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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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Special Issue 2.2022

MOBILE PHONE DATA FOR EXPLORING SPATIO-TEMPORAL TRANSFORMATIONS IN CONTEMPORARY

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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.

[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.

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