumps.
However, a contrasting and common phenomenon found in the *marine* is the construction of unauthorised structures. The roots of this practice are found in the informal constructions that initially developed thanks to the infrastructure and land grid created by reclamation works that — particularly in the 1970s and 1980s — became a sort of guide for unauthorised plots (Fig.1).
Besides the dualism of legality and illegality, there is also another dualism of natural and artificial elements. These contrasts constantly deteriorate the area with evident effects on coastal erosion (Fig.2), the dismantling of dune systems, hydrogeological instability, and the formation of sinkholes.[4]
Recent years have seen an intensification in the processes of sea intrusion, rising water tables, the return of marshes, and the reappearance of ancient coastal lakes. On the one hand, all this has contributed to increased

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1 Articles dedicated to the theme of the urban waterfront have often been published in this journal (Giovinazzi & Moretti, 2009; Pirlone & Erriu, 2016), while the theme of informal coastal settlements has rarely been dealt with.

2 For all more specific references relating to mobile phone data, please refer also to the other article of this thematic issue.

3 We have decided not to translate the Italian noun *marina* (pl: *marine*) — seaside settlements — because there is no perfectly corresponding English term.

4 Sinkholes are cracks in the limestone floor which, in the coastal area of Lecce, are lapped by a very shallow water table.

hydrogeological risks, especially in the autumn and winter months. On the other hand, it has taken large portions of fertile soil away from agriculture.

(a) (b)

Fig.1 Lecce. (a) Spontaneous settlements of holiday homes in Torre Chianca, and (b) Spiaggiabella

(a) (b)

Fig.2 Spiaggiabella (Lecce). (a) Buildings on the shoreline and (b) disruptions to beach accessibility

The legacy of land reclamation, an engineering commitment to dominating the landscape and making it valuable and healthy, has mainly been lost: the canals are clogged, the water scoops are inactive, houses have replaced the fields, and the *Xylella* bacterium is transforming the Salento landscape of olive groves into something that cannot yet be foreseen.

(a) (b)

Fig.3 Lecce. (a) Dunes and (b) wetlands that claim their natural space

These complex, problematic phenomena are accompanied by threats due to climate change, especially from rising sea levels. On a low coastline, where land reclamation and illegal construction have taken away the natural space of water and sand (inhibiting the natural dynamics of dune movement and water flow) (Fig.3), the expected rise in average sea level leads to a radical rethinking of the relationship between artificial elements and nature and a necessary process of adaptation to climate change.

The settlements, mainly built in a short time and with poor construction quality caused by the use of cement made of sand from the dunes, the absence of sewage systems, and building on top of marshy, unstable land have been in a critical — if not terminal — phase in their life cycle for at least a decade. Many are in a state of decay while others are abandoned (Fig.4).

(a) (b)

Fig.4 (a) Alternation of abandoned vacant lots and (b) holiday homes with serious hydraulic problems due to rising water tables

Some quantitative elements are helpful for outlining the extent of the phenomenon of unauthorised building and the precariousness — even legal precariousness — of the built heritage.

The preliminary document for the new urban plan of Lecce, dating back to the early 2000s, found that the entire coast of Lecce[5] had a housing stock of more than 3,500 dwellings for a few hundred resident inhabitants. The maximum number of visitors during the summer season was estimated at about 30,000, of which just under half were campsites (Coletta, 2010, p. 288).

The building stock has been subject to various building amnesties, most often without receiving a legal status from the public administration. This means that thousands of buildings wait in a sort of legal limbo, adding to unauthorised buildings for which amnesty has never been requested and the many enclosures of buildings that have never been started or finished. To provide a measure of the phenomenon of unauthorised building in the *marine* of Lecce (San Cataldo, Frigole, Torre Chianca, Spiaggiabella, Torre Rinalda), we refer to data from the Sogeaa Report (Centro Studi Sogeaa, 2016)[6] and an initial mapping — still in progress — launched in 2017 by the municipal offices.[7] Considering only the *marine*, the documents show that under the three laws on building amnesty of 1985, 1994, and 2003, there are about 1400 pending applications under Law 47/85, about 130 under Law 724/94, and about 30 under Law 326/03.[8] This legal precariousness also affects building maintenance, which is scarce or at least very differentiated (between regular and irregular buildings), and the building market, where supply exceeds demand.

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5 Until 15 May 2012, Casalabate, which now belongs to the municipalities of Squinzano and Trepuzzi, was also part of the Municipality of Lecce.

6 In the municipality of Lecce, 19,850 requests for building amnesty were presented. About 14,000 (70%) were submitted pursuant to Law 47/85. A total of 6,450 are still waiting to be processed.

7 The authors were allowed access by virtue of an agreement signed in 2018 between the Department of Architecture and Urban Studies of the Politecnico di Milano and the Municipality of Lecce.

8 These numbers appear small in relation to the total (see note 8) if we do not consider that requests for building amnesty in the *marine* are almost exclusively related to 'total' abuses.

If we look beyond the houses and their relationship with open space, semantic poverty emerges due to the continuous repetition of fences and gates (all different but all similar), the alternation of spontaneous buildings, open spaces and abandoned walls, and an even lower quality of public space. The narrow and unpaved streets are often the result of allotments designed to maximise land use and are only compliant with the civil code. Except for San Cataldo, the squares, gardens, car parks, and seafronts are inadequate because they were created with limited investment and poor materials.

In this context, polarised between intensive summer use and winter abandonment, between illegal and regular housing, nature reclaiming its spaces and derelicts defacing it, it is challenging to investigate population dynamics and interweave demographic data with the different spatial characteristics of the settlements. Thus, innovative data and methods can help outline possible policies, direct the allocation of public investments, and organise policies for withdrawal from the coast in time and space.

2. The *Marine* of Lecce as part of a larger phenomenon: emerging issues in Southern Italy

The *marine* of Lecce exemplifies the complexity encountered today in illegal coastal settlements. As various surveys have shown in recent years, many of these settlements based on unauthorised construction are increasingly affected by dynamics of decline and value loss inherent both in low building quality and premature landscape degradation. Here, two different dynamics intertwine.

On the one hand, we recognise more marked filter-down dynamics affecting the lowest-quality segments of the building stock, and consequent repopulation processes of former second homes by immigrant and poorer resident populations, with instances of marginalisation and concentration of social unease. Such is the case of settlements along the Domitia state road north of Naples, the south-eastern Sicilian coast, the areas of Rosarno and Crotonese in Calabria, upper Apulia, and the province of Latina south of Rome (Fucile & Di Figlia, 2017; Miano, 2017).

On the other hand, we are witnessing the takeover of a variegated population of individuals with limited economic capital who are expressing more permanent residential demands. They are permanently re-inhabiting a residential heritage based on tourism which is currently in decline since it is more accessible than the residential heritage of urban markets from which they are expelled, cases of which have occurred near various capitals of the centre-south such as Bari, Gela, Taranto, Caserta, and Latina. Both phenomena must deal with the scarcity of all types of equipment and services which are rarely present in the settlements in question, and with the consequences of climate change, which in many cases expose the assets of former second homes to substantial risks tied in particular to coastal erosion and rising sea levels.

Therefore, the central question that these places raise today not only relates to the complex management of outstanding amnesty practices and building assets that have lost much of their value (which in some cases have such a low value that paying building taxes related to the amnesty is no longer convenient). The question also concerns how to politically channel this complex and urgent building amnesty process and the selective reuse of the building stock in light of the emerging dynamics of repopulation of some segments of decayed heritage — raising delicate social issues — and in light of climate change — which raises equally complex matters of public safety.

3. The use of mobile phone data in understanding informal coastal settlements: its potential and critical issues

Mobile phone data or mobile positioning data (MPD) offer essential information on temporary populations and non-systematic mobility, which can support and increase the efficiency of urban and mobility policies (Pucci, 2013). Due to the high pervasiveness of cellular phones in society, MPD have been mainly used to quantify

the volume of tourist flows, analyse tourist behaviours, verify the reliability of the official data collected through hotel/accommodation surveys, support the production of official tourism statistics (Grassini & Dugheri, 2021). They have also been used to analyse mobility practices within some informal settlements and reveal slum dynamics that are usually impossible to grasp with official statistics (Wesolowski, 2012).

Informal coastal settlements, especially those with no hotels but only vacation homes, are excellent contexts for exploiting MPD. Their predominantly 'illegal' nature — from an urban planning point of view — and their use for *proximity tourism* (Dıaz Soria & Llurdes Coit, 2013) makes the analysis of both residential and tourist practices challenging. Therefore, demographic representation based on census and registry data is insufficient. Such data are not always effective and reliable in detecting the resident population in contexts of unauthorised second homes. This is also due to the tendency of homeowners to circumvent taxation and regulations, which makes data from institutional sources less reliable. MPD can be beneficial in coastal contexts with a strongly seasonal use and marked by unauthorised construction, not only for testing the effectiveness of census and registry data but primarily for providing new analytical elements supported by greater spatial and temporal detail.

On the one hand, the data obtained from mobile phone users and activities, suitably anonymised by the operators putting them on the market, make it possible to overcome the 'latency' of data collection, a typical characteristic of data from traditional sources, and exploit the widespread mass distribution of mobile phones. Therefore, these types of data will be increasingly used to analyse and interpret people's presence and movements (Pucci et al., 2015).

On the other hand, these types of data are never truly complete. They contain a certain level of uncertainty, since each operator's users represent a particular population sample. Moreover, they cannot be considered 'neutral' as they are the output of algorithms and calculation processes highly dependent on selective choices made upstream by the operators themselves (Gillespie et al., 2014). For these reasons, it is essential to compare and integrate MPD with other data from official sources when possible, if only to verify their reliability and effectiveness. The opposite is also true, however, as phone data allow us to understand where census data are incomplete, stimulating their integration and 'correction'.

Regarding two aspects in particular, MPD may allow us to formulate innovative reflections on the case study in question.

a. Seasonality/Residency. Compared to census data, telephone data allow for a greater temporal frequency in detecting behaviours related to residential mobility, especially concerning tourist-recreational mobility. The sub-municipal scale reveals the actual uses of the area. It is free of administrative, fiscal, and legal aspects, enabling reading and interpretation of even short-term de facto residency and informal tourist practices, which are difficult to trace in other ways. Furthermore, MPD allows behaviours to be monitored throughout the summer season to understand the trend in a more extended time while also allowing for targeted inter-weekly and inter-seasonal comparisons, between the high and low beach seasons and between ordinary weekdays and holidays. This will enable us to analyse the growth (May–June) and decay (September–October) curves of residents and attendance in the high beach season. These data can also be crossed with other fiscal and administrative information owned by the Municipality of Lecce to perform quality checks on the coverage and significance of the data;
b. Environmental risks/Demolitions. In the fragile environmental described in Paragraph 1, anthropogenic presence still plays an important role. It is essential to ask whether there is a correlation between the rate of residency and environmental risks. The use of MPD makes it possible to strengthen or create new evidence with public value, also confirming some hypotheses that have not yet be proven or only partially demonstrated. The propulsive dynamics of unplanned building development have weakened significantly compared to the 1970s and 1980s.It is necessary to think about what to do with a building stock that is increasingly characterised by abandonment and underuse. Amnesty policies and planning activities that

provide essential services and infrastructure have often treated the coastal territory uniformly, regardless of the recreational character of the settlements. The hypothesis underlying this text is that the differences are substantial and require differentiated plans and projects, particularly strategies to lighten the anthropic pressure, starting with removal of the most impactful and most risk-prone building components. It is clear that along the 22 km of Lecce coast, it will be impossible to indiscriminately demolish all the buildings closest to the beach or those in dangerous areas. Still, MPD can help produce evidence and arguments that facilitate demolition policies. In this sense, MPD can provide valid arguments supporting difficult public decisions such as those relating to the demolition of buildings that cannot be condoned.

With regard to the topic and the case in question, a unique possibility was provided by the DASTU Project 'Department of Excellence on Fragile Territories' through the creation of a 'custom scenario' centred precisely on the *marine* of Lecce. We were able to acquire specific passive mobile positioning data accessible through the TIM Data Visual Insight (DVI) platform and referring to September 2019–September 2020.

Given the apparent advantages and potential described above, there is always a need to deepen detection methods to understand the practical reliability of TIM data, even in territories where there is not a dense distribution of telephone antennas (this is also true of the *marine* of Lecce). In addition, it is necessary to deepen the data synthesis and aggregation methods, conduct qualitative analysis, and discuss the results. Among the main limitations of the data purchased by DASTU and made available through the TIM DVI platform, we point out: the impossibility of building time series with data before 2019; the impossibility of making comparisons with other similar settlements, mainly due to the high costs of the data and service offered by TIM, which does not facilitate the start of more custom scenarios on similar territories; the under-representation of some social groups (in particular people under 18 and foreigners); and the impossibility of extracting data in grid or vector formats to process them independently in the GIS environment. Despite these limitations, we have conducted various analyses described in the next section.

4. Data analysis and statistical comparison

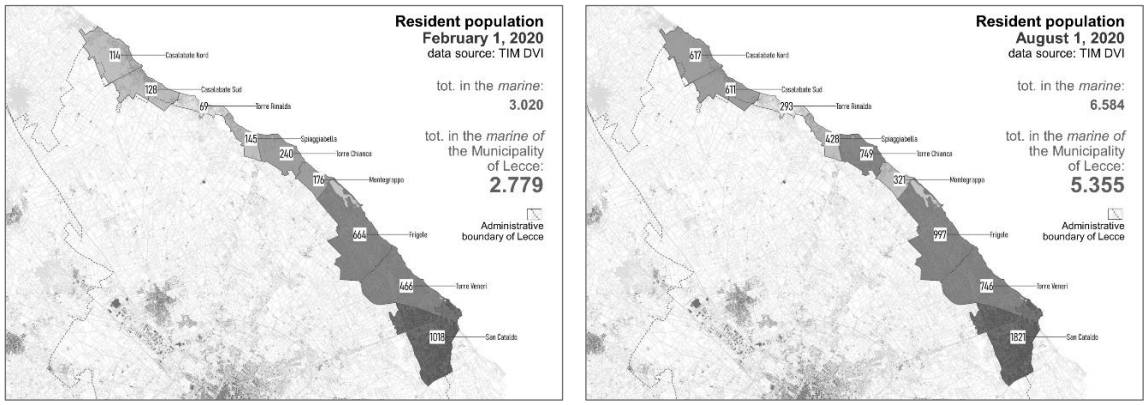
Since the registry data provided by ISTAT[9] refer to either the entire municipal territory or the ACEs[10], we opted for an analysis that would relate and compare the MPD with census data. With regard to the data from ISTAT, census data are the only data that reach the sub-municipal scale and rely on a large number of variables referring to the resident population and housing. Accordingly, at our request, the 'custom scenario' built ad hoc by TIM was based on specific aggregates of census tracts (2011 Census) that would trace, albeit with some approximation, the different *marine* of Lecce with the addition of those located in the municipalities of Trepuzzi and Squinzano, which were part of the Municipality of Lecce until 2012.

The first type of analysis is based on comparing summer and winter seasons in the same year. We selected two specific dates to perform the data extraction: Saturday, 1 February 2020, and Saturday, 1 August 2020. This first assessment aimed to analyse the change in resident population as classified by TIM through its resident population detection algorithm. The 'cell' of residence is calculated starting from the telephone 'events' made by the user in the 30 days before the observation, in particular in the first four days of the week (Monday, Tuesday, Wednesday, and Thursday), from 00:00 to 06:00 and from 22:00 to 24:00, and on Fridays from 00:00 to 06:00. With this type of data, we estimated the actual number of 'residents' in the *marine* of Lecce in the middle of the summer period. We ascertained that the southernmost *marine* in Lecce (San Cataldo, Torre Veneri, Frigole, Montegrappa, Torre Chianca) have more winter residents in absolute terms. The settlements located further north (Spiaggiabella, Torre Rinalda, and also Casalabate), on the other hand,

[9] The analyses conducted so far have not yet been able to draw on the registry data owned by the Municipality of Lecce.

[10] ACE's (Census Areas) are large clusters of census tracts with 13,000 to 18,000 inhabitants.

acquire a permanent population in August while remaining less 'permanent' in relative terms compared to the southern *marine* (Fig.5). In general, we see a doubling of the resident population between February and August. This is a notable increase even if it is not as striking as that of some seaside resorts in Salento that are very attractive from a touristic standpoint. Otranto and Porto Cesareo come to mind in particular, which are populated in the summer by tens of thousands of vacationers compared to a municipal population of about 6,000 residents.

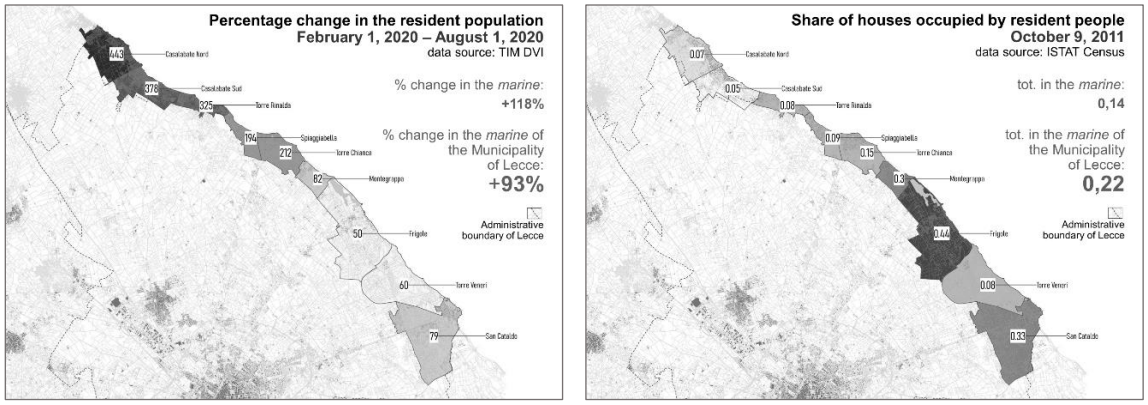


(a) (b)

Fig.5 Resident population (average) detected through mobile phone data on (a) Saturday, 1 February 2020, and (b) Saturday, 1 August 2020. The chromatic gradient is based on "natural breaks" classification

In particular, we concentrated on the following dynamics.

— *Percentage change in resident population between Saturday, 1 February 2020, and Saturday, 1 August 2020.* The more significant seasonality of the northern *marine* compared to the southern ones is noted. To confirm this, we were able to ascertain that the percentage change in residents, calculated using MPD, is negatively correlated (-0.8) with the occupancy rate of the houses, an indicator that can be obtained from the 2011 census data (surveys from 9 October) (Fig. 6/b). The winter-summer variability, that is, the intermittent nature of these settlements, is more substantial where there is a larger number of second homes (Fig. 6/a).

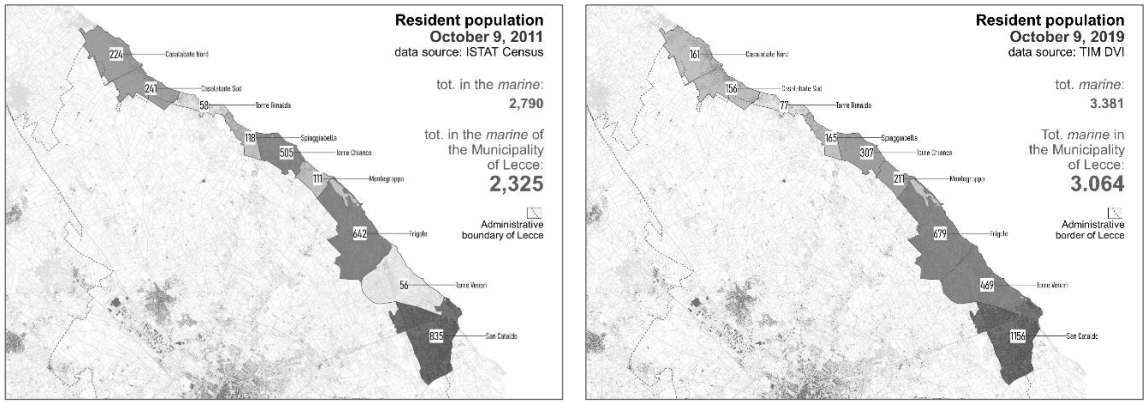


(a) (b)

Fig.6 Percentage change in resident population between Saturday, 1 February 2020, and Saturday, 1 August 2020. The map shows the absolute increase for each area of observation (our processing of TIM DVI data); and (b) share of houses occupied by residents on Wednesday, 9 October 2011. The chromatic gradient is based on "natural breaks" classification

— *Spurious comparison of resident population on Wednesday, 9 October 2019 (TIM DVI data) and on Wednesday, 9 October 2011 (ISTAT Census)*. In this case, we opted for a 'spurious' comparison since census data were compared to MPD (Fig.7). Although the data cannot be compared appropriately, this analysis, based on the same day of the year and of the week, is useful to verify some anomalies and/or

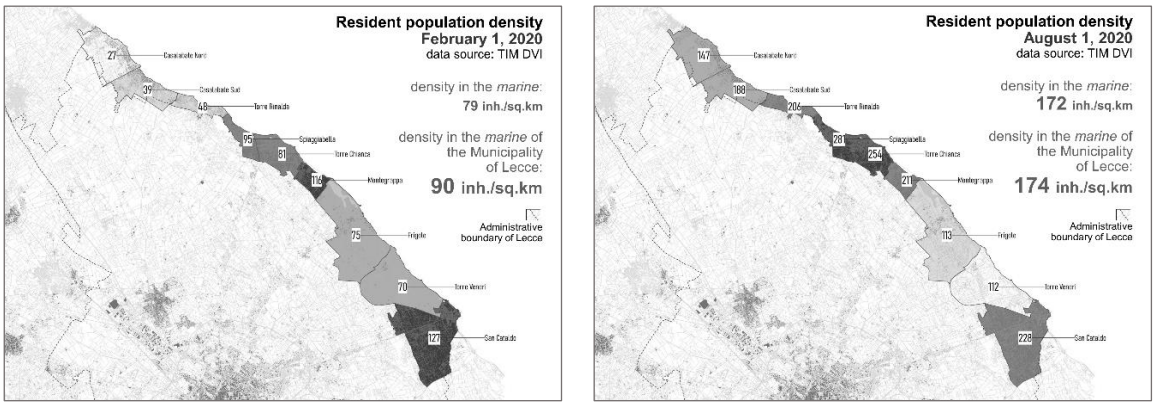
divergencies as well as to test the general distribution of the resident population within the different *marine*. In this case, it is interesting to note that in Torre Veneri, the MPD also classifies the personnel present in the military base as a 'resident' population, which was not registered by ISTAT. This only apparent anomaly actually constitutes proof of the validity of the data and a confirmation of the two different types of surveys.



(a) (b)

Fig.7 Resident population detected (a) through the national census on Wednesday, 9 October 2011, and (b) through mobile phone data on Wednesday, 9 October 2019. The chromatic gradient is based on "natural breaks" classification

– *Comparison of population density between Saturday, 1 February 2020, and Saturday, 1 August 2020.* The densest areas in winter are San Cataldo (127 inhabitants per sq. km) and Montegrappa (116 inhabitants per sq. km) (Fig. 8/a). However, if we consider the population density in summer, the densest *marine* are Spiaggiabella (281 inhabitants per sq. km) and Torre Chianca (254 inhabitants per sq. km) (Fig. 8/b). These areas have fewer resident services and more unstable conditions due to coastal erosion and wetlands, with frequent events related to hydrogeological instability. The population density of San Cataldo, which remains high even in winter, shows that it is the most planned and infrastructure-equipped *marina* in Lecce (with both a water and sewage network). San Cataldo has the lowest seasonal fluctuations, together with the more rural *marine* of Montegrappa and Frigole. Here, despite some obvious changes that have occurred in the past fifty years, the structure of an 'agricultural village' (*borgo rurale*) remains thanks to some essential services for permanent residents, including a nursery school that is still active today. It is the only school in the *marine* of Lecce.

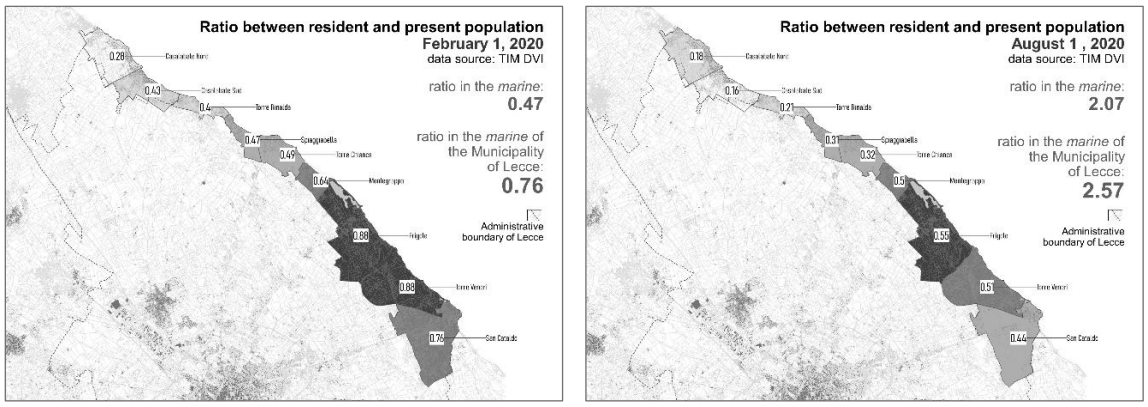


(a) (b)

Fig.8 Resident population density (a) on Saturday, 1 February 2020, and (b) on Saturday, 1 August 2020. The chromatic gradient is based on "natural breaks" classification

– *Ratio between resident and present population between Saturday, 1 February 2020, and Saturday, 1 August 2020.* In this case, the goal was to build a simple statistical index that would allow us to read the

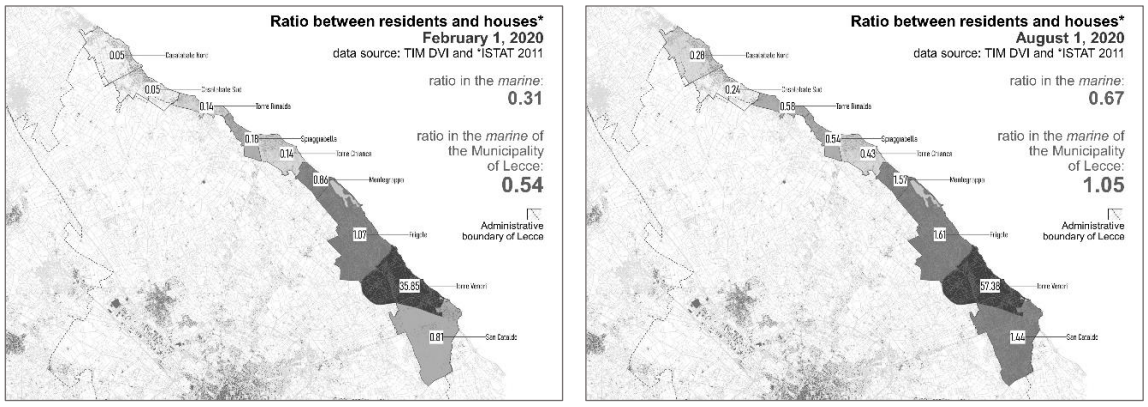
propensity of each *marina* for residential use. Again, the southern *marine* prove to have a better ratio between residents and commuters/visitors, i.e. with less intermittent human presence (Fig. 9). In particular, Frigole stands out with a higher index than all other *marine*, both in summer (0.55) and in winter (0.88), surpassing San Cataldo.



(a) (b)

Fig.9 Ratio between resident and present population (a) on Saturday, 1 February 2020, and (b) on Saturday, 1 August 2020. The chromatic gradient is based on "natural breaks" classification

— *Ratio between residents and houses between Saturday, 1 February 2020, and Saturday, 1 August 2020.* In this comparison, we have again resorted to a spurious approach by building an index based on mobile phone tracking (number of residents, 2020) and a variable from the national census (number of houses, 2011). Assuming an insubstantial change in the number of homes between 2011 and 2020, the calculated index makes it possible to read the occupancy status of residential properties, highlighting the locations with the most significant underuse of the housing stock (Fig. 10). In addition to a higher rate of occupancy, among the southern *marine* (with Frigole standing out both in summer and in winter, followed by Montegrappa and San Cataldo), the anomaly of Torre Veneri emerges once again due to the presence of the military base: the high number of residents (according to MPD) does not correspond to a proportional number of houses.

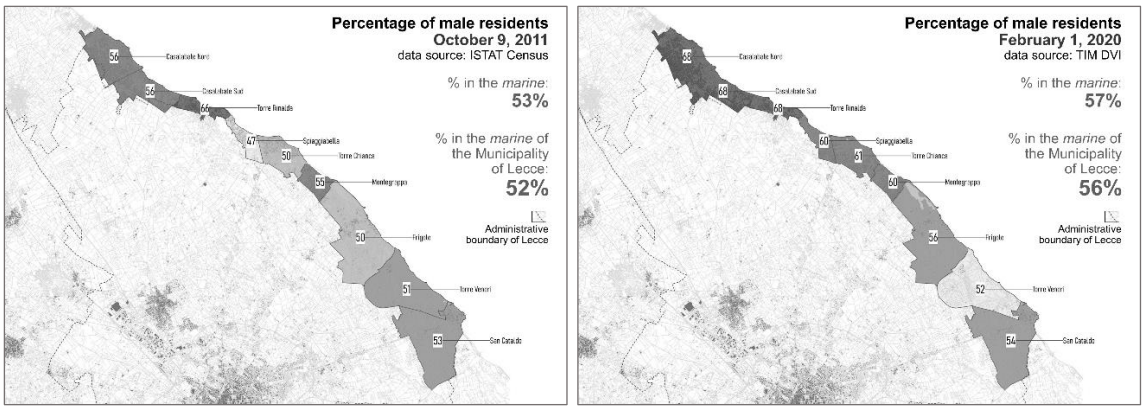


(a) (b)

Fig.10 Ratio between residents and houses (a) on Saturday, 1 February 2020, and (b) on Saturday, 1 August 2020. The chromatic gradient is based on "natural breaks" classification

— *Percentage of male residents on 9 October 2011 (ISTAT Census) and on 1 February 2020 (TIM DVI data).* The analyses show that a greater male presence is correlated with underuse of the housing stock and the tendency of the settlements to seasonality. Accordingly, the northern *marine* record percentages of male residents over 60% during the winter, with a peak of 68% in Torre Rinalda and Casalabate.

From a methodological point of view, we once again compared MPD with census data to assess the degree of overestimation of the female presence conditioned by the social habit of avoiding taxes on second homes. We refer, in particular, to official residency data, which must be considered unreliable due to untrue declarations designed to profit from the tax benefits provided for first homes. This analysis shows an overestimation of the female presence (on average by four percentage points) that the 2011 census seems to have produced compared to the MPD of 2020 (Fig. 11).



(a) (b)

Fig.11 Percentage of male residents (a) on 9 October 2011 (census data), and (b) on 1 February 2020 (TIM data). The chromatic gradient is based on "natural breaks" classification

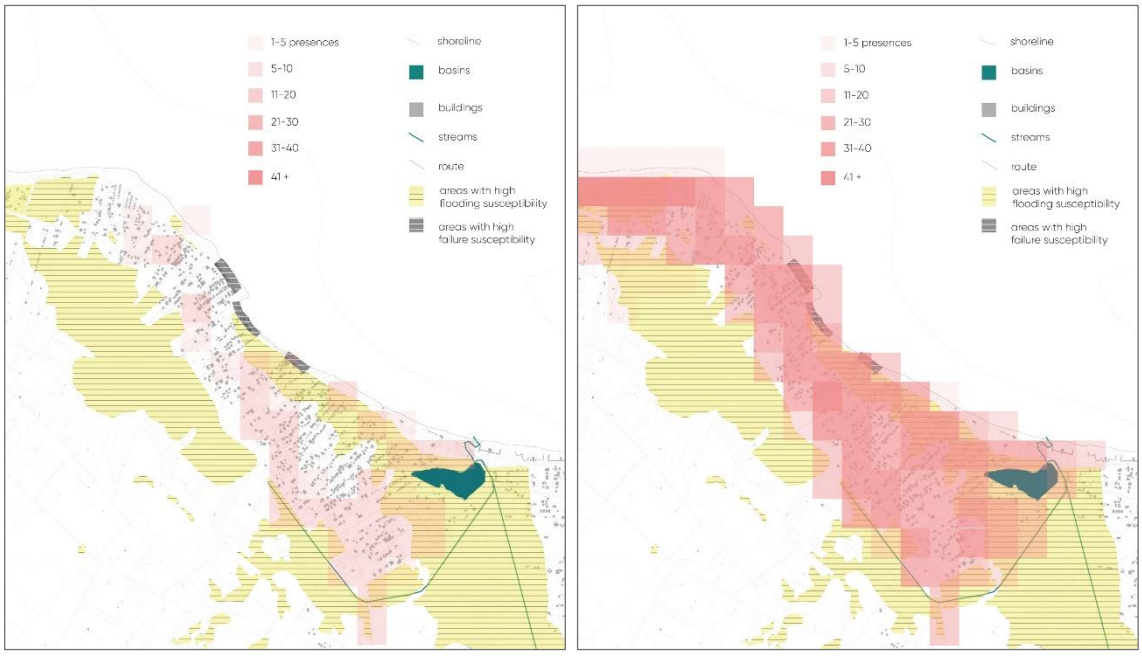
— *Changes in presence, residents, and visitors between Monday, 23 September 2019, and Monday, 21 September 2020*. To understand how the COVID-19 pandemic has changed the behaviour of residents and population gravitation in the *marine* of Lecce, we compared data from September 2019 and September 2020. In this case, we used the TIM DVI platform to extract daily average data (calculated on an hourly basis) relating not only to the people present and the resident population, but also to the origin of visitors (intra-regional, extra-regional, or foreign). We compared two Mondays at the end of summer: the penultimate Monday of September 2019 with the penultimate Monday of September 2020 (Table 1).

Although it is impossible to explain with certainty what emerges without qualitative feedback obtained in the field, the 2020 MPD show a general increase in presence during the pandemic compared to the previous year (+24% in the *marine* of Lecce, +28% including Casalabate). In particular, intra-regional visitors increased the most (+104% in the *marine* of Lecce, +116% including Casalabate), but foreigners also increased (+18% in the *marine* of Lecce, +10% including Casalabate). However, the latter could be explained by Italians returning to Italy due to the pandemic and the possibilities offered by smart working; such Italian citizens, for example, may reside abroad with a foreign telephone number (SIM). Moreover, it can be noted that the only *marine* that saw a decline in foreign visitors are Torre Veneri (-49%), which, as mentioned, hosts a military base, and San Cataldo (-44%), which is the *marina* most frequented by foreign tourists visiting the centre of Lecce. In favour of the general increase in presence, the lockdown and consequent search for living spaces with appurtenant open spaces such as gardens, terraces, and vegetable gardens, but also those closer to the sea and places suited to outdoor activities, could have played a role. This would also explain the increase in residents (+15% in the *marine* of Lecce, +22% including Casalabate) as well as the overall human presence, where many families in the Lecce hinterland could have opted for a longer transfer to their second homes by postponing the return to their urban homes.

marina	**Δ presences**	**Δ residents**	**Δ visitors**		
(from South to North)	**all**	**all**	**intra-regional**	**extra-regional**	**foreign**
San Cataldo	+199 (+11%)	+216 (+16%)	+40 (+19%)	+10 (+22%)	-50 (-44%)
Torre Veneri	+127 (+18%)	-21 (-4%)	+135 (+175%)	+18 (+174%)	-7 (-49%)
Frigole	+262 (+29%)	+35 (+5%)	+170 (+223%)	+37 (+313%)	+11 (+32%)
Montegrappa	+97 (+31%)	=	-3 (-19%)	-5 (-51%)	+8 (19%)
Torre Chianca	+258 (+45%)	+136 (+31%)	+56 (+160%)	+8 (+20%)	+59 (160%)
Spiaggiabella	+109 (+32%)	+79 (+36%)	+34 (+139%)	+6 (+31%)	+21 (94%)
Torre Rinalda	+101 (+49%)	+88 (+79%)	+40 (+252%)	+6 (+49%)	+7 (43%)
Casalabate So.	+198 (+53%)	+173 (+78%)	+73 (+202%)	-6 (-26%)	+1 (+3%)
Casalabate No.	+235 (+48%)	+183 (+66%)	+90 (+149%)	+6 (+17%)	-12 (-18%)
tot. *marine* (all)	+1585 (+28%)	+888 (+22%)	+635 (+116%)	+80 (+40%)	+40 (+10%)
tot. *marine* (Lecce)	+1152 (+24%)	+532 (+15%)	+472 (+104%)	+80 (+55%)	+50 (+18%)

Tab.1 Absolute and percentage change of the daily averages (calculated on an hourly basis) of presences, residents and visitors in the *marine* of Lecce between Monday, 23 September 2019, and Monday, 21 September 2020

Finally, in addition to the statistical comparisons referring to the *marine* as a whole, we conducted some in-depth analyses, particularly on the Spiaggiabella area (Fig.12), to understand whether there are local differences in the human presence between summer and winter that have a relationship with the environmental risks present in the area. The maps developed show a more widespread presence throughout Spiaggiabella in summer, even in areas with a high susceptibility to flooding and soil instability. This greater diffusion of the presence of people in summer — in some ways indifferent to the environmental criticalities in the area — could be justified by the lower danger compared to the winter period. In fact, adverse events, particularly floods, are more frequent during autumn and winter. The concentration of people in the drier and less risky areas in winter would seem to bear witness to a greater awareness of the existing risks of people who live and frequent these territories even in colder months.



(a) (b)

Fig.12 Detailed comparison of the presence in Spiaggiabella between (a) 1 February 2020 and (b) 1 August 2020: 150 m x 150 m cells overlapped with areas susceptible to hydrographic issues, flooding, and instability

5. Conclusion: policy and research perspectives on the use of mobile phone data for informal coastal settlements

Mobile phone data (MPD) can serve as a valuable tool for investigating concrete human presence within coastal settlements characterised by second homes and unauthorised buildings. They can integrate and fill some gaps in official statistics and help produce public evidence favouring difficult political decisions such as the order of priority of demolitions. They can also provide helpful elements for urban planning and the programming and maintenance of public works.

From this perspective, it is understood how the use of telephone data can make it possible to strengthen or create new evidence to be used in the construction of a more reasoned public discourse on these issues, also confirming some hypotheses that have not yet or only partially been demonstrated, relating to practices of restocking or new uses of the building stock, the concentration of the seasonal population around the provision of services, and conflicts between land use and environmental risk conditions. In this sense, the analysis of data related to mobile phone traffic in the *marine* of Lecce provides valid arguments in support of targeted municipal policies in terms of urban planning, taxation, and investment in public works, as well as supporting difficult public decisions, such as, for example, the targeted demolition of buildings that are incurable or at risk.

The case study of the *marine* of Lecce, in which we used TIM DVI data, shows that: there are large differences in terms of seasonality and permanence between adjacent and similar coastal settlements; census data may be effective in some areas and less effective in others; the areas with more infrastructure and less exposed to environmental risks are also the least seasonal and intermittent ones.

What has been analysed is only a part of what could be explored with MPD. First of all, with their greater spatial detail, MPD allow us to analyse the uses of the coastal space in its various hydro-geo-morphological and botanical-vegetational components: beaches, back dunes, wetlands, coastal roads, protected areas, state-owned land. Moreover, even though we have not treated this specific issue in paper, MPD may allow us to formulate innovative reflections about socio-spatial effects of COVID-19. The historical phase marked by the COVID-19 pandemic has conditioned behaviours and lifestyles both in urban and permanently inhabited territories and coastal areas with robust seasonal use. Thanks to MPD we could detect and interpret the ability of different settlements to accommodate 'anomalous' permanent housing practices in the pandemic period, comparing them with what happened previously, since changes in the use of the housing stock may anticipate more structural changes that will influence the settlement arrangement in the coming decades.

References

Blondy, C., Vacher, L. & Vye, D. (2013). L'apport de la notion de population présente dans l'analyse du peuplement littoral. *Espace populations sociétés*, 2013/1-2, 95-110. https://doi.org/10.4000/eps.5354

Centro Studi Sogeea (2016). *Primo rapporto sul condono edilizio*. Rome.

Coletta, M. (2010). *Il territorio urbanistico di Lecce*. Edizioni Scientifiche Italiane.

Díaz Soria, I., & Llurdés Coit, J. (2013). Thoughts about proximity tourism as a strategy for local development. *Cuadernos de Turismo*, 32, 65–88.

Fagiolo, M., & Cazzato, V. (1984). *Lecce*. Laterza.

Fucile, R., & Di Figlia, L. (2017) *L'associazionismo come risorsa e azione per la trasformazione del territorio Castel Volturno (Caserta)*, in Curci, F., Formato, E., & Zanfi, F., *Territori dell'abusivismo. Un progetto per uscire dall'Italia dei condoni*. Donzelli.

Gillespie, T., Boczkowski, P. J., & Foot, K. A. (Eds.) (2014). *Media Technologies: Essays on Communication, Materiality, and Society*. MIT Press.

Giovinazzi O., & Moretti M. (2009). Port cities and Urban Waterfront: Transformations and Opportunities. *TeMA - Journal of Land Use, Mobility and Environment*, *2* (3). https://doi.org/10.6092/1970-9870/123

Grassini, L., & Dugheri, G. (2021). Mobile phone data and tourism statistics: a broken promise? *National Accounting Review*, *2021, 3*(1): 50-68. https://doi.org/10.3934/NAR.2021002

Mainardi, M. (2017). C*antieri di bonifica. L'Opera Nazionale per i Combattenti a San Cataldo e Porto Cesareo*. Edizioni Il Grifo.

Manfredini, F., Pucci, P., & Tagliolato, P. (2014). Toward a Systemic Use of Manifold Cell Phone Network Data for Urban Analysis and Planning, *Journal of Urban Technology*, 21:2, 39-59. https://doi.org/10.1080/10630732.2014.888217

Martinelli, N., & Savino, M. (2017). *Demolizioni: per riconquistare i beni pubblici e mitigare i rischi*, in Curci, F., Formato, E., Zanfi, F., *Territori dell'abusivismo. Un progetto per uscire dall'Italia dei condoni.* 277-290. *Donzelli*.

Miano, M., (2017). *La marginalità socio-spaziale di gruppi di popolazioni migranti*, in Aa.vv., *Atti della XIX Conferenza nazionale SIU. Cambiamenti. Responsabilità e strumenti per l'urbanistica al servizio del paese*. 1724-31. Planum Publisher.

Mininni, M. (2010). *La costa obliqua. Un atlante per la Puglia*. Laterza.

Paganoni, A. M., & Secchi, P. (2015). *Advances in Complex Data Modeling and Computational Methods in Statistics*. Springer.

Pirlone F., & Erriu D. (2016). Waterfront and urban regeneration. *TeMA - Journal of Land Use, Mobility and Environment*, *9* (3), 305-322. https://doi.org/10.6092/1970-9870/3990

Porcaro, S. (2022). *L'estate è finita. Racconto corale del litorale domizio*. Monitor.

Pucci P. (2013). Mobile Phone Data and Mobility Policy. *TeMA - Journal of Land Use, Mobility and Environment*, *6* (3), 326-340. https://doi.org/10.6092/1970-9870/1935

Pucci, P., Manfredini, P., & Tagliolato, P. (2015). *Mapping Urban Practices Through Mobile Phone Data*. Springer International.

Tagliolato, P., Manfredini, F., & Pucci, P. (2014). Discovering Regularity Patterns of Mobility Practices through Mobile Phone Data. *IJAEIS*, *5* (3): 37-54. https://doi.org/10.4018/ijaeis.2014070103

Trombino, G., (1984). *Le ragioni dell'abusivismo. Una analisi interpretativa del fenomeno*. Libreria Dante-Quattro canti di città.

Viganò, P. (2001). *Territori della nuova modernità. Il piano territoriale di Lecce*, Electa.

Wesolowski, A., & Eagle, N. (2012). Mobile Phones as a Lens into Slum Dynamics. In C. Silva (Ed.), *Online Research Methods in Urban and Planning Studies: Design and Outcomes*, 334-352. IGI Global. http://doi:10.4018/978-1-4666-0074-4.ch020

Image Sources

Fig.1: Photo by Authors;

Fig.2: Photo by Authors;

Fig.3: Photo by Authors;

Fig.4: Photo by Authors;

Fig.5: Authors' elaboration on TIM DVI data;

Fig.6: Authors' elaboration on TIM DVI and ISTAT Census data;

Fig.7: Authors' elaboration on ISTAT Census and TIM DVI data;

Fig.8: Authors' elaboration on TIM DVI data;

Fig.9: Authors' elaboration on TIM DVI data;

Fig.10: Authors' elaboration on TIM DVI and ISTAT Census data;

Fig.11: Authors' elaboration on TIM DVI and ISTAT Census data;

Fig.12: Authors' elaboration on TIM DVI and Municipality of Lecce data.

Table Sources

Tab.1: Authors' elaboration on TIM DVI data.

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TeMA Journal of
Land Use, Mobility and Environment

Call for papers – Special Issues 2023

WHAT TRANSITIONS? SCIENTIFIC DEBATE, RESEARCH, APPROACHES AND GOOD PRACTICES

The current challenges (climate change, pandemic, social divide, lack of resources, economic crisis, population ageing, depopulation of inland areas) affecting cities require a global renewal of methodologies, approaches, tools, policies and behaviours, calling into action all urban actors (planners, decision-makers, investors, city-users, citizens). The convergence point identified as a possible solution, both in the academic and political spheres, refers to the "transition" towards more sustainable, resilient and compatible management, governance and use of cities. With this input being accepted, TeMA Journal aims to investigate possible scenarios of urban transition inviting scholars, professionals, technicians, and urban actors to present contributions that address the following topics:

- *transitions in methods and approaches particularly concerning*
  transport-territory integration
  roles of planners and experimental governance
  assessment of impacts on the organization of urban and regional systems
  15 minutes-city
  urban accessibility to goods and services
  ageing of the population
  research scenarios for resilience and sustainability appliance synergies between urban infrastructures
- *transitions related to digital technological innovations particularly concerning*
  urban digital twin
  smart city
  augmented reality applications for urban planning
  participation and Big Data
- *environmental* transition with particularly concerning
  best practices in applying the principles of resilience and sustainability
  mitigation and adaptation to climate change in the urban environment
  requirements and challenges for the creation of sustainable green cities
  optimization of energy consumption in urban areas
  sustainable and responsible cities and ways of use
  overtourism
  post Covid-19 city
  healthy cities
  optimization of energy consumption

The call for contributions for this Special Issue, also in a critical/provocative key, aims to delve into the state of art regarding a goal/challenge (the transition) that risks being a new "label" hard to define and implement.

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Impacts of the Covid-19 pandemic in inner areas

Remote work and near-home tourism through mobile phone data in Piacenza Apennine

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Abstract
While the impacts of the Covid-19 outbreak on urban areas have been deeply investigated, the effects of the virus on sparsely populated and marginal areas are still poorly explored. In Italy, those "inner" areas are often characterized by processes of marginalization due to aging and loss of population, low occupational rate and income, a progressive deprivation of local know-how, and the shrinking of essential services. Yet, a reverse migration from urban centers to rural and peripheral areas has been reported worldwide among the main effects of the Covid-19 pandmic, being in some cases an opportunity to slow down and even reverse the process of marginalization. By combining mobile phone and socio-spatial data, this paper aims to analyze the space-time variability of human presence before and during the Covid-19 lockdown in the Apennine area of the e province of Piacenza, a representative case of Italy's inner areas, to read if and how the pandemic has contributed to modify the rhythms and trends of those territories. Two dynamics have been investigated: remote and near-home tourism. In addition to provide a picture of the changes that occurred in these marginal contexts, the outcomes have shown the great potentiality of mobile phone data, along with some limits that may prejudice their usability, particularly for territorial research in low-density areas.

Keywords
Marginal territories; Covid-19; Mobile phone data; Remote working; Near home tourism.

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1. Introduction

The transformations produced by the Covid-19 Pandemic in major urban areas have been deeply described in the literature, focusing on how the effects of the pandemic and the consequent policies for social and physical distancing and lockdown impacted people's behaviors and urban contexts (Banai, 2020; Chandran, 2020; Klaus, 2020; Kunzmann, 2020; McFarlane, 2021; Sharifi and Khavarian-Garmsir, 2020; Shenker, 2020). Many of these studies have analyzed the sudden changes in mobility and social interaction patterns by making use of big digital data produced in increasing quantities by humans living in urban environments, as in the case of Bonaccorsi et al. (2020) and Beria & Lunkar (2021) who exploited data provided by Facebook [1]. However, few studies focused on low-dense and marginal areas (Boterman, 2020) to describe how far those territories have changed under the effect of the virus. Nevertheless, massive waves of reverse migration were reported worldwide, from urban centers to rural areas (FAO, 2021), also fostered by the widespread affirmation of remote working (Manzini Ceinar and Mariotti, 2021; Petrillo et al., 2021).

The Eurofound's Covid-19 survey also demonstrates the same trend, showing that 39% of EU employees in 2020 started to work from home due to the Pandemic (Sostero et al., 2020) and the rules imposed on social distancing and the restriction of mobility. Indeed, the observation of mobility flows in Italy during March-April 2020 lockdown revealed a significant migration from the main cities' centers toward the outskirts (Beria and Lunkar 2021), as well as in France, where more than one million residents moved away from Paris in one week in March 2020 (Untersinger, 2020). These studies, showing that the first lockdown caused a temporary migration flow from main cities toward rural areas, also identify several factors influencing this dynamic. Among them, the housing factors, as rural houses are on average larger than city apartments and equipped with external and green spaces, thus, more suitable for home working (Tomaz et al., 2020, p.9) and more comfortable to handle the rules of social distancing and the periods of lockdown. The development of local near-home tourism had represented another important factor when the opportunities for movement outside regional or national boundaries were severely restricted.

Even if the pandemic outbreak started a significant crisis in leisure travel, impacting forms of tourism-based and sharing economies, with up to a 100% decrease in accommodation occupancy rate registered for the week of 21st March compared to previous years (Gössling et al., 2021), several countries reported an increase in rural tourism and staycation. This trend was registered in France[2] and Italy in 2020, with 72% of tourists that preferred destinations nearby their residence and 59% choosing less crowded and famous destinations (ANIASA, 2020). In addition, a new feeling of proximity is rising that pushes people to be part of these territories more than only tourists or villagers (Barca, 2021).

In Italy, these trends appear of particular interest when affecting rural territories marked by constant depopulation since the second half of the XX century to continue hitherto as a consequence of the internal migrations toward areas with better accessibility to services and a better welfare system (Colucci, 2018, p.329). Along with population decline, many Italian rural inner areas suffered a process of progressive deprivation of local know-how, tradition, and culture, hand in hand with the abandonment of built heritage and the shrinking of essential services such as schools, health services, and public transport, but also local services such as small stores, banking services, libraries, bars, jobs as well as a more generalized loss of sense of community. Small demographic growth due to the arrival of amenity migrants (Moss, 1994) or mountaineers by choice (Dematteis, 2012) in some cases have inverted depopulation trends, such as in the French western Alps (Löffler et al., 2016, p.491), or in the eastern part of the Italian Alps (Borsdorf et al., 2012) but did not start a veritable regeneration process.

[1] https://dataforgood.facebook.com

[2] https://www.francebleu.fr/infos/economie-social/l-annee-2020-a-ete-exceptionnelle-pour-les-gites-de-france-en-dordogne- 1608308951

Assuming that the Covid-19 outbreak may have represented an opportunity for the revitalization of inner areas after many years of crisis, the paper aims to investigate if and how this disruptive event has prompted an increase in territorial attendance related to remote working and near-home tourism by making use of mobile phone data tracking human presence in the Apennine area of the province of Piacenza, Emilia Romagna region. The Piacenza Apennine area (around 2,200 km^2) occupies the central and southern portions of the province (Fig.1) and is marked by different orographic and settlement conditions. While the nothern side is primarily flat and hilly, with larger centers and higher population density, the environment becomes typically mountainous while proceeding southward along the major valleys (Val Trebbia and Nure). In this remote and rural part of the territory, which we refer to as the high valleys, the main centers are usually located on the valley floor, along the main roads, surrounded by many small, dispersed hamlets at higher altitudes. Thus, the Apennine high valleys are orographically complex territories with low settlement density where, in the last ten years, significant shrinking processes have affected the mountain villages more than the municipalities in the hilly area and the plains. As for many Italian inner areas, the depopulation process was mainly induced by internal migration towards more dynamic contexts of the province or the Country, only partially contrasted by the arrival of young inhabitants, the return of the old ones after retirement, and the strenuous resistance of those who have always remained here (SNAI report, 2018). As a consequence, the municipalities of the high valley are today characterized by an aging population, low income and educational rate, unemployment, and work/study-related mobility practices over long distances and at high speed, revealing low levels of attractivity and significant dependence on more dynamic areas of the region (Vendemmia et al., 2021).

These trends also explain why some of the municipalities in the high valleys were classified as peripheral according to the Italian National Strategy for Inner Areas (SNAI), an Italian national policy for territorial cohesion and development that classifies the Italian municipalities based on the level of accessibility to three citizenship rights: mobility, education, and health. According to the SNAI, the level of accessibility to these rights is proxied by the driving distance from three essential services: a small/medium size train station mainly served by local trains (defined as *silver-level* stations according to the official classification provided by RFI, the national railway system manager), secondary schools, and hospitals with an emergency room. The resulting classification further identifies three types of peripheral territories: intermediate, peripheral, and ultra-peripheral areas (Materiali Uval, 2014), suitable for the implementation of local policies for territorial revitalization.

Although the Apennine area of the province of Piacenza is affected by complex and long-standing problems common to many other rural and mountainous inner areas, several studies also show that these contexts have high resilience and adaptability to crises (Phillipson et al., 2020). This was the case, for example, during the 2008 financial crisis, and is confirmed for the Covid-19 Pandemic and the climate crisis we are currently experiencing. In this regard, a project conducted in 2020 on Val Nure[3] highlighted that the area might potentially attract new inhabitants from the province of Milan, 100 km far, intercepting different population profiles based on the characteristics of the territory: the most remote and mountainous areas, requested mostly for holiday homes and short stay; central and hillsides, more attractive for remote workers; municipalities on the valley floors which are the most attractive for permanent residents who may also commute toward the main urban centers (Lucatelli and Sonzogno, 2021).

Therefore, a return to these territories as spontaneous migratory flows, such as those that may have occurred since the 2020 lockdown, could represent an opportunity to revitalize these areas and strengthen their role in facing present and future crises.

The remainder of the paper is as follows. Firstly, it introduces the methodology used to measure the space-time variability of human presences in Val Trebbia and Val Nure before and during the Covid-19 lockdown

[3] Appennino in salute, https://fondieuropei.regione.emilia-romagna.it/piani-programmi-progetti/cittadinanza-europea/progetti- 2020/enti-locali/appennino-in-salute

through mobile phone data (section 2). Subsequently, it investigates if two dynamics induced by the pandemic, namely the increase of remote working in sparsely populated, low-connected, poorly accessible territories (section 3) and near-home tourism (section 4), were prompted in the study area and to which extent. Moreover, by analyzing and comparing mobile phone data with conventional data sources, a plurality of trends in the different portions of the study area are unveiled and linked to the intrinsic qualities of the contexts (orography, accessibility and provision of services). Finally, the great potentialities of mobile phone data for territorial research are discussed, along with the significant limits that may prejudice their usability, particularly for research in low-density areas (section 5).

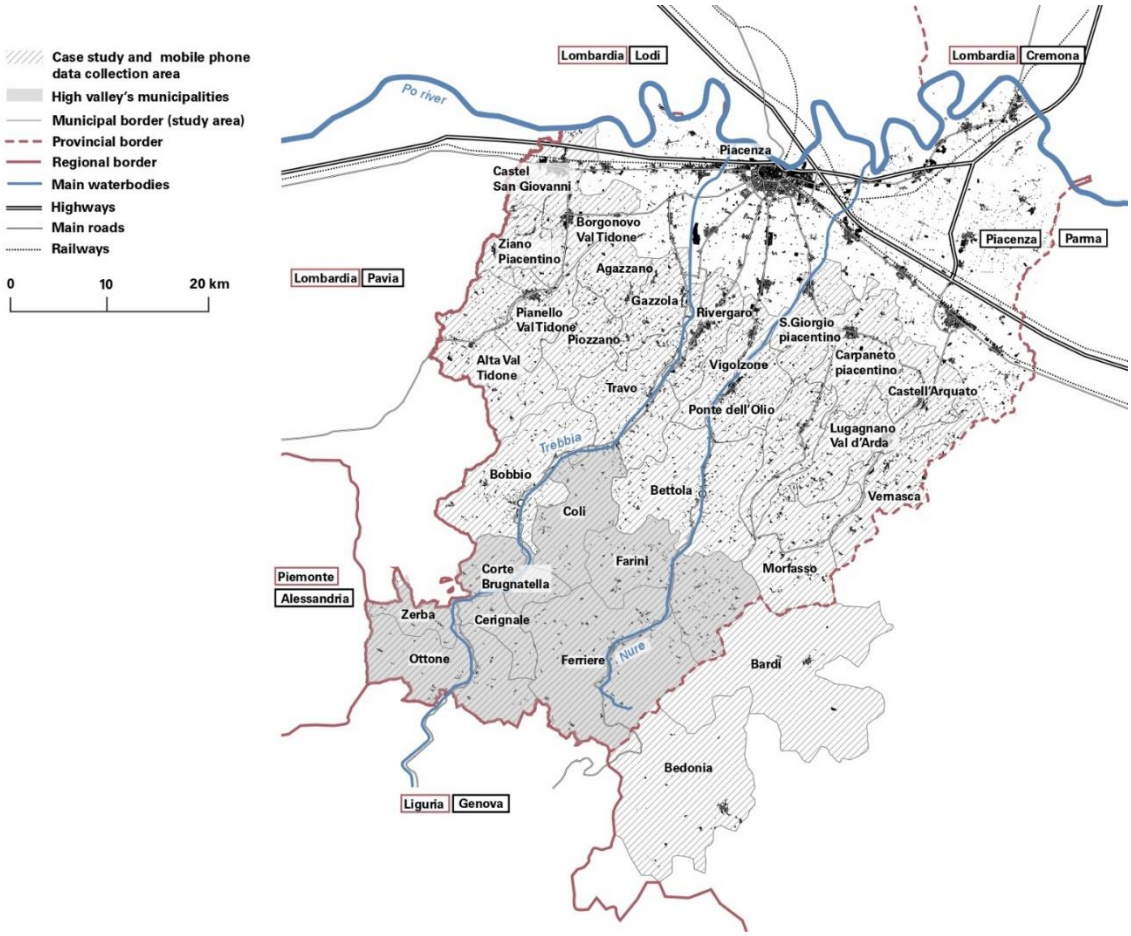

Fig.1 Territorial framework of the municipalities included in the study area

2. Mobile phone data for describing remote working and near-home tourism: the methodology

The paper explores the changes induced by the Covid-19 pandemic in the time-space variability of human presence, focusing on remote working and near-home tourism in the Piacenza Apennine and its high valleys municipalities.

The measurement of these phenomena and their variation, which occurred suddenly and unexpectedly, required the use of different data. In previous work[4], conventional socioeconomic and demographic spatial data were coupled with an accessibility assessment to essential services to build a baseline knowledge of the

[4] The accessibility analysis has been conducted by a research group lead by P. Pucci in 2020 for the General plan of the province of Piacenza 8PTAV) cfr. (PTAV 2020) Dotazione di Servizi, accessibilità e rango dei centri in Piano Territoriale di Area Vasta Piacenza – Quadro conoscitivo. Pp 157 – 164. Source: https://ptavpiacenza.it/wp-content/uploads/2021/05/2021-05-PTAV-Quadro-ConoscitivoWEB.pdf

territory before the pandemic and identify the most marginal areas that could be most positively affected by a revitalization process. More in detail, the socio-demographic profiling of the inhabitants and the evaluation of the levels of accessibility to the basic local and territorial services in the study context allowed the preliminary construction of a "static" overview that confirmed an imbalance between the plain, the hilly area and mountain municipalities.

The latter are in particular affected by a well-known process of depopulation, an employment rate under 20% that is specifically low for the youth, a percentage of NEET up to 20% in some villages, a meager average income, and a high percentage of residents aged more than 75 y.o. (Fig.2).

Additionally, the accessibility analysis confirmed the disparity between the northern plains and the high valley municipalities in terms of the availability and accessibility to daily services due to the low population and high dispersion of the hilltop settlements generating an insufficient demand for the maintenance of local activities and reliable public transport systems.

This study also confirmed the crucial role of Bobbio (Trebbia Valley) and Bettola (Nure Valley) as the major centers and poles of reference for the marginal areas of the mountain, thanks to the availability of a good range of essential services.

The small data processed for the first analysis provides an outdated and static framework of the trends affecting the territory, unable to describe the impact of disruptive phenomena such as the Covid-19 Pandemic and to show their longitudinal evolution with a high spatial and temporal resolution in the areas of analysis.

For this reason, conventional data have been combined in this research with mobile phone records tracking human presence provided by TIM, one of the leading telecommunication operators in Italy.

Data were supplied covering 31 municipalities, 29 in the province of Piacenza and 2 in the neighboring province of Parma, in Ceno's valley, but with similar socioeconomic characteristics to the Piacenza province high valleys. Not all the municipalities included in the case study area fall within the geography of the high Apennine valleys (see Fig.1). Indeed, some are located in the intermediate hilly area, but they were considered in the analysis because, although they do not suffer from the same problems as the mountain villages, they are part of the same territorial system and have continuous relations with the more peripheral area of the province.

Thus, their inclusion in the analysis is useful in comparative terms to identify how certain phenomena manifest differently according to the settlement and socioeconomic characteristics that co-exist in the study context.

The TIM data used for the present research work record the absolute number of telephone users located within a territorial unit of analysis (the municipality)[5] at 15-minute intervals. Together with the measurement of human presence, TIM data offer demographic information of the users (age, gender) and define profiles corresponding to users' nationality and travel behaviors.

The latter are defined by TIM based on the user's prevalent location during daytime and nighttime to determine if they can be classified as residents, commuters, intra/extra regional or foreign visitors of the municipality where they are registered.

Putting in value the preliminary socio-spatial framework provided by statistical data and the spatial analysis showing the peculiar territorial morphology characterized by the presence of municipalities with wide territorial extensions, scattered and small hamlets, and sprawled settlements, two different analytical scenarios were foreseen:

- a so-called *standard scenario*, with mobile phone data collected and aggregated at the municipality level;
- a *custom scenario*, in which the municipalities were divided into sub-areas based on the settlement characteristics (main centers, hamlets, industrial areas) to better reproduce the distribution of human presence at the micro-scale, particularly for low-density areas.

[5] For a description about the TIM Data processed, see Manfredini et al. in this special issue.

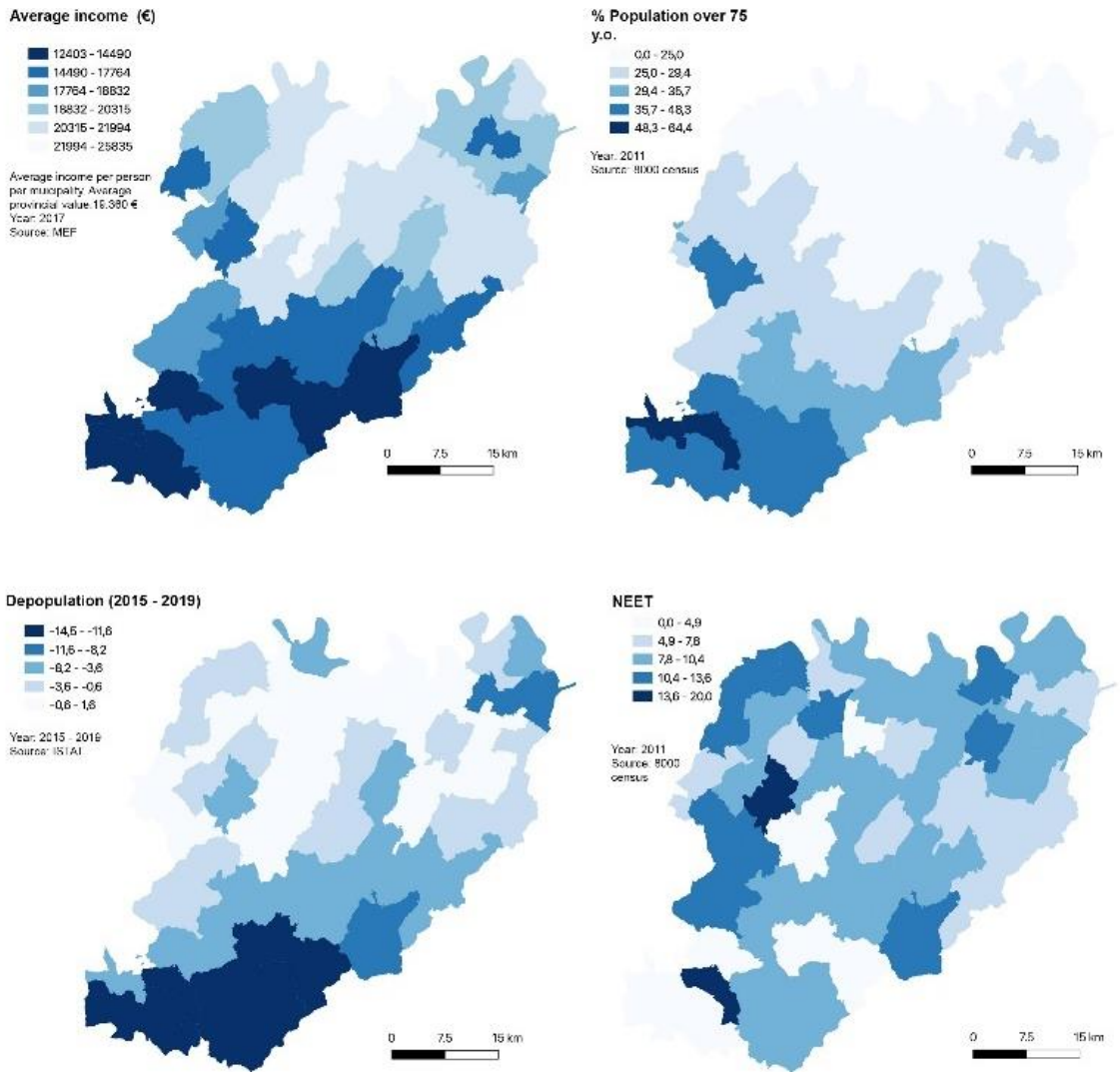

Fig.2 Demographic and socioeconomic data in the Province of Piacenza (source: our elaboration on Istat and MEF data)

The latter scenario posed evident interpretative problems due to the TIM data features (see paragraph 5). Therefore, it was excluded from the present analysis, even if it could have provided relevant information to measure how human presence is distributed in time across the territory with a greater level of detail.

Data were collected over five weeks: 15-21 July 2019 (pre-lockdown summer break), 23-29 September 2019 (pre-lockdown working week), 23-29 March 2020 (lockdown period), 13-19 July (post-lockdown summer break), 21-27 September (post-lockdown working week), aggregating the presence value by 15-minute time slots. We selected the 23-29 September period as a typical pre-pandemic working week serving as a reference baseline for the analysis. Events recorded along the baseline week, such as weekly markets, festivals, long weekends, school openings, and holidays, showed common trends that allowed comparison between different areas of the territory.

As previously described, the present analysis focused on the changes in human presence related to remote working and near-home tourism straddling the Covid-19 Pandemic, identifying these as phenomena that might have increased over the lockdown period. To carry out the investigation, mobile phone data were analyzed to understand the general variability of human presence in the baseline week and then compared with lockdown and post lockdown periods.

Regarding the analysis on remote work trends, human presence variability was observed on a daily basis in five different time slots: early morning (from 6 a.m. to 8 a.m.), morning (from 9. a.m. to noon), afternoon (from 1 p.m. to 6 p.m.), evening (from 7 p.m. to 10 p.m.) and night (from 11 p.m. to 5 a.m.), focusing on

working days (Monday to Friday). We have then considered the variability of the average number of human presence in the different timeslots. This operation allowed profiling the municipalities based on their propensity to be "stable", "attractors", or "generators" of daily human presence. The comparison between the baseline week, the lockdown working week (23-29 March 2020), and the post-lockdown working week (21-27 September 2020) helped to understand how remote working and learning may have contributed to modify the rhythms of presence and mobility in the study area during working hours, and if those practices may represent a potential driver for the repopulation of some municipalities with new inhabitants occupying family or holiday houses and working remotely.

To investigate the near-home tourism during July 2020, when the freedom to travel entered a period of enforced abeyance, we compared the trends described by mobile phone data during the baseline week (23-29 September 2019) assumed as a period with limited amounts of tourists, with two summer break weeks in July 2019 (pre-Covid-19) and July 2020 (during the Covid-19 pandemic). The aim is twofold. On the one hand, data can help highlight the extent of the pre-Covid tourism in the study area, measured as the difference in the amount and spatial distribution of human presence between typical pre-pandemic vacation and working periods. On the other hand, the aim is to measure the variation between a pre and post-Covid outbreak summer break to highlight the possible increase of near-home tourists during Covid-19 and the potential impact on the further development of tourism in these territories.

3. Variability of the human presence and the role of the remote working

TIM mobile phone data analysis described the variability of human presence in each municipality of the study area during working days considering five timeslots, as explained in the methodology section. Therefore, based on the trends detected during the baseline week period before the pandemic outbreak, three main profiles were identified – Stable, Attractor and Generator - regarding the attractiveness of each municipality based on the variation of human presence on different hours and weekdays. Stable municipalities are characterized by a non-significant variability of human presence between the different moments of the day. Municipalities are defined as attractors when the average human presence increases from the early morning until the evening (working hours). Conversely, generators are municipalities that lose population from the early morning to grow back in the afternoon until night when the peak is registered. These profiles also implicitly describe the characteristics of the offer of jobs and services in the different municipalities.

In a typical pre-pandemic baseline week (September 2019), among the 31 municipalities considered only Castel San Giovanni, in the North-West of the province, is gaining population from early morning, reaching a peak of human presence in the afternoon, defining the city as 1) attractor. The capacity to attract people during the day is due to the presence of platforms for transport and logistics that generate important job mobility toward this city. On the contrary, we have identified some municipalities as 3) stable, as they are subject to non-significant variability of human presence during the different moments of the day. Those are mainly mountainous villages located in the high valleys, with high depopulation and unemployment rate and a high percentage of elders. The remaining municipalities have been defined as generators because the highest number of people has been registered at night. In contrast, the number of human presence decreases in the early morning to grow again in the late afternoon and at night. It is still possible to notice that some of the generator municipalities, mainly the ones located on the valley floors, such as Gazzola, Bettola, and Bobbio, even losing presence in the morning, are characterized by a peak of presence in the evening, suggesting that they attract small flows of users for leisure and nightlife.

Generally, those generator municipalities are located on the foothill, in the outskirts of Piacenza and Castel San Giovanni, because their inhabitants are probably moving every day to those more attractive places for work or study reasons. Nevertheless, even though education is one of the most important commuting reasons, the low percentage of the population under 18 y.o. living in the area and the lower diffusion of mobile phones

among the youngest population groups[6] do not allow to make relevant considerations about commuting for study reasons in this work.

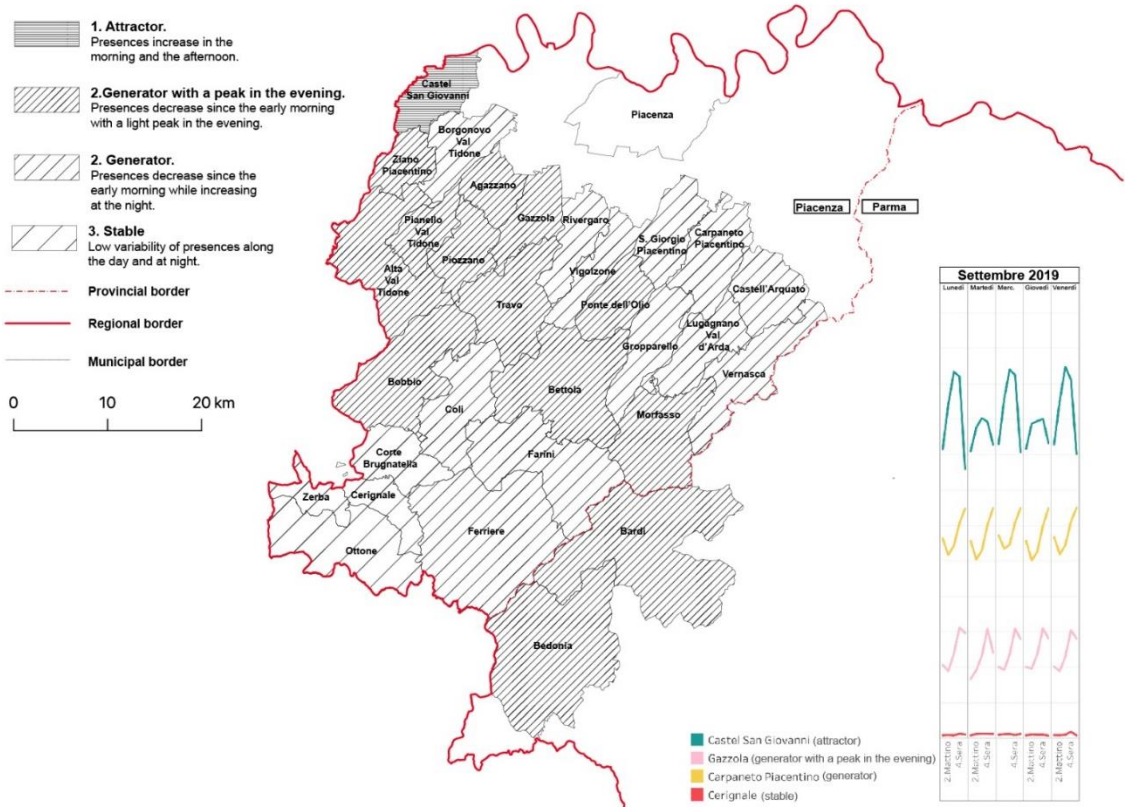

Fig.3 Four profiles of the municipalities and the trend of human presence (source: our elaboration on TIM data)

Comparing the baseline week with March 2020, the first lockdown in Italy, and September 2020 (Fig. 4), it is evident that Castel San Giovanni registered only a slight reduction of presence in March 2020 during the day, with unvaried human presence at night, but a significant increase in September 2020. As stated before, Castel San Giovanni hosts important transport and logistic platforms requiring employees to work on-site both day and night, even during the lockdown. At the same time, the post-Covid-19 growth in delivery, transportation, and warehouse jobs related to the e-commerce sector (Mckinsey Global Institute, 2021) may explain the increase in local presence registered in September 2020.

The data show that among the municipalities considered stable, the most geographically marginal high valleys municipalities such as Zerba, Corte Brugnatella, and Ottone lost population in March 2020 and registered a further general decrease in September 2020. It is possible to guess that the low accessibility of these territories caused a migratory flow toward the cities and the villages of the plain during and after the lockdown to have better access to basic services. On the opposite, Cerignale, despite its remoteness, gained population in March 2020 and still in September 2020.

The municipalities defined as generators are generally characterized by low variability of presence in March 2020 and September 2020, apart from San Giorgio Piacentino and Bettola, where the population increased

[6] Tim data on human presence are classified based on the age of the sim card owner, including the age range 0-18. According to Census data in 2018 the 54,6% of this group was using a mobile phone (the 17,6% of population aged 4-10, the 90,8% of population aged 11-17, while population 0-4 is not reported) although only the 47,9% of the group was owning the device. The percentage of use rises to 97,2% for population aged18-34 y.o. and 85,8% for population aged 35-64 y.o. While decreases to 27,8% for population over 65 y.o. Source: 1° Rapporto Auditel-Censis. Convivenze, relazioni e stili di vita delle famiglie italiane, Roma, 25 Settembre 2018. Availabe at: https://www.censis.it/sites/default/files/downloads/Sintesi_3.pdf. Accessed 04/01/2022. Furthermore, children under 8 are not allowed to buy a TIM sim card, while until 16 years is needed the consent from both parents, which are in many cases the official owners of the sim for their kids.

during the lockdown and still registered a higher number of human presence in September 2020 compared to the same month in 2019.

The analysis highlights the following trends: in some municipalities, such as Bobbio, Travo, Ponte dell'Olio, and Carpaneto Piacentino (see Fig.4), a smaller delta between night and morning during the lockdown suggests that fewer people were commuting every day from those municipalities to work taking advantage of remote working[7], to return at pre-Covid trends in September 2020 (see for example Carpaneto Piacentino, Fig. 4). In other cases, a general increase in human presence was registered in September 2020 (see, for example, Gazzola in Fig.4), with a significant delta between day and night and a decrease in presence in the early morning.

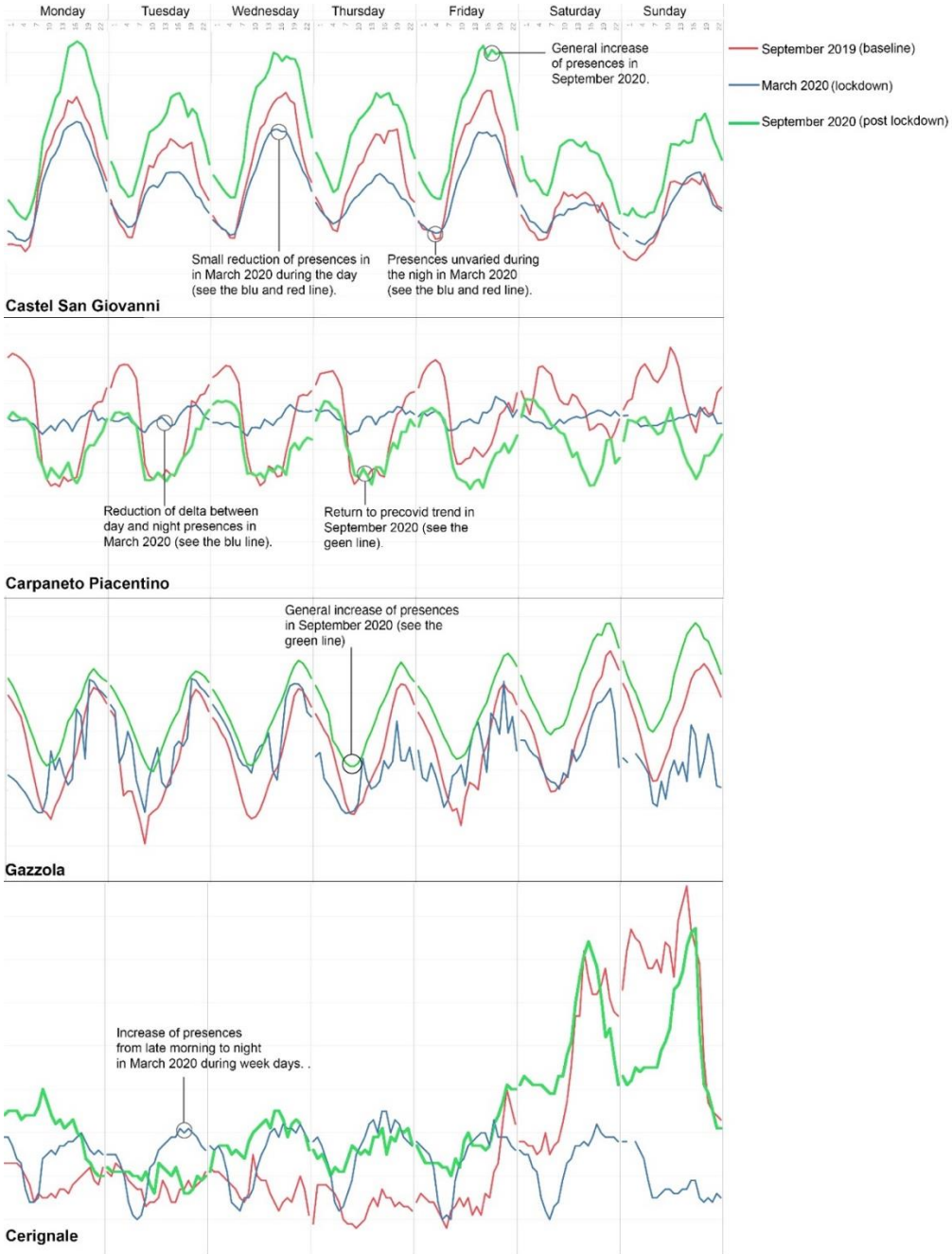

Fig.4 Human presence values in four municipalities of the study area. Comparison between September 2019, March 2020 and September 2020. (source: our elaboration on TIM data)

[7] Data collected in Italy show that the percentage of employees working remotely increased during the first lockdown in March and April 2020 and afterward, going from 58% to 97% in large companies and from 16% to 94% in public administrations (Osservatorio Smart Working, 2020), with 60% of workers that would like to continue remote working after Covid. Source: https://www.ilsole24ore.com/art/lavoro-cgil-8-milioni-italiani-smart-working-epidemia-covid-19-AD7aAMR?refreshce=1, accessed 16/09/2021

These cases suggest that new residents that commute every day for work and study-related reasons might have oriented their residential choices toward those generator territories following the Pandemic outbreak. Undoubtedly, the reduction of the differences between day and night in human presence in March 2020 in nearly all the municipalities of the study area with higher numbers during the morning confirms that "confinement measures are fomenting remote working practices, remote learning and e-services" (OECD, 2020, p. 4).

Additionally, the most remote municipalities, which have limited internet and transport connections, lose presence in favor of the municipalities on the high valley floors and along the main roads. On the one hand, this last trends exacerbate pre-existing problems related to the abandonment and depopulation of mountainous inner areas. On the other, it suggests that forms of smart working can still redirect residential choices toward lower-density areas in the high valleys and may also be extended to the most remote municipalities, provided that physical and virtual accessibility to goods and resources is improved and ensured.

4. Near-home tourism

Studying the near-home tourism during the Covid-19 Pandemic can reveal "aspects of holidaymaking practices, possible path dependencies, prospects for habit changes, and indications of holidaymaking adaptation to a post-pandemic and conceivably also a low-carbon future" (Jens et al., 2021). In the study area, it represents an additional topic to analyze the potentialities for increasing the attendance and touristic attractiveness of the territory, especially the high valleys, and supporting new economies for these marginal areas. In fact, the high Val Trebbia played a significant role as a vacation destination in the past, offering valuable equipment for tourists[8].

Based on this perspective, the pandemic could be a starting point to transform tourism activity (Cheer, 2020; Nepal, 2020) and offer an opportunity for more sustainable forms of near-tourism (Lew et al. 2020; Romagosa, 2020), enabling the future economic and social development of these valleys.

The comparison between the baseline week (23-29 September 2019), the summer weeks in July 2019 (15-21) and July 2020 (13-19) of intra-regional, extra-regional, and foreign visitors' presence highlights a slight increase in the attendance during the pandemic, especially on the weekend and in particular on Sundays. These trends affect the study area differently: in the northern hilly area, the July 2020 trend is similar to the baseline of September 2019, highlighting a non-touristic vocation of these territories. Conversely, in the high valleys, a relevant increase in human presence in July 2020 in all the municipalities emerges, particularly during the weekend and starting from Friday evening. In these mountain areas, forms of near-home tourism prevail that are concentrated on the weekends, with human presence coming almost exclusively from the same region and characterized mainly by daily attendance. This trend may be a consequence of the diffused presence, in the high valleys, of sports and leisure equipment (Fig.5), trekking opportunities, and cultural events organized during the summertime.

Therefore, the Covid-19 has led to a general slight increase in summer human presence in the municipalities of the study area, specifically concentrated on weekends and in some more attractive centers such as Bobbio, where the weekly market on Sunday attracts many visitors (+26% in weekend attendances). However, the increase is not equally distributed since the most peripheral and mountainous villages of the high valleys (Ottone, Ferriere, Farini, Cerignale, Zerba, Coli, Corte Brugnatella), characterized by a lack of services and facilities and low accessibility, were affected by a slight drop in presence during July 2020 compared to the previous year. However, if these figures indicate that the more peripheral municipalities were less affected by the propulsive effect of Covid-19 on the increase in tourist attendance, a comparison between the presence values during the summer break and the baseline (September 2019) in the same centers still shows that

[8] Spas in Bobbio, beaches in Bobbio and Marsaglia equipped also for the canoeing, horseback riding.

mountainous villages are more populated and lively during summertime and steadily attractive for vacationers regardless the effect of the pandemic (Fig.6, right side).

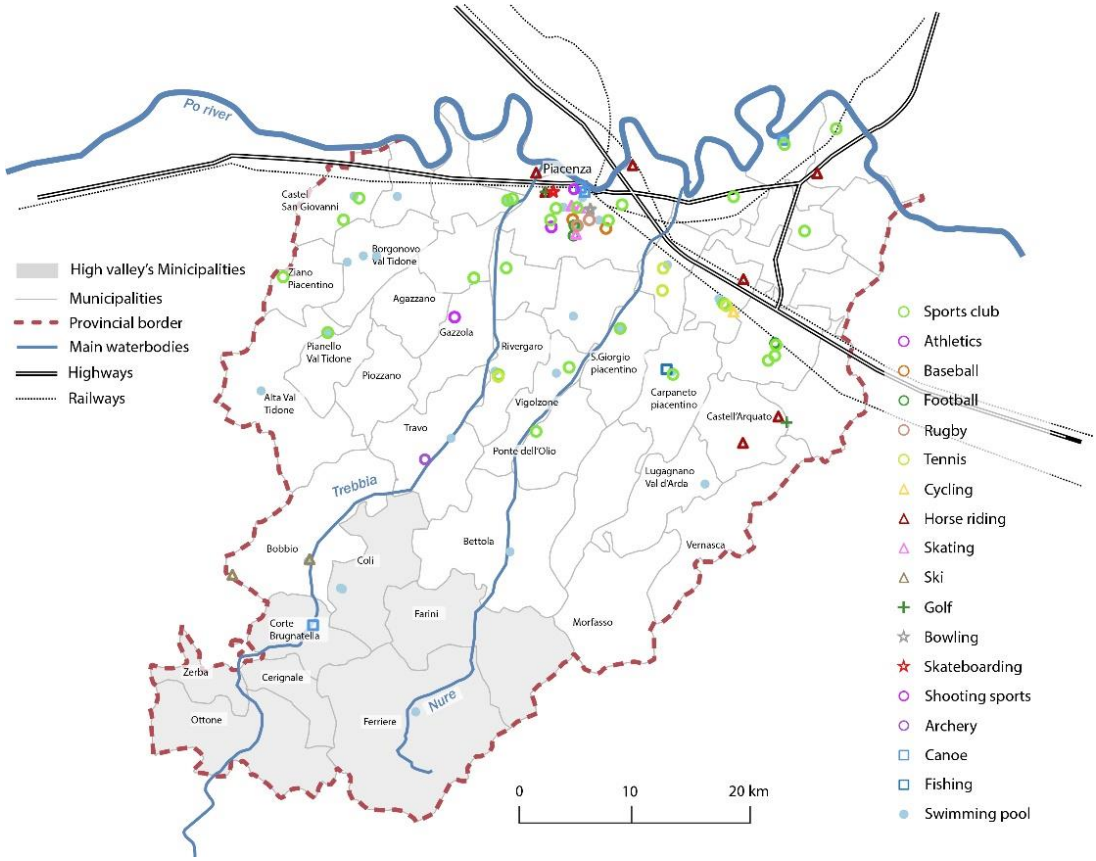

Fig. 5 Map of localization and typology of sports equipment in the province of Piacenza, affecting near-home tourism

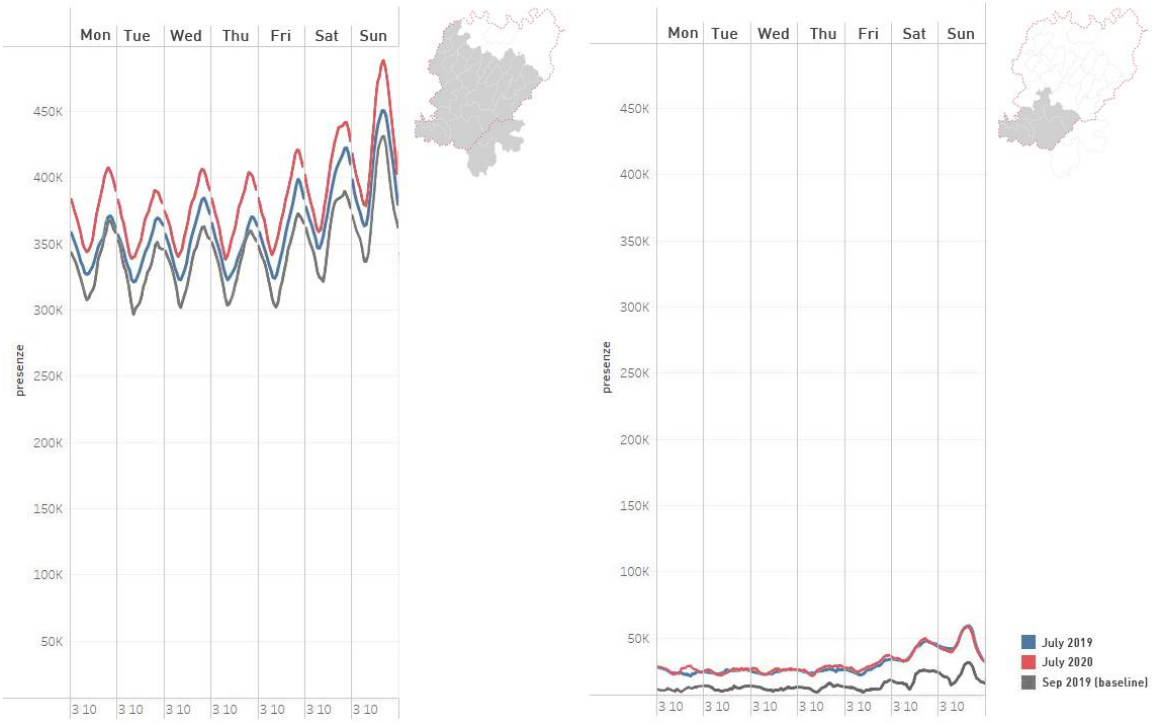

Fig.6 Total human presence values in the whole study area (left) and the high valleys (right). Comparison between July 2019, September 2019 and July 2020

Still, the study area and the high valleys municipalities are mainly a destination for short-range tourism, as visitors from the Emilia Romagna region are significantly more than those outside. Foreigners - in modest numbers in July 2019 - are almost absent in 2020 also due to the restrictions on international travels that were in place during that period. Visitors inside and outside the region confirm the pre-pandemic trend, although there is a slightly more significant presence on weekdays than in July 2019. This trend implies that, alongside daily tourism, a slight increase in sedentary tourism could be noticed, which involves significantly more visitors from the region (Fig. 7).

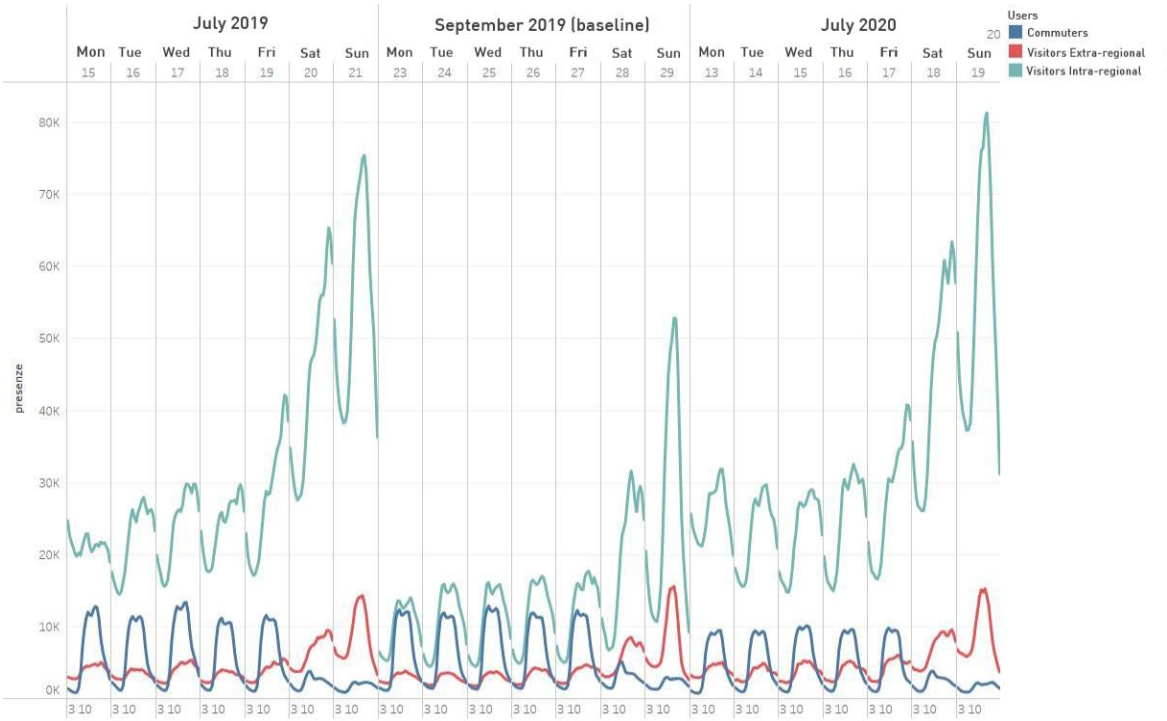

Fig.7 Human presence by type of user in the highr valleys

Considering the profiles by age in July 2019 and July 2020, the human presence mainly concerns people over 60 years old, with a stable trend. The other age groups, albeit less represented in the high valleys, were more present in July during the pandemic than the baseline week in September, with significant peaks on weekends. In conclusion, the trends measured through mobile phone data do not show substantial transformations in the touristic uses of the area of study. The main exception concerns a general increase in the number of presence that proved to be almost uniquely concentrated in specific parts of the territory such as major high valleys urban centres (Bobbio) and in the municipalities that offer a wider availability of sports and leisure-related activities. The marginality of these changes between a pre and post-lockdown period confirms that "path dependencies towards second homes and spatially stretched social obligations, as well as the emphasis on freedom of movement, ostensibly constrain vacation travel habit discontinuities at this time of the year" (Jens et al., 2021).

5. Limits and potentialities of mobile phone data in sparsely populated areas

The research approach based on mobile phone analysis has shed light on several aspects related to the potential contribution of these sources of information for scientific research on inner areas, their fragilities, and the existing spatial-temporal dynamics of human presence and mobility. More precisely, it emerged how digital data could support the analysis of territorial phenomena otherwise challenging to identify and investigate with conventional sources based on "small" data, as in the case of the remote working during the lockdown and post-lockdown and the near-home tourism during the pandemic, when displacement restrictions pushed many families to change travel programs in favor of closer destinations.

Concerning remote working, the use of mobile phone data revealed the higher human presence in nearly all the municipalities of the two valleys, except for the very remote ones, during the Covid-19 lockdown and in some cases also after. This result highlights the potentiality of promoting remote working in these territories, confirming the existence of municipalities more attractive for remote workers, and others that are more likely to host new residents that could commute to big cities (Lucatelli and Sonzogno, 2021). These results are also confirmed by other research on the topics. Beria and Lunkar, (2021) thanks to the use of Facebook data for good, have measured a massive displacement from the big cities in March 2020 toward intermediate territories and, to a lesser extent, toward peripheral and ultra-peripheral areas, suggesting that the increase of population in suburbs and rural areas was a consequence of the lack of commuting. This pattern is also confirmed by more qualitative works. A recent research based on a survey of residents and remote workers on Campo Ligure, a small village in the province of Genova, highlighted that during and after the lockdown of March 2020, many residents avoided commuting, while workers from abroad temporary moved to live in the town thanks to remote working (Larsen et al., 2021). Nevertheless, the lack of transport, fast connections, and the distance from the workplace were among the main reasons not to move permanently to live in the village, suggesting that improvements need to be made to turn remote working into a compelling opportunity for recovering rural areas.

In this perspective, mobile phone data analysis offers the opportunity to understand the spatial and social patterns of frequentation of the valleys and whether these dynamics can represent a resource in the medium-term period for these territories and their economies. Simultaneously, the approach has shown that data-driven research requires essential management and analytical skills coupled with the careful construction of methodological frameworks. These are necessary conditions due to the characteristics and, above all, the intrinsic limits of mobile phone data, which may prejudice their usability in research aimed at exploring complex mobility patterns.

The first relevant limitation encountered in this work concerns the relationship between a research question and the possibility that the data, as they are collected and made available by owners and providers, can offer valuable and rigorous answers. The problem, already raised by Miller (2010), is related to the fact that digital data, expensive to generate, process, and store, are produced in very controlled ways using sampling techniques that limit their scope, size, and temporal detail. For this reason, the possibilities for researchers to customize and query preconfigured data provided with some easy-to-use basic features are minimal, making them not always adequate to answer complex research questions except through intensive processing or data fusion (Calabrese et al., 2010). Exploring the phenomena of interest in the case of the Piacenza Apennines required the use of preliminary analysis on socioeconomic and accessibility conditions based on conventional data necessary to contextualize and interpret the spatiotemporal patterns emerging from the data (Alexander, 2015). Therefore, mobile phone data analysis was not considered a stand-alone research methodology but became a compendium of a more comprehensive mixed-method research approach.

A second limitation relates to the low spatial flexibility of the data and the available high level of aggregation. Since Telecommunication operators gather mobile phone data unrelated to scientific research, the collected and processed data by TIM are not entirely suitable for spatially disaggregated analysis at the sub-municipal scale. At the same time, these data offer a somewhat limited spectrum of options for socio-demographic profiling (Calabrese et al., 2010). If, in the latter case, the in-depth analysis of individual characteristics and behaviors would raise critical issues due to privacy concerns and the limited scope of socio-demographic data collected by the operators, increasing the spatial disaggregation of the data represents a more concrete opportunity. In the Piacenza Appennine case study, an attempt was made to measure human presence at the sub-municipal scale to explore their temporal variations in rural areas and the sparsely located hamlets. Given the technical complexity of the request, the attempt did not return valid results, effectively limiting the significance of the contribution of mobile phone data to the analysis of micro-scale dynamics such as differences in the presence patterns of tourists and workers in different areas of the same municipality.

Finally, a third limitation concerns the reliability of the mobile phone data collected and processed in a low density and aging context as that of the Apennines of Piacenza. When compared to dense urban environments, rural areas present a sparser distribution of antennas that are the basic infrastructure to infer user location, with the risk of underestimating the movements of individuals and returning spatially incorrect results (Williams et al., 2015) in the municipal-level redistribution of hourly tracking. Such a problem is reflected in the significant occurrence of outlier values in more remote and less populated municipalities, which the algorithm used to translate the raw data into geospatial position is not always able to correct. Also entrusted to recalculation algorithms is the quantification of presence based on the market share of the telephone company, a step that can, in turn, create bias linked to the uneven territorial distribution of customers (Salat et al., 2020). This aspect is also reflected in the representativeness of different age groups, especially in territories inhabited by high percentages of youngsters and the elderly. However, this latter bias seems to become less relevant thanks to the steady growth of mobile phone penetration in all age groups in Italy and other countries around the world (Deloitte, 2019).

The limitations encountered, even if significant, can be overcome or, at least, mitigated by fruitful collaboration and negotiation between the data provider and the research institution and by referring to the numerous experiences in the literature that confronted these well-known issues [9].

At the same time, the awareness of limitations can lead to a more mature use of these data, which can have interesting implications in the field of academic research and for multisector policy making. In fact, mobile phone data proved to be valuable in the analyzed case to describe specific trends with a higher speed of update and detail than conventional data, potentially providing public administrations with a more complete picture of what is happening within the territory in terms of attendance, socio-demographic profiles of the users and inhabitants of the territory, use of services and infrastructure, and seasonality of these usually hidden dynamics. Possible applications relate, for example, to the provision of services to attract populations capable of working remotely, to be implemented as a priority in those contexts that have shown an ability to attract these professionals, by designing policies that promote the creation of coworking spaces in rural areas, supporting a significant trend already developed in many European countries (Flipo and Ortar, 2020; Capdevila 2021). The most urgent action, in this perspective, concerns the extension of the internet network and the provision of spaces with high-speed Internet (often unavailable in the study context). However, these "basic" actions, already undertaken through the fiber optic extension plan[10], should be followed by a substantial improvement of local proximity services for daily subsistence in the most peripheral villages whose current absence hinder the possibility for remote workers to moving permanently into the territory and represent a factor generating profound territorial inequalities. This proposal is also consistent with the objectives of local policies that are under implementation in the study area (e.g., the SNAI strategy) that could profitably use the information provided by the exploitation of digital data for designing strategic interventions.

More geographically precise data could also allow the observation of more minute phenomena of human presence related to work activities, even at a sub-municipal scale, identifying the potential for attractiveness even in more peripheral areas found to be poorly affected by the increase in remote working observed at the aggregate provincial level.

Instead, the analysis confirmed the general attractiveness of the area and the high valleys, especially for near-home tourism. The information gathered through mobile phone data can be useful in tourism service planning, identifying the most attractive areas of the province, measuring the impact of public gathering events, and profiling the frequenters of different parts of the territory according to seasonality and local events. This is a basic knowledge that, combined with data on the territorial supply of leisure facilities and accommodation,

[9] For an account, see Manfredini, Lanza and Curci in this special issue.

[10] To this regard, refer to BUL (Broadband extension plan) adopted by Regione Emilia Romagna. https://digitale.regione.emilia-romagna.it/notizie/archivio/2017/settembre/banda-ultra-larga

can support the development and targeting of the services for tourists and, more generally, assist the strategic development of this sector by making it a resource for the revitalization of the Apennine area.
Undoubtedly, telephone data still represent a relevant opportunity to be further explored to analyze "hidden" spatio-temporal practices both in dense urban settings and in dispersed, low-density territorial contexts, provided that researchers and public administration can get easy access to high-quality data. As a matter of example, future research prospects could include the analysis of existing forms of immobility - by gender and age - in the municipalities characterized by low accessibility and lack of daily services where the use of mobile phone data provides insights for reading the possible inequalities in the access to urban opportunities, and the profiling of the use and consumption, diversified by timing, for updating the land-use classification without the burden of a direct survey.

References

Alexander, L., Jiang, S., Murga, M., González, M. C. (2015). Origin–destination trips by purpose and time of day inferred from mobile phone data. *Transportation Research Part C: Emerging Technologies, 58, 240–250.* https://doi.org/10.1016/j.trc.2015.02.018

ANIASA (2020). Trionfa il turismo di prossimità, l'Italia è la meta preferita dal 94% degli intervistati: Trentino-Alto Adige (15%), Toscana (11%), Sardegna e Puglia (entrambe 8%) le regioni più scelte. 17/09/2020. Retrieved from: https://www.aniasa.it/aniasa/aniasa-informa/public/ultime_dal_settore/4070. Accessed: 01/01/22

Banai, R. (2020). Pandemic and the planning of resilient cities and regions. *Cities* 106 (2020) 102929. https://doi.org/10.1016/j.cities.2020.102929

Barca, F. (2021). Costruire il territorio, redistribuire i poteri. In F. Barbera, A. De Rossi (eds.*) Metromontagna. Un progetto per riabitare l'Italia*. Roma: Donzelli editore.

Beria, P., Lunkar V. (2021). Presence and mobility of the population during the first wave of Covid-19 outbreak and lockdown in Italy. *Sustainable Cities and Society 65 (2021) 102616.* https://doi.org/10.1016/j.scs.2020.102616

Bonaccorsi, G., Pierri, F., Cinelli, M., Flori, A., Galeazzi, A., Porcelli, F., Schmidt, A.L., Valensise, C.M., Scala, A., Quattrociocchi, W., Pammolli, F. (2020). Economic and social consequences of human mobility restrictions under COVID-19. *PNAS*, July 7, 2020, vol 117, n. 27. 15530-15535. https://doi.org/10.1073/pnas.2007658117

Borsdorf, A., Hidalgo, R., Zunino, H. (2012). Amenity Migration: a comparative study of the Italian Alps and the Chilean Andes. *Journal of Sustainability Education* Vol. 3, March 2012 ISSN: 2151-7452

Boterman, W. R. (2020). Urban-rural Polarisation in Times of the Corona outbreak? The early demographic patterns of the sars-cov-2 epidemic in the Netherlands. *Tijdschrift voor Economische en Sociale Geografie* – 2020, https://doi.org/10.1111/tesg.12437, 111 (3), 513–529.

Calabrese, F., Di Lorenzo, G., C. Ratti, C.(2010). Human mobility prediction based on individual and collective geographical preferences, *13th International IEEE Conference on Intelligent Transportation Systems*, 312-317, https://doi.org/10.1109/ITSC.2010.5625119.

Capdevila, I., (2021). Spatial processes of translation and how coworking diffused from urban to rural environments: The case of Cowocat in Catalonia, Spain. In Hracs, B., Brydges, T., Haisch, T., Hauge, A., Jansson, J., Sjöholm J. (eds). *Culture, Creativity and Economy*, London : Routledge, 14-30.

Chandran, R. (2020). City centres to see "radical' redesign amid coronavirus. *Thomson Reuters Foundation*. Retrieved from: https://news.trust.org/item/20200602231724-6k5a2/. Accessed 01/01/22.

Cheer, J.M, (2020). Human flourishing, tourism transformation and COVID-19: A conceptual touchstone. *Tour. Geogr.*. 22, 514–524.

Colucci, M. (2018). Antichi percorsi, nuove mobilità: le migrazioni interne. In F. Barbera, A. De Rossi (eds.) *Riabitare l'Italia. Le aree interne tra abbandoni e riconquiste* (317 – 332). Donzelli, Roma.

Deloitte (2019) Smartphone, Smart City, Smart Life. Global Mobile Consumer Survey 2019. Italian cut. Retrieved from: https://www2.deloitte.com/it/it/pages/technology-media-and-telecommunications/articles/global-mobile-consumer-survey-2019---deloitte-italy---tmt.html. Accessed 03/01/22

Dematteis G. (2012). La metro-montagna: una città del futuro. In Bonora P. (ed.), *Visioni politiche del territorio. Per una nuova alleanza tra urbano e rurale*, Archetipolibri, Bologna, 85-92.

FAO (2021). Reverse migration to rural areas of origin in the context of the COVID-19 pandemic. Retrieved from: https://www.fao.org/publications/card/en/c/CB4712EN/. Accessed 01/01/22.

Flipo, A., & Ortar, N. (2020). Séparer les espaces pour maîtriser le temps, *Temporalités* [En ligne], 31-32. https://doi.org/10.4000/temporalites. 7712

Gargiulo, C., Gaglione, F., Guida, C, Papa, R, Zucaro, F., Carpentieri, G. (2020). The role of the urban settlement system in the spread of Covid-19 pandemic. The Italian case. *TeMA Special Issue.* Covid-19 vs City-20, 189-212. https://doi.org/10.6092/1970-9870/6864

Gössling, S., Scott, D, & Michael Hall, C., (2021) Pandemics, tourism and global change: a rapid assessment of COVID-19, *Journal of Sustainable Tourism*, 29:1, 1-20, https://doi.org/10.1080/09669582.2020.1758708

Jens, Kr., Jacobsen, S., Farstad, E., Higham, J., Hopkins, D., & Landa-Mata, I. (2021): Travel discontinuities, enforced holidaying at home and alternative leisure travel futures after COVID-19, *Tourism Geographies*, https://doi.org/10.1080/14616688.2021.1943703

Klaus, I. (2020). Pandemics Are Also an Urban Planning Problem. Will COVID-19 change how cities are designed? Michele Acuto of the Connected Cities Lab talks about density, urbanization and pandemic preparation. *Bloomberg CityLab*. Retrieved from: https://www.bloomberg.com/news/articles/2020-03-06/how-the-coronavirus-could-change-city-planning. Accessed 01/01/22

Kunzmann, K.R. (2020) Smart Cities After Covid-19: Ten Narratives, *disP - The Planning Review*, 56:2, 20-31, https://doi.org/10.1080/02513625.2020.1794120

Larsen, D.C., Seeberg Dyremose, K., Guazzardi L. (2021). *Shrinking towns and Post Pandemic: Smart workers as possible trigger for regrowth, a Case Study of Campo Ligure*. Master thesis, Aalborg University. Retrieved from: https://projekter.aau.dk/projekter/en/studentthesis/shrinking-towns-post-pandemic-smart-workers-as-possible-trigger-for-regrowth-a-case-study-of-campo-ligure(e33326e2-e3a5-4159-ab7a-ff34cfe6beab).html

Lew, A.A., Cheer, J.M., Haywood, M., Brouder, P. & Salazar, N.B. (2020). Visions of travel and tourism after the global COVID-19 transformation of 2020. *Tour. Geogr.*, 22, 455–466.

Löffler, R., Walder, J., Beismann, M., Warmuth, W., Steinicke, E. (2016). Amenity Migration in the Alps. Applying Models of Motivations and Effects to 2 Case Studies in Italy. *Mountain research and development*, 36(4): 484-493. https://doi.org/10.1659/MRD-JOURNAL-D-16-00042.1

Lucatelli, S., Sonzogno, G. V. (2021) Confini, sviluppo locale e relazioni aree interne/aree urbane. L'esperienza Snai e I legami tra territori. In F. Barbera, A. De Rossi (eds.) *Metromontagna*. *Un progetto per riabitare l'Italia*. Roma: Donzelli editore.

Manzini Ceinar, I., Mariotti, I. (2021). Teleworking in post-pandemic times: may local coworking spaces be the future trend? *Romanian Journal of Regional Science Vol. 15, No. 1, Summer 2021*

Materiali Uval. (2014). Strategia nazionale per le Aree interne: Definizione, obiettivi, strumenti e governance. Materiali Uval n. 31 anno 2014. Retrieved from: http://www.dps.gov.it/it/pubblicazionidps/materialiuval. Accessed 01/01/22.

McFarlane, C. (2021). Repopulating density: COVID-19 and the politics of urban value. *Urban Studies,* special issue article: Urban public health emergencies and the COVID-19 Pandemic, 1-22. https://doi.org/10.1177/00420980211014810

McKinsey Global Institute (2021). The future of work after COVID-19. Retrieved from: https://www.mckinsey.com/featured-insights/future-of-work/the-future-of-work-after-covid-19#. Accessed 03/06/22

Miller, H. J. (2010). The data avalanche is here. Shouldn't we be digging? *Journal of Regional Science, 50*(1), 181–201. https://doi.org/10.1111/j.1467-9787.2009.00641.x

Moss, A.L.G., (1994). Beyond Tourism: the Amenity Migrants. In M. Mannermaa, S. Inayatullah, R. Slaughter (eds.) *Coherence and Chaos in Our Uncommon Futures*. World Futures Studies Federation. 121 – 128.

Nepal, S.K. (2020). Adventure travel and tourism after COVID-19–business as usual or opportunity to reset? *Tour. Geogr.* 22, 646–650.

OECD (2020) Policy implications of Coronavirus crisis for rural development. Paris: OECD Publishing. http://doi.org/10.1787/6b9d189a-en.

Petrillo, A., De Felice, F., Petrillo, L. (2021). Digital divide skills and perceptions of smart wprking in Italy:from necessity to opportunity. *Procedia Computer Science* 180 (2021) 913–921. https://doi.org/10.1016/j.procs.2021.01.342

Phillipson, J., Gorton, M., Turner, R., Shucksmith, M., Aitken-McDermott, K., Areal, F., Cowie, P., Hubbard, C., Maioli, S., McAreavey, R., Souza Monteiro, D., Newbery, R., Panzone, L., Rowe, F., and Shortall, S., (2020). Covid-19 and rural economies. Briefing note prepared by staff of the Centre for Rural Economy1 and Rural Enterprise UK2, Newcastle University, April, 2020. Retrieved from: https://www.ncl.ac.uk/media/wwwnclacuk/centreforruraleconomy/files/researchreports/CRE-briefing-Covid19-and-rural-economies.pdf. Accessed 01/01/2022.

Romagosa, F. (2020). The COVID-19 crisis: Opportunities for sustainable and proximity tourism. *Tour. Geogr.* 22, 690–694.

Salat, H, Smoreda, Z., Schläpfer, M. (2020). A method to estimate population densities and electricity consumption from mobile phone data in developing countries. *PLoS ONE* 15(6): e0235224. https://doi.org/10.1371/journal.pone.0235224

Sharifi, A., Khavarian-Garmsir, A.R. (2020). The COVID-19 Pandemic: Impacts on cities and major lessons for urban planning, design, and management. *Science of the Total Environment* 749 (2020) 142391. https://doi.org/10.1016/j.scitotenv.2020.142391

Shenker, J. (2020) Cities after coronavirus: how Covid-19 could radically alter urban life. *The Guardian* Thu 26th March 2020. Retrieved from: https://www.theguardian.com/world/2020/mar/26/life-after-coronavirus-pandemic-change-world. Accessed 01/01/22

SNAI report (2018) – Appennino smart. Adattamento intelligente per cambiare gli schemi d'azione e superare le criticità con nuove idee. Retrieved from:https://www.agenziacoesione.gov.it/wpcontent/uploads/2020/07/Definitivo_Strategia_AI_Appennino_PC_PR_dic_18.pdf. Last accessed 11/04/2022

Sostero, M, Milasi, S., Hurley, J., Fernandez-Macía, E., Bisello, M. (2020). A Joint European Commission–Eurofound Report. *JRC Working Papers Series on Labour, Education and Technology* 2020/05

Tomaz, E., Moriset, B., Teller, J., (2021). Rural coworking spaces in the Covid-19 era. A window of opportunity?. 2021.

Untersinger, M. (2020). Confinement: plus d'un million de Franciliens ont quitté la région parisienne en une semaine. *Le Monde*, 26 March.

Vendemmia, B., Pucci, P., Beria, P. (2021). An institutional periphery in discussion. Rethinking the Inner Areas in Italy in *Applied Geography* special issue: Patterns and Consequences of Inequalities in the Geographic Periphery, a cura di Bagchi-Sen, S., and Rodríguez-Posez, A. https://doi.org/10.1016/j.apgeog.2021.102537

Williams, N.E., Thomas T.A., Dunbar M., Eagle N., Dobra A. (2015). Measures of Human Mobility Using Mobile Phone Records Enhanced with GIS Data. *PLoS ONE* 10 (7): e0133630. https://doi.org/10.1371/journal.pone.0133630

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Mobile phone data: challenges for spatial research

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Abstract
The paper investigates if and how mobile phone data can help to describe the complexity of urban phenomena, highlighting the challenges faced by researchers integrating mobile phone data into their activities. Two perspectives are offered: the first is a reflection on the features of these data collected anonymously by mobile phone users, as a condition for understanding its potentialities and limits for the analysis, visualization, and interpretation of people's presence and movements in urban spaces (research on mobile phone data). The second perspective focuses on the uses of mobile phone data in spatial research, starting from the outcomes described in this special issue and highlighting the potentialities and limits of these data in facing several research questions in urban studies (research with mobile phone data).

Keywords
Mobile phone data; Digital data; Spatial analysis.

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"Data do not exist independently of the ideas, techniques, technologies, people and contexts that conceive, produce, process, manage, analyse and store them" and "raw data is an oxymoron" (because) "data are always already 'cooked' and never entirely 'raw'"

(Gitelman & Jackson, 2013, p.2)

1. Introduction

Research into the use of mobile phone data has, for some years, been showing the great potential of this source in reading fine-grained variations in urban spaces over time and estimating human movements through urban spaces (Ratti et al., 2006; Kwan et al., 2007; Reades et al., 2007; Becker et al., 2013; Järv et al., 2014;). Several research works have experienced how mobile phone data can be one of the most promising sources for analysing, visualizing, and interpreting people's presence and movements in the urban spaces, acting as a powerful environmental, social, and economic microscope (Bibri, 2017). These data have been tested for the real-time knowledge of urban practice in cities (Mobile Landscape Method in Ratti et al., 2006; Sevtsuk & Ratti, 2010); for classifying different "basic" profiles of city usages and consumption (Reades et al., 2007; Soto & Frías-Martínez, 2011); for analysing trip chaining (Srinivasan & Raghavender, 2006), for updating the origin/destination matrix and transport models (Noulas et al., 2012); for inferring dynamic origin-destination flows by transport mode (Bachir et al., 2019), for detecting mobility behaviour (Bayir et al., 2010; Yue et al. 2014).

More recently, during the global outbreak of COVID-19 in 2020, mobile phone data have been largely used for emergency management (Wang et al., 2020), at least covering five themes: resource management, evacuation, pre-planning, decision-making, and education and training, to predict epidemic transmission', 'developing pre-warning system, 'finding victims', 'making evacuation plans', 'delivering emergency announcement' and 'guiding psychological recovery'.

Although mobile phone data show relevant potential for urban research related to an unprecedented coverage of population and geographic area, continuous and sufficiently long collection periods, and detailed and accurate information about location and motion (Steenbruggen et al., 2013), their use in urban studies, particularly for urban and spatial analysis, remains marginal. The availability of a large amount of data, on the one hand, improves the accuracy and completeness of the measurements to capture phenomena that were previously difficult to investigate, but at the same time increases the level of complexity in the approaches finalized to process and integrate this data (Einav & Levin, 2013). Emerging issues on datacy (Batini, 2016), the methods of processing these data with algorithms, and its representativeness and interoperability open further fields of study. Data assemblage notion (Kitchin & Lauriault, 2018) synthesizes well "the complex socio-technical system composed of many entwined elements for the production, management, analysis and translation of data for a particular purpose" (p.8), affecting their usability.

The paper investigates under what conditions mobile phone data can help describe the space-time variability of the urban phenomena, highlighting the challenges researchers face when trying to integrate mobile phone data into their activities. Starting from the outcomes of the research done with TIM mobile phone data and introduced in this special issue, two perspectives are offered: research on mobile phone data and research with mobile phone data.

2. Research on mobile phone data

Research on mobile phone data focuses on their features as *automated data* (Kitchin, 2014, p.4), highlighting the relevance of considering the typology of sources producing them as an essential condition for understanding their uses, potentialities, and limits. Dealing with how data is produced is relevant to defining their qualities and characteristics, as well as knowing how they have been processed after collection to test their reliability and completeness.

As introduced by Manfredini et al. in this special issue, mobile phone data and, particularly, TIM data, are based on information collected by antennas distributed in space, thus making users real "sensors" and allowing the anonymous collection of geographic data with high temporal detail has long been proven that this passive monitoring of anonymous telephone traffic represents a valuable alternative to traditional research methods because it can simultaneously overcome the limitations of the detection latency time typical of traditional data sources and take advantage of the ubiquity of mobile phone networks and the pervasive diffusion of mobile devices (Ahas & Mark, 2005; Ratti et al., 2006; Reades et al., 2007).

Pioneering approaches, investigating the potentialities of these data, highlighted their significance in at least four research and applicative fields (Pucci et al., 2015).

A first approach, named *Mobile Landscape Method*, focused on the relationships between mobile phone measures and people's daily activities in cities (Ratti et al., 2006; Sevtsuk & Ratti, 2010). The aim was to understand patterns of everyday life in the city, using a variety of sensing systems (mobile phone traffic intensity, location-based data as GPS devices, wireless sensor network) and to illustrate and confirm the significant differences in the distribution of urban activities at different hours, days and weeks. Graphic representations of the intensity of urban activities and their evolution through space and time, based on the geographical mapping of mobile phone usage at different times of the day, are the main output of this approach.

A second approach, known as *Social Positioning Method* (Ahas & Mark, 2005), studied social flows in time and space by analysing the location of mobile phones and the social identification of people carrying them. Searching for interoperability, mobile positioning data combine "active mobile position (tracing) data collected after a special query/request to determine the location of a mobile phone" and "passive mobile positioning data collected from secondary sources such as the memory or log files of mobile operators" (Ahas et al., 2010). After obtaining participants' personal acceptance, it provides maps with a survey of real-time data of who is moving, where, and how, visualizing people's social composition and movements.

A third approach is based on the *classification of urban spaces,* according to their users' practices and behaviours, as detected by georeferenced data and in particular by data derived by mobile phone networks – assuming that people's behaviour can be a good indicator of the effective urban zoning (Soto & Frías-Martínez, 2011). Based on the traces of users or aggregated data directly attributed to places, the approach classifying different kinds of people's behaviour (generally this is done considering similarities among different time-series), often called signatures. The signatures are then analysed and clustered to define the zoning, i.e., the city's division into areas, sharing specific behavioural characteristics.

The fourth approach uses mobile phone data as *traffic monitoring tools,* working on simulated frameworks, as well as in field tests, often by means of appropriate processing to relate phone counts and vehicle counts (Fontaine & Smith, 2005) or analyzing billions of anonymous location samples to determine the daily range of travel, carbon footprint of home-to-work commutes, and other mobility characteristics (Becker et al., 2013).

Despite the potentialities of these approaches, some implementation barriers have limited the use of mobile phone data in urban studies and synthesized in the literature (Kitchin, 2021).

First, mobile phone data – as well all the so-called big data – are not neutral because the algorithms and systems used to process these data "play an increasingly important role in selecting what information is considered most relevant to us, as a crucial feature of our participation in public life… [and] provide a means to know what there is to know and how to know it (…)" (Gillespie et al., 2014). Based on this, its usability depends on the selection and interpretation of a large amount of unstructured information through tools, such as algorithms, who can act "as technical counters" (Greenfield, 2017, p. 257), developing potentially partial and not neutral ways of understanding the world around them (Mattern, 2017).

The actors that produce, manage and own public and private data, configure more complex geographies of power and arenas in which urban problems are defined, discussed, and finally addressed by new constellations

of actors (Concilio & Pucci, 2021). These conditions have led some authors to talk about a " new data regime" (Dalton & Thatcher 2014), setting out seven "provocations" as follow: situate data regimes in time and space; expose data as inherently political and whose interests they serve; unpack the complex, non-deterministic relationship between data and society; illustrate how data are never raw; expose the fallacies that data can speak; explore how new data regimes can be used in a socially progressive way; examine how academia engages with new data regimes and the opportunities of such engagement (Dalton & Thatcher, 2014).

Third, the availability of a huge amount of digital data – challenging to use and process – can produce an abstract and immature use of these data, which is mostly limited to experiments, still mainly service-oriented, and dedicated to supporting operational decisions (Semanjski et al., 2016), since it collides with a low level of datacy (Batini, 2018). In addition, the interoperability and the integration with other data sources are still necessary also to make sense of such information selectively, as emerging in the academic debate (Batty, 2013; Graham & Shelton, 2013; Kitchin, 2014; Kwan, 2016; Poorthuis & Zook, 2017; Schwanen, 2017).

Finally, the epistemological change in the methodological approaches of empirical sciences, hypothesized by some authors as a condition through which moving from a "hypothetical-deductive method, driven by an incremental process of falsification of previous hypotheses" to "an inductive analysis at a scale never before possible" (Rabari and Storper, 2015, p. 33), is likely to produce a technocratic-positivistic attitude, presuming that new phenomena and correlations between them may emerge as the result of the massive processing of data (Kitchin, 2014; Schwanen, 2017).

Based on this and considering the outcomes of the research presented in this special issue about three different territorial settlements (Milan, Lecce, and Piacenza Apennines), we found that the processed mobile phone data pose issues in terms of nature and forms of these data and its lifecycle (generation, handling, processing, storing, sharing, analysis, interpretation, deletion), affecting how we can use them.

In our applications, we realize that these data are incomplete and need integrations with other databases to explain some dynamics taking place.

If in Milan city, TIM data are characterized by a high spatial-temporal resolution and they support the analysis of the change of the city users' presence in the neighbourhoods during Covid Pandemic, in Lecce and province of Piacenza, based on the issues investigated and the settlement conditions characterizing both territorial settlements, mobile phone data have needed integration with traditional data sources and in-field survey.

In the case of Nura and Trebbia Valleys in Province of Piacenza, to investigate both remote working on sparsely populated, low-connected, and poorly accessible territories, and near-home tourism during Covid pandemic, Tim data have been complemented with census Istat data on population and commuter flows and integrated with an analysis of the distribution of the main services, facilities and equipment for understanding the variability of the presences during different period of the year. In Lecce too where the aim is to detect the effective anthropic presence on the coastal territory to provide an assessment of the permanent and seasonal residents of the marine, TIM data have been processed along with census data, fiscal and administrative information owned by the Municipality of Lecce and maps on the illegal buildings.

This raises the necessity to deal with interoperability[1] issues for ensuring the ability to put together data that belong to different sources, and, therefore, organized in a different way. This condition that we have empirically addressed, would require more sophisticated technical skills to integrate the mobile phone data with other data sources, even with a DVI (Data Visualization Insight) platform made by the provider that, as we experienced, is not fully fit to deal with the research questions investigated.

In addition, because mobile phone data, detected by the antennas, refer to those subjects who are users of portable devices, in order to ensure their representativeness, the analytical procedure made by TIM in applying

[1] The term "interoperability" is defined by the IEEE Glossary (1991) as "the ability of two or more systems or components to exchange information and to use the information that has been exchanged" (Geraci, 1991).

a coefficient based on the market share of the company to calculate a proxy of the "human presences", does not deal with the variety of settlement conditions and (im)mobility practices of the investigated territories. This operative procedure appears effective for densely urbanized contexts but poses some problems in low-density areas where the antennas' spatial distribution is less widespread.

In Nure and Trebbia Valleys in the Province of Piacenza where a TIM customer scenario has been tested, dividing each municipality into sub-areas based on the settlement characteristics (main centres, villages, industrial areas), TIM data have failed in reproducing the dynamics at the micro-scale, in particular for low-density areas. Limits of the contribution of mobile phone data to the analysis of micro-scale dynamics emerge in these territories where a sparser distribution of antennas that are the basic infrastructure to infer user location, risks of underestimating the variability of the human presence and the reliability of the mobile phone data.

However, mobile phone data provide a partial representation of urban phenomena, based on those subjects who can move and are tracked while on the move, thanks to their portable devices. Other groups instead remain invisible to data as for the traditional data sources (i.e., immobile persons), so that the incomplete information provided by these data questions its policy usability as a valuable but partial source of information, which has to be complemented with other data sources (Vecchio, 2019).

The same user profiling offered by the provider (residents, commuters, visitors) and deriving from some analytical assumptions[2] can be fallacious, especially in the pandemic period when residential mobility, forms of remote working and, more in general, new urban practices and mobility behaviours emerged. Thus, for example, the need to analyze phenomena such as multiresidentiality, particularly important in Milan, would question the assumptions on which the profiling of residents in the TIM DVI (Data Visualization Insight) platform is based.

3. Research with mobile phone data

The applications of mobile phone data in the three study contexts investigated in this special issue highlight the potentialities of mobile phone data, as well as their limits. Compared to traditional methods of urban survey (such as census data or interviews), mobile phone data provide real-time maps of daily practices, thanks to valuable information on transient populations and their distribution over spaces (Pucci et al., 2015). Referring to our applications, they allowed investigating the variability of the human presences at the neighbourhood's scale in Milan, in sparsely populated and low connected mountain territories as Nura and Trebbia Valleys in Piacenza province before and during the first Covid-19 lockdown, but also the emerging spatialized practices as remote-working during the pandemic and the uses of areas characterized by seasonal vocation, second homes and unauthorised construction in the *marine* of Lecce.

Even if all these phenomena, which are not readable by systematic analyses based on administrative and census data, have been studied thanks to the availability of mobile phone data, still, some *ecological fallacies* (Kitchin, 2021) emerge from the outcomes of our research. Among them: drawing conclusions from a set of data not representative of the population under investigation, changing scales of analysis altering the results

[2] In order to define the human presence data clusters category, TIM defines the profiles as follows:
- Residents: counting of the Italian users of the TIM network, for each pixel of the map, who are (at the time selected in the timeline) in their ACE of residence;
- Commuters: counting of the Italian users of TIM network, for each pixel of the map, who are (at the time selected in timeline) in their ACE of work;
- Intra-regional visitors: counting of the Italian users of TIM network, for each pixel of the map, who are (at the time selected in timeline) outside their ACE of work or residence but in the region of residence;
- Extra-regional visitors: counting of the Italian users of TIM network, for each pixel of the map, who are (at the time selected in timeline) outside their ACE of work or residence and the region of residence;
- Foreign visitors: counting of users with a foreign SIM cards detected on the TIM network.

(from city level to ACE, to urban blocks), or analysing these data through the TIM DVI (Data Visualization Insight) platform to find statistically significant results, rather than testing a hypothesis.

The analyses highlighted that mobile phone data are not always representative of the population and, above all, they "do not speak for themselves", but they need interpretative models that guide their use, along with the integration with other data sources.

In the applications proposed in this special issue, we use almost always raw data in spite of the Data Visualization Intelligence platform and the elaborations available in the dashboard that customized the representations because they often are not effective in dealing with our research questions. Indeed, the use of raw mobile phone data allowed integration with other quantitative sources and with the spatial analysis tools as a necessary condition to support the interpretation of the dynamics emerging in our study areas.

In the cases study of Milan, Nura and Trebbia Valleys and Lecce, TIM data processed have been complemented with traditional data sources, to contextualize and interpret the spatiotemporal patterns emerging from mobile phone data, according to the spatial and functional characteristics of the study areas, aware that this type of data represents a re-proportion based on a population sample[3].

Combining mobile phone data - and in general digital data - with quantitative data is a very well know challenge faced over the years (Geraci, 1991) for synthesizing data from different data sources – usually independent of each other – into a unified "view" according to a "global" schema (Halevy et al., 2006). The relevance of the comprehensive frameworks to capture the many facets of data integration and data interoperability[4] (Candela et al., 2010; European Commission, 2004) is a shared condition, even if the development and wide adoption of common standards are extremely difficult.

In addition, looking at the urban studies, these processes are relevant if they enable data concerning similar problems, considering that data have value if and only if they can be re-used.

As argued by Pagano et al. (2013), "in order to make it possible to actually re-use data that have been collected or produced by a different entity, it is fundamental that a rich set of contextual information about such data be made available thanks to a mutual understanding in the use of data between collaborating systems" (i.e., the characteristics this set of contextual information should capture, the format this information should be represented in, and the manner it should be communicated). In some countries - such as Spain - this process is supported by open access to mobile phone data.

Beyond the reported challenges, our research highlights that mobile phone data represent an undoubtedly valid source for creating new evidence in testing some research hypotheses, and in the construction of a more argued public discourse, as in the case of Lecce. In this urban context where informal coastal settlements, predominantly 'illegal', make the analysis of both residential and tourist practices challenging and demographic representation based on census and registry data insufficient, TIM data highlighted a known phenomenon, but never represented in its space-time dynamics, so as to represent a support for political argumentations about the actions to be taken, also for addressing the environmental risk phenomena affecting some buildings. In this way Tim data help produce public evidence favouring difficult political decisions such as the order of priority of demolitions.

Reporting human presences at different hours of the day, in different periods of the week, in relation to special temporary events, makes these data very useful for reading urban rhythms, not necessarily as a result of the functional features, land use or the times of the activities, but rather to the ways in which people use the city and its spaces (Pucci, 2017). It makes them equally useful for managing different types of emergencies. Less evident are the contributions provided in bringing out unexpected situations and, in this, the data mostly confirmed assumptions and trends that researchers already knew and tested.

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[3] Tim provided the data on its customers' activity. The data were then extended to the entire population using Tim's market share.

[4] As argued by Pagano et al. (2013) interoperability can not be relegated to a merely technical issue, but it is a problem affecting the interaction of entities at various levels including: organisational level, semantic level and technical level.

References

Ahas, R., Mark, U. (2005). Location based services: new challenges for planning and public administrations? *Futures* 37:547–561

Ahas, R., Aasa, A., Silm, S., Tiru, M. (2010). Daily rhythms of suburban commuters' movements in the Tallinn metropolitan area: Case study with mobile positioning data. *Transportation Research Part C: Emerging Technologies 18* (1), 45–54. http://dx.doi.org/10.1016/J.TRC.2009.04.011

Bachir, D., Khodabandelou, G., Gauthier, V., El Yacoubi, M., & Puchinger, J. (2019). Inferring dynamic origin-destination flows by transport mode using mobile phone data. *Transportation Research Part C: Emerging Technologies*, *101*, 254-275.

Batini C. (2018) Datacy, perché una scienza per studiare l'impatto dei dati sulla società. *Agenda Digitale*. Retrieved from: https://agendadigitale.eu/cittadinanza-digitale/datacy-percheuna-scienza-per-studiare-limpatto-dei-dati-sulla-societa/a.

Batty, M. (2013) Big data, smart cities and city planning. *Dialogues in Human Geography 3* (3) 274–279 http://dx.doi.org/10.1177/2043820613513390

Becker, R., Caceres, R., Hanson, K., Isaacman, S., Loh, J.M., Martonosi, M., Rowland, J., Urbanek, S., Varshavsky, A. and Volinsky, C. (2013). Human mobility characterization from cellular network data. *Communications of the ACM 56* (1), 74-82. https://doi.org/10.1145/2398356.2398375

Bibri, S.E. (2018). *Smart sustainable cities of the future: the untapped potential of big data analytics and context-aware computing for advancing sustainability*. Cham: Springer

Bayir, M. A., Demirbas, M., Eagle, N. (2010). Mobility profiler: A framework for discovering mobility profiles of cell phone users. *Pervasive and Mobile Computing, 6* (4), 435–454. http://dx.doi.org/10.1016/J.PMCJ.2010.01.003

Candela, L., Castelli, D., & Thanos, C. (2010). Making Digital Library Content Interoperable. *Digital Libraries - 6th Italian Research Conference*, IRCDL 2010, Padua, 13-25

Concilio G., Pucci P. (2021). *The Data Shake: An Opportunity for Experiment-Driven Policy Making*. In: Concilio G., Pucci P., Raes L., Mareels G. (eds) The Data Shake. SpringerBriefs in Applied Sciences and Technology. Springer, Cham. https://doi.org/10.1007/978-3-030-63693-7_1

Einav, L., Levin, J. D. (2013). The Data Revolution and Economic Analysis (*NBER Working Paper Series No. 19035*). Cambridge.

European Commission (2004). *European Interoperability Framework for Pan-European eGovernment Services*. Luxembourg: European Commission.

Fontaine, M., Smith, B. (2005). Part 1: freeway operations: probe-based traffic monitoring systems with wireless location technology: an investigation of the relationship between system design and effectiveness. *Transp Res Rec: J Transp Res Board,* 1925 (1), 2–11

Geraci, A. (1991) IEEE Standard Computer Dictionary: Compilation of IEEE Standard Computer Glossaries. IEEE Press.

Gillespie, T., Boczkowski, P. J., Foot, K. A. (2014). *Media technologies: es-says on communication, materiality, and society*. Cambridge - London: MIT Press.

Graham, M., & Shelton, T. (2013). Geography and the future of big data, big data and the future of geography. *Dialogues in Human geography 3* (3), 255-261.

Greenfield, A. (2017). *Radical technologies: the design of everyday life*. Brooklyn: Verso.

Halevy, A., Rajaraman, A., & Ordille, J. (2006) Data Integration: The Teenage Years. *Proceedings of the 32nd International Conference on Very Large Data Bases* (VLDB '06), 9-16

Jarv, O., Ahas, R., Witlox, F. (2014). Understanding monthly variability in human activity spaces: a twelve-month study using mobile phone call detail records. *Transportation Research Part C 38*, 122-135, http://dx.doi.org/10.1016/j.trc.2013.11.003

Kitchin, R. (2014). The real-time city? Big data and smart urbanism. *GeoJournal* 79, 1-14, http://dx.doi.org/10.1007/s10708-013-9516-8

Kitchin, R. (2021). *The Data Revolution: A critical analysis of big data, open data and data infrastructures*. Sage Publications Ltd, London.

Kitchin, R., & Lauriault, T. P. (2018). *Toward critical data studies*. In: Eckert, J., Shears, A. and Thatcher, J. (eds) Geoweb and Big Data. University of Nebraska Press.

Kwan, M. P. (2016). Algorithmic geographies: Big data, algorithmic uncertainty, and the production of geographic knowledge. *Annals of the American Association of Geographers 106* (2), 274-282.

Kwan, M.P., Dijst, M., Schwanen, T. (2007). The interaction between ICT and human activity-travel behaviour. *Transportation Research Part A, 41* (2), 121–124. http://linkinghub.elsevier.com/retrieve/pii/S0965856406000255.

Mattern, S. (2017). Mapping's Intelligent Agents. *Places Journal*. http://dx.doi.org/10.22269/170926

Noulas, A., Scellato, S., Lambiotte, R., Pontil, M., Mascolo, C. (2012). A Tale of Many Cities: Universal Patterns in Human Urban Mobility. *PLoS ONE*, *7* (5), e37027. http://dx.doi.org/10.1371/journal.pone.0037027

Poorthuis, A., & Zook, M. (2017). Making big data small: strategies to expand urban and geographical research using social media. *Journal of Urban Technology 24* (4), 115-135.

Pagano, P., Candela, L., Castelli D. (2013). Data interoperability. *Data Science Journal*, 12, 23 July.

Pucci, P., Manfredini, F., Tagliolato, P. (2015). *Mapping urban practices through mobile phone data*. Berlin: Springer.

Pucci,P. (2017). Revealing the temporal profile of the city through mobile phone data, in Besecke, A., Meier, J., Patzold, R., Thomaier S., (eds.). Perspectives on Urban Economics. A General Merchandise Store, Universitätsverlag der TU Berlin, Berlin, ISBN 978-3-7938-2918-8 (print); ISBN 978-3-7983-2919-5 (online), 146-149.

Rabari, C., and Storper, M. (2015). The digital skin of cities: urban theory and research in the age of the sensored and metered city, ubiquitous computing and big data. Cambridge Journal of Regions, *Economy and Society, 8* (1), 27–42. http://dx.doi.org/10.1093/cjres/rsu021

Ratti, C., Frenchman, D., Pulselli, R. M., Williams, S. (2006). Mobile Land-scapes: Using Location Data from Cell Phones for Urban Analysis. *Environment and Planning B: Planning and Design*, 33(5), 727–748. http://dx.doi.org/10.1068/b32047

Reades, J., Calabrese, F., Sevtsuk, A., Ratti, C. (2007). Cellular Census: Explo-rations in Urban Data Collection. *IEEE Pervasive Computing*, 6(3), 30–38. http://dx.doi.org/10.1109/MPRV.2007.53

Schwanen, T. (2015). Beyond instrument: Smartphone app and sustainable mobility. *European Journal of Transport and Infrastructure Research*, 15(4), 675–690.

Schwanen, T. (2017). Geographies of transport II: Reconciling the general and the particular. *Progress in Human Geography*, 41(3), 355–364. https://doi.org/10.1177/0309132516628259

Semanjski, I., Bellens, R., Gautama, S., & Witlox, F. (2016). Integrating big data into a sustainable mobility policy 2.0 planning support system. *Sustainability* 8 (11), 1142**.**

Srinivasan, K. K., & Raghavender, P. N. (2006). Impact of mobile phones on travel: Empirical analysis of activity chaining, ridesharing, and virtual shopping. *Transportation Research Record,* 1977(1), 258-267.

Sevtsuk, A., Ratti, C. (2010). Does Urban Mobility Have a Daily Routine? Learning from the Aggregate Data of Mobile Networks. *Journal of Urban Technology, 17* (1), 41–60. http://dx.doi.org/10.1080/10630731003597322

Soto, V., Frías-Martínez, E. (2011). Automated land use identification using cell-phone records. *In Proceedings of the 3rd ACM* international workshop on MobiArch.

Steenbruggen, J., Borzacchiello, M. T., Nijkamp, P., & Scholten, H. (2013). Mobile phone data from GSM networks for traffic parameter and urban spatial pattern assessment: a review of applications and opportunities. GeoJournal, 78(2), 223-243.Vecchio, G. (2019). Big data: hidden challenges for a fair mobility planning in: Pucci, P., Vecchio G., *Enabling mobilities*. PoliMi Springer Brief: Springer, 57-73

Yue, Y., Lan, T., Yeh, A. G., & Li, Q. Q. (2014). Zooming into individuals to understand the collective: A review of trajectory-based travel behaviour studies. *Travel Behaviour and Society, 1* (2), 69-78.

Wang, Y., Li, J., Zhao, X., Feng, G., & Luo, X. R. (2020). Using mobile phone data for emergency management: a systematic literature review. *Information Systems Frontiers*, *22* (6), 1539-1559.

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