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Mapping Urban Practices Through Mobile Phone Data

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This research is the result of an interdisciplinary collaboration, involving the expertise of each author. In particular, Fabio Manfredini oversaw the representations, in GIS environment, of the variables and measures of mobile phone trends, Paola Pucci supervised the methodological approach and the interpretation of mobile phone traffic data with respect to the territorial dynamics, while Paolo Tagliolato oversaw data mining and statistical analysis of mobile phone traffic data.

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Contents

Chapter 1
Mobility Practices and Mobile Phone Data

Abstract This chapter introduces the debate on the role of spatial mobility in describing and assessing urban changes. In accordance with the practice in an established literature, the role of mobility will be discussed as a key for describing the forms and the extent of different life practices and consumption patterns, producing diversified uses of the city. This is a necessary framework for an understanding of the challenges that the new data sources—such as mobile phone data—have to meet in order to interpret users' practices and behaviours, described in the realm of mobility. In fact, descriptions of the different social dimensions highlighted by mobility practices call for new empirical and analytical approaches, able to better capture people's movements, variation in them over time and space, and the multi-sited nature of the activities. In this context, we will investigate the contribution that tracking technologies and mobile phone network data have to offer. Because analysis of the space-time variability of urban practices is difficult to achieve with traditional data sources, our focus will be on the opportunities and limits of mobile phone data in mapping the spatial dimension and the density of use of the city and its services.

Keywords Mobilities · Urban rhythms · Contemporary city · Analytical tools · New sources

Our research focuses on the potentialities offered by mobile phone data in the interpretation of mobility practices and rhythms of use of the contemporary city by different urban populations.

The challenge is to describe the different dimensions of mobility and its rhythms in urban spaces, and it is this that characterizes our approach, not limited to trying to validate mobile data, but attempting to interpret them from the point of view of urban transformation processes in which mobility is an effective return.

In this way, the debate on the role of mobility in the contemporary city is a necessary framework for an understanding of the challenges that the new data sources—such as mobile phone data—are now having to face in interpreting urban changes, comprehension of which is made possible by studying the routinization of

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Paola Pucci is the author of this chapter.

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site practices that follow their own rhythms[1] of appearance and disappearance (Amin and Thrift 2002).

Because analysis of the space-time variability of urban practices is difficult to achieve with traditional data sources, our focus will be on the opportunities and limits of mobile phone data in mapping the spatial dimension and the density of use of the city and its services.

The nature of mobile phone data provides the longitudinal activity patterns of network cells, rather than individual users. This is why our research focused on aggregate behaviours related to the intensity of mobile phone use, implying consideration of telephone traffic data as the effect of individual behaviour and habits.

These data become information about the user behaviours and thus about the characteristics of a territory, which varies in densities of uses and populations, over time. In this perspective, the maps produced with mobile phone data represent the territories defined by "communities of practice"[2] (Wenger 1998), detected by mobile phone data.

1.1 How and Why Should We Interpret Mobile Practices in the Contemporary City

Urban mobility is one of the challenges that cities face, with massive material and immaterial investments in the future.

Knowing the intensity and the rhythms of the mobility practices becomes a necessary condition to ensure efficiency, livability and equity in the organization of everyday lives.

Analysis of mobility practices is important not only in relation to the changes in the dynamics of spatial mobility over the last 20 years, but goes back to the role of mobilities as a useful fact-finding tool to describe urban transformations in times and in places, according to personal social life and work programs, as well as constituting a structural element of contemporary cities.

For some years, an established literature (Ehrenberg 1995; Urry 2000; Urry 2007; Kaufmann 2002; Ascher 2004; Bourdin 2005; Scheller and Urry 2006; Cresswell 2006), has drawn attention to the role of spatial mobility as a key for "understanding the connections, assemblages, and practices that both frame and generate

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[1] Borrowing from the work of Lefebvre, Amin and Thrift argue that the rhythms of the city are "the coordinates through which inhabitants and visitors frame and order the urban experience" (Amin and Thrift 2002, p. 17).

[2] Wenger's concept (1998) "communities of practice" is employed to focus attention on the fact that urban populations cannot be reduced to predefined and fixed categories due to the phenomenon by which they belong to multiple categories. For this reason it is important to consider populations not as static categories (inhabitants, commuters, city users, etc.), but as "groups of subjects that, temporarily and intermittently, share practices of daily life" (Pasqui 2008, p. 148). Hence they can be considered "communities of practice" that generate particular space-time geographies.

contemporary life"[3] because, thanks to its "transverse dimension" in reference to any social practice, it is possible to interpret mobility as a cause and a consequence of changes in the organisation of everyday life (Urry 2000).

Spatial mobility, interpreted as a "total social phenomenon (…), as the action at the heart of social processes of operation and change" (Bassand 1986, p. 25), emerged in the 1980s in the work of Michel Bassand and Marie Claude Brulhardt (1980), laying the foundations for a critical review of a limited vision of mobility both in the social sciences and in transport engineering (Jaccoud and Kaufmann 2010).

Following the reconstruction of conceptual evolution of mobility by Bourdin (2005) and by Gallez and Vincent (2009), we can detect a conceptual and methodological renewal in the analytical tools and approaches in social science and in transport engineering too.

Mobility emerged in the social sciences lexicon in the ′20s with the work of Sorokin (1927) and the formalization of the concepts of "social mobility" as well as the research of the Chicago School as a "factor of social disorganization". In the conceptualization of Sorokin, mobility does not necessarily imply movement in space.[4] The physical movement acquires meaning only if it involves a change of status or position in the social space. Favoring the social dimension of mobility, space is neither an explanatory factor, nor becomes the object of analysis.[5]

In the approach of the Chicago School, and in particular in the work of Park (1925) "mobility is one of the main factors of ecological organization of the city"; it is both a factor of enrichment and diversification of individual experience, even if the founding manifesto, written by Park, Burgess and McKenzie (1925), shows an ambivalent connotation of mobility: mobility was interpreted as "the lifeblood of urban metabolism" (1925, p. 59), but at the same time mobility was a key factor in moral decay because "the mobility of city life, with its increase in the number and in the intensity of stimulations, tends inevitably to confuse and to demoralize the person" (p. 59).

This interpretation would be marginal in sociology, which considers mobility largely as a change of social position, role or status, focusing especially on the professional path and their effects on the construction of inequalities, at least until the ′80s.

In parallel, in transport engineering and in econometric modeling approaches—as from the ′20s in the U.S.—mobility was studied in terms of quantitative assessment of the flows from an origin to a destination. The focus on social interactions or on change of position in social space are implied; they are taken into account only through attention to the effect, i.e. the movement.

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[3] Interview with John Urry by Adey and Bussel (2010, p. 2).

[4] Sorokin (1927) defines social mobility as "the phenomenon of movements of individuals in the social space" and recognizes two types of movement: vertical mobility that involves a change of position in the social scale; horizontal mobility that defines a change of status or social class, without necessarily implying an evolution in the relative position in the social scale.

[5] For a critical analysis see Bourdin (2005) Les mobilités et le programme de la sociologie. Cahiers internationaux de sociologie.118:5–21 e Gallez and Kaufmann (2009) Aux racines de la mobilité en sciences sociales. In: Flonneau M, Guigueno V (eds) De l'histoire des transports à l'histoire de la mobilité? Presses Universitaires de Rennes, pp. 41–55.

Individual behaviours were not addressed: the traffic models were built on the assumption of temporal stability of behaviours, formalizing a state of equilibrium, in a short-term perspective.

The shift from the notion of flow to the notion of displacement, with the new research field on "socio-economics of transport" in the ′70s, focuses on a better understanding of individual practices of displacement as a condition serving for analysis of mobility demand and needs.

In this case, particular attention is paid to individual behaviours, although still treated at the aggregate level and according to a rationale based on minimization of costs and travel times.

At the same time, introducing the criterion of modal choice, traffic patterns reconstructed parameterizations based on the individual utility function (socio-economic characteristics, income, residential location), resulting in a greater adherence to the actual conditions that characterize the spatial mobility.

With the gradual shift from displacement to mobility the possibility arose to explore different forms of integration and differentiation between these two terms[6]:

- On one hand, the movements were conceptualized as a "derived demand" with consequences in terms of the need to know in detail the social interactions lying behind the movements;
- On the other hand, the displacement constraints (accessibility, skills, availability of means and resources, as well as the spatial organization of settlements …) represent a framework for explaining the dynamics of mobility.

In this way, mobility is more than a movement between an origin and a destination (Cresswell 2006, p. 9). As a socio-spatial phenomenon, mobility reflects all social relationships, becoming the main organizer of the social world.

Being the focus of many theoretical reflections, the progressive "slippage" towards a more complex conceptualization of mobility has important consequences in the evolution of the approaches, especially in the social sciences.

John Urry, in *Sociology beyond societies: mobilities for the twenty-first century* (2000) attributes a central dimension in social life to mobility because the contemporary world is defined more by the circulation of goods than by stable structures and organisations.

Emphasizing "the complex assemblage between five interdependent mobilities"[7] that "produce social life organized across distance and that form (and re-form) its

[6] See Vincent-Geslin and Kaufmann (2012, p. 31).

[7] Five interdependent mobilities are (Larsen Axhausen and Urry 2006 p. 263):

- Physical travel of people for work, leisure, family life, pleasure, migration;
- Physical movement of objects to producers, consumers, retailers;
- Imaginative travel, through memories, texts, images, TV, films;
- Virtual travel often in real time on the internet, so transcending geographical and social distance;
- Communicative travel, through person-to-person messages via letters, postcards, e-mail, text messages, mobile phone.

countours" (Elliot and Urry 2010, p. 16), Urry argues that mobilities "may make and contingently maintain social connections across varied and multiple distances" (Büscher and Urry 2009, p. 102).

In doing so, "because different forms of mobility reflect all social relationships, and they are the main organizer of the social world" (…) diverse mobilities are materially reconstructing the "social as society" in the form of the "social as mobility" (Urry 2000; Chap. 3).

This new mobilities paradigm (Scheller and Urry 2006) considers mobility as an all-inclusive concept with a number of interrelated claims (Elliot and Urry 2010), including "network capital" concept, diverse types of connections "more or less "at a-distance", more or less fast, more or less intense and more or less involving physical movement" (p. 32), as well as new research methods (Sheller and Urry 2006).

The so-called "mobilities turn" (Cresswell 2006; Sheller and Urry 2006; Urry 2007) is showing how 'moves' make social and material realities: all movements in space made by human beings are considered to be mobility and all are considered as social constructions. Thus, according to Cresswell (2006), three dimensions are relevant: observable facts, representations (mobility as ideas and ideology) and experiences (mobility as a way of being in the world).

Working with the material conditions of mobility and associated practices, Kaufmann (2002) proposes a conceptualization of mobility as "the intention and realization of an act of movement in physical space that involves social change" and, therefore, analysis of mobility tells us about the composition of and changes in a society. This implies seeing mobility as a tool that must be well-defined and fine-tuned to be able to "read" a society (Kaufmann 2014). From this conception of mobility as change, expressions of which are organized in the form of temporal interlocking, Kaufmann conceptualizes three dimensions of analysis: the physical, spatial and institutional possibilities of each context, called the "field of possibilities"[8]; the aptitude for movement, depending on a set of skills called "motility"[9]; and the movement in space.

[8] Each context offers a specific field of possibilities with regard to mobility. This receptiveness comprises several ingredients, including: (1) the available networks and their development, performance, and conditions of access (road, highway and railroad networks, airport hubs, and regional telecommunication equipment); (2) space and all of its territorial configurations (urban layout, functional centralities, institutional territories, etc.); (3) the employment market (possibilities for training/employment and the unemployment rate); (4) the institutions and laws that, in different ways, govern human activity (family policies, property/housing assistance, immigration policies, etc.)—in short, all of the social relationships and models of success a society proposes and the trials to which it subjects its various actors in order to succeed (Kaufmann 2014, p. 6).

[9] Motility comprises all those factors that determine an actor's potential to move or be mobile (i.e. physical ability, income, aspirations to move or be sedentary), technical systems (transportation and telecommunication) and their accessibility, and skills acquired through training (holding a driver's license, command of international English for travel, etc.). Motility therefore comprises factors relative to access (the conditions by which it is possible to *use* the supply in the broadest sense of the term), skills (those needed to utilize the supply), and appropriation (using the supply to

This approach, characterizing a new relationship between space and social practices, opens interesting perspectives also on the quality of the spaces of contemporary mobilities that are often “staging places”. In *Staging Mobilities*, Jensen (2013) explores the mobile sense-making, experiencing of and meaningful engagement with the environments that ‘makes mobility’, drawing attention to the process of design and planning that give rise to and shape urban mobilities. In this perspective, design and planning processes are tasked with creating new potentials, capacities and experiences.

Providing a transformative nexus for explaining the role of mobility as a “social product” (Cresswell 2006), as well as an “unquestionable process of urbanogenesis”[10] (Lévy 1999), in the social sciences mobility becomes a “transversal frame for reading social issues”.[11] It represents an “analyser” (Bourdin 2005) useful for describing urban life and identifying “communities of practice” (Wenger 1998), such as “mobile communities”[12] (Le Breton 2006).

According to Cresswell (2013, p. 92) “we are simultaneously part of different groups, we live our lives across a number of spaces as we move through the splintered city. We belong to many groups that rarely intersect. It may be the case that our identity as a national citizen is increasingly likely to be the less important one”.

In this perspective the challenge is not to analyse mobility as such, but to analyse contemporary society through the realities of mobility (Bourdin 2005).

If mobilities become a useful research tool for understanding transformations in times, places, social life and work programs structuring contemporary cities (Ascher 2004; Bourdin 2005; Montulet 2005; Scheller and Urry 2006; Cresswell 2006), at the same time, mobilities play an important role in social inclusion/exclusion processes (Tarrius 2000; Kaufmann 2002; Orfeuil 2004; Cass et al. 2005; Viry et al. 2009; Urry 2007 and 2012). This is because mobility implies a “mobility project” (Ehrenberg 1995) depending on available resources, abilities, competences, acquired knowledge and organisational capacity, which are either strengthened or weakened by our practices.

Within this logic, by applying Kaufmann’s motility concept (Kaufmann 2002; Kaufmann et al. 2007), as well as Urry’s idea of a “network capital” (Urry 2007), we are able to investigate key aspects related to the role that mobility plays also in terms of a “dualisation”, occurring within contemporary cities; what Estèbe (2008) refers to as “club-territories”: socially homogenous areas where people live, produce and work.

(Footnote 9 continued)
implement personal projects). Thus, motility is the way a person or group appropriates and makes use of the field of possibilities (with regard to movement) and relates to aspirations and plans (Kaufmann 2002).

[10] My translation from “la mobilité constitue aussi une technique incontestable de “urbanogenèse” et non un problème externe aux pratiques urbaines les plus fondamentales, c’est à dire à ce qui fait d’une ville une ville, à son urbanité” (Lévy 1999, p. 157).

[11] My translation from “cadre transversal de lecture du social” (Bourdin 2005, p. 20).

[12] “Groupes sociaux définis à partir de leurs inscriptions territoriales, de leurs pratiques de mobilité, des dispositifs techniques qu’ils mettent en oeuvre” (Le Breton 2006, p. 26).

From this standpoint, in our research, mobility can represent both a fact-finding tool and a policy tool for understanding and regulating the process of transforming the contemporary city (Pucci 2014), mobility being also “part of the process of social production of time and space” (Cresswell 2006, p. 5), including the dimensions of space and time, rarely addressed within an integrated perspective by public policies.

Mobility is a fact-finding tool because it is able to describe urban rhythms[13] and the space-time dimensions of the practices in using a territory. The users’ practices and spatial mobilities can help to achieve a better understanding of the complexity of the behaviour in human activities, and indeed of the urban spaces (Cresswell 2013).

Mobility is a policy tool by virtue of the possibility that provides to found policy on the basis of the observation of daily practices, so as to construct policies coherent with the emerging demands being made by diverse populations using the city and its services, at varying rhythms and intensities. Through study of mobility practices and their “territorialisation” as configuration in space, it is possible to recognise temporary populations generating new claims, but also new common goods, as well as “communities of practice” and the intensities with which they utilise territorial services and infrastructures. This makes it possible to gather useful information on urban dynamics as a condition for structuring more effective urban policies. In this perspective, we view urban populations not as users of policies but as potential generators of common goods (Pasqui 2008).

Combining social and spatial theory in new ways (Scheller 2011), mobility as a knowledge tool and a policy tool, challenges the analytical approaches and available sources of urban studies: there is a need to understand more about human spatial travel behaviour and its temporal variability in relation to a myriad of different social issues (Järv et al. 2014, p. 122), hardly reflected in the daily travel patterns derived from traditional data.

1.2 The Challenges for Analytical Tools

The assumption behind our research is that mobility practices are among those that best reflect the complexity of urban processes and rhythms in contemporary cities because the evolution we are witnessing, can be better understood as an accelerated reorganisation and restructuring of the geography of movements that define the spatiality of human societies (Soja 2004, p. 176).

Spatial mobility contributes to describing the forms and the extent of different life practices and consumption patterns, producing diversified uses of the city.

This conceptualisation of mobilities calls into question the available analytical tools and data sources. The tools and data must serve to describe different patterns

[13] Because “the time of urban populations oscillates and is comprised of cyclical temporalities intertwined with a plurality of uses of spaces and places” (Pasqui 2008), the rhythm of the city can be defined—according to Lefebvre—as “localised time” and “temporalized place”.

of mobility in the form of "active biographies", which increase the range of "post-Fordist living and labour styles" (Nuvolati 2003, p. 71).

According to Sheller and Urry's article "The new mobilities paradigm", which called for new research methods "on the move" and able to "simulate intermittent mobility" (Sheller and Urry 2006, p. 217), it is important to formulate pertinent analytical approaches with the aim of describing different densities in the use of the city and the combined movements of people, objects and information in all of their complex relational dynamics.[14]

This is also because new forms of mobility are emerging in the contemporary city and have intensified the density and typologies of movements (Edensor 2011) that traditional sources are unable to describe with procedural continuity (Pucci 2013; Järv et al. 2014).

These mobility practices result from the combination of physical and virtual mobility, leading to new, mixed forms of daily, residential, and travel mobility (Flamm and Kaufmann 2006).

If long-distance travel for leisure, occupational or social interaction has become part of the daily activity of many people (Limtanakool et al. 2006), work-related or mandatory travel is increasingly characterized by spatial and temporal variability, describing "a reversible use of territories and networks" (Vincent Geslin and Kaufmann 2012, p. 40).

No longer referable to traditional categories of commuting,[15] these new forms of mobility are always work-related trips, even if they show more complex patterns in terms of time and movements. These mobilities—defined by Kaufmann (2005) as "reversible"—are the result of two combined processes: the evolution of the labor market, which requires ever more flexibility and is subject to increasing unpredictability; the performance of the territorial, transport and communication networks, doing away with physical distances.

Even if the definition of reversible mobile practices is quite clear,[16] the impact that they have on the relation between people and territory it is still uncertain.

[14] "Mobile methods" proposed by Sheller and Urry (2006) include: interactional and conversational analysis of people as they move; mobile ethnography involving itinerant movement with people, following objects and co-present immersion in various modes of movement; after-the-fact interviews and focus groups on mobility; keeping textual, pictorial, or digital time–space diaries; various methods of cyber-research, cyberethnography and computer simulations; imaginative travel using multimedia methods attentive to the affective and atmospheric feeling of place; tracking affective objects that attach memories to places; and finally methods that measure the spatial structuring and temporal pulse of transfer points and places of in-between-ness in which the circulation of people and objects is slowed down or stopped, as well as facilitated and speeded up (Scheller 2011, p. 7).

[15] Daily commuters, city users, businessmen, tourists, but also long-distance commuting and multiple residences.

[16] The EU research "Job mobilities and Family Lives in Europe" (http://www.jobmob-and-famlives.eu/) identifies among the new forms of daily mobility: Long-Distance Commuters (LDC); Overnighters spending at least 60 overnights away from home during the last 12 months for occupational reasons; Recent Relocators over a distance of at least 50 km; Long-Distance Relationships (LDR).

These transformations of mobility practices open up operational challenges in transport and in sociological inquiry (Büscher and Urry 2009).

The aggregate methods (traffic census, O/D matrices of flow, travel diaries, questionnaires and interviews) to study mobility as geographic displacement, predominantly based on short periods and on proportional relations between utility and cost/time of movement, are unable to explain the complexity of mobility as a spatialized form of social interactions, depending not only on the availability of transport and communication services, but also on the personal projects, attitudes, habits, abilities and preferences related to the so-called mobility biographies (Lanzedorf 2010).

Considering mobility as a complex pattern of paths and activities in space and time and the outcome of the interconnections between individual and external (environment and social structure) factors (Pred 1984; Järv et al. 2014), operational challenge calls for new empirical and analytical orientations able to observe people's movements, and their variations in time and space, as well as the multi-sited nature of human activities.

In this perspective, we will try to investigate the contribution provided by mobile phone network data as a potential tool for the real-time monitoring of mobile practices.

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Chapter 2
Mobile Phone Data to Describe Urban Practices: An Overview in the Literature

Abstract This chapter focuses on the potentialities offered by mobile phone data in reading the site practices and rhythms of usage of the contemporary city, providing a research framework of the most promising approaches. Research approaches using ICT and aggregated cellular network log files to identify fine-grained variations in urban movements are presented to argue how mobile phone data can be treated as a useful source of information on the real use of cities. Because of the pervasiveness guaranteed by the ubiquity of mobile phone networks, this chapter shows how these datasets can overcome limitations in the detection of latency, typical of traditional data sources, while also providing valuable information on temporary urban populations. Referring to the outcomes of research on passive and anonymous monitoring of cell phone traffic (i.e. Social Positioning Method, Mobile Landscape and Real Time Monitoring, Automated Land Use Identification), we illustrate the potential and the challenges of these data source in complementing more traditional survey methods.

Keywords Mobile phone data · Tracking technologies · ICT · Mobile landscapes · Social Positioning Method

Research into the use of mobile phone data and ICT has for some years been showing the great potential of these data in reading fine-grained variations in urban movements over time and estimating human movements through urban spaces (Ahas and Mark 2005; Ratti et al. 2006; Kwan et al. 2007; Reades et al. 2007).

ICT and the passive and anonymous monitoring of cell phone traffic provide information that traditional data sources for urban studies (census data, surveys and interviews or the deployment of sensor networks) are unable to produce, because they consider the users generating telephone traffic as “sensors of a network”.

In doing so, with these data we can, at the same time, overcome the limitations in detection of latency typical of traditional data sources and exploit the pervasiveness guaranteed by the ubiquity of mobile phone networks, as well as offering a “longitudinal perspective” on the variability in human travel activities (Jarv et al. 2014), validly complementing traditional methods.

Paola Pucci is the author of Sects. 2.1, 2.2 and 2.3. Paolo Tagliolato is the author of Sect. 2.4.

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If we consider the observed individual traces and aggregated mobile phone traffic as the result of individual behaviours and habits, mobile phone data can be treated as a useful source of information on the *real* use of cities. These data capture traces of temporary populations and densities in the use of urban spaces (Ahas et al. 2010a, b), difficult to intercept using traditional data sources. These temporary practices have an increasing quantitative and qualitative effect on urban spaces, services and transport supply. Human presence and its variability over time is an index of urban vitality and liveability over time (temporal extension of urban activities), although there is not necessarily reference to functional patterns. This confirms the importance of ICT and mobile phone data in urban analyses (Becker et al. 2011) and in its contribution to the classification of urban spaces according to their users' practices and behaviour (Reades et al. 2007; Soto and Frías-Martínez 2011a, b).

Considering the experiments undertaken as reported in the literature, there are basically three main types of survey methodology (Manfredini et al. 2012) (Fig. 2.1):

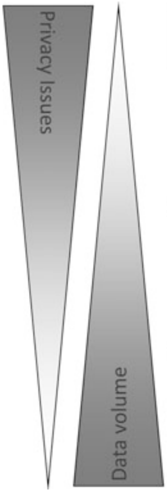
- Individual traces detected with tracking technologies of a sample, useful to study the mobility behaviour of specific groups of people;
- Individual trajectories, previously anonymized and collected by mobile phone carriers, useful to study geometric patterns of individual mobility, without geographical references (Network science);
- Mapping geo-referenced and aggregated mobile phone data of utility in studying land use density (Mobile landscapes); network measurement results related to active calls allow for tracking of all active handsets.

The first technique—individual traces of a selected sample—offers a more precise result because it is possible to record the origin and destination track of individual moves. On the other hand this means a greater cost for data processing and the necessity to build up a statistical sample of users. Moreover, problems related to individual privacy raised several ethical questions for this type of research. This technique is based on active mobile positioning (tracing) that is performed on specific location request, both as network based positioning and as handset positioning method.

By contrast, with the use of aggregated data collected from the network (mainly cell towers), it is possible to shift the focus from the individual level, directing interest on the emergence of complex urban dynamics related to the places that people use and frequent (Song et al. 2010; Gonzalez et al. 2008).

With the third technique, the focus becomes the use of urban space by the people, considered as time and space dependent variable. The scale of investigation of this type of synthetic data allows for representation of urban density also through mapping in real time (called soft real-time because the data are usually returned with a 15-minute lag).

Unlike origin-destination matrices or individual mobile phone tracking, aggregate data do not indicate where a caller comes from or goes to, but simply estimate the amount of call volume in a given network cell at a given time. Although we lose the traces of the origins and destinations of individual movements, this limitation does not appear relevant if, by using the volume of cell activity in mobile network



Data	Research area	Purpose
Tracks of displacements of individuals of a small selected sample (case study)	Tracking technologies (GPS, SMS, ...)	Study of mobility behaviour of specific group/population category
Tracks of calls of individual phone users (active mobile positioning)	Network science	Study of geometrical patterns of the mobility of individuals (deprived of the specific geographical reference)
Spatial distribution of cell phone activity (derived from cellular network log files)	Mobile landscapes	Study of the density of use of a territory

Fig. 2.1 The research fields on active and passive mobile positioning

cells, we can estimate the distribution patterns of the population in the different time slots considered for the survey (hourly, weekly, seasonal).

From a technical point of view, the third technique (spatial distribution of the cell phone activity) is based on analysis of aggregated data and traffic volume detected on network towers. Among the methods proposed in the literature, we may mention the social positioning method (SPM) of Positium LBS (Ahas and Mark 2005; Ahas et al. 2010a, b) based on active and passive positioning systems, and mobile census (MIT Senseable City Lab) which is instead a totally passive tracking system.

The opportunities offered by the use of mobile phone data compared to traditional data sources are:

- A more regular distribution of data in time and space;
- A finer network of detection;
- The precision of information (the accuracy of locational data, the frequency of data availability);
- The time required for calculating the position;
- The availability of service coverage, especially in urban areas;
- The characteristics of aggregated and anonymous data do not infringe on the privacy of mobile phone users;
- The implementation of integrated solutions that enhance the information obtained from mobile data, combining information from the identification code of the telephone prefixes for outgoing and incoming calls (ID of incoming and outgoing calls), but also on user profiles (social identification).

Conceived within the stream of studies on the use of ICT and mobile data, this project sought to verify whether mobile traffic data could be used to describe the rhythms of the city and its spatial differences in terms of the density of practices.

The aim of our project is to understand patterns of daily life in the city, using three types of mobile phone data (Erlang measures as telecommunication traffic intensity, O/D matrix as aggregated tracks of mobile phone users and MSC as Mobile Switching Center) and to illustrate people's movements and the multi-sited nature of the daily-urban activities.

2.1 About Mobile Phone Data

Since locational data (GPS, A-GPS, SMS) are becoming increasingly available and their applications are currently a hot topic in the mobile phone industry, aggregated locational data have not yet been widely used to describe urban systems.

Research projects on this topic are emerging in particular on the mapping of the mobile phone activity in cities or on the visualization of urban metabolism[1] based on handset movements.

Using mobile phone traffic as a means for monitoring urban practices shows that phone calls are closely related to population density in urban areas: the intensity of activity in a cell (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 researches focus on the Erlang data,[2] using the volume of call activity in mobile network cells as the spatial unit of analysis, in order to describe the correlation between mobile phone data and people's daily activities (Ratti et al. 2006; Sevtsuk and Ratti 2010).

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 the Mobile Landscape approach (Ratti et al. 2006).

The main question is how to correlate the Erlang trends—a measure of the density of phone activities—with the density of people.

Because the data can be used to map different urban domains and their occupants, some studies focused on integrating available mobile phone data with traditional data sources and surveys (Witlox 2007; Manfredini et al. 2012).

[1] About the definition of urban metabolism: Wolman (1965); Brunner (2007).

[2] Erlang data are the average number of concurrent contacts in a time unit. The Erlang data provided by Telecom Italia describe the density of mobile phone traffic every 15 minutes across areas measuring 250 × 250 meters.

In this direction, statistical models supported by empirical data (traditional sources or surveys) are proposed to investigate:

- the relationships between location coordinates of mobile phones and the social identification of the people carrying them as Social Positioning Method and its possible applications in the organization and planning of public life proposed by Ahas and Mark (2005);
- the relationships between mobile phone measures (the volume of call activity in mobile network cells as Erlang) and population distribution in cities (Sevtsuk and Ratti 2010);
- the classification of urban spaces, according to mobile phone uses (Reades et al. 2007; Soto and Frías-Martínez 2011a, b), in which different "basic" profiles of city usages can concur to identify different profiles of use and consumption.

Another important perspective concerns the use of mobile phone data as traffic monitoring tools (Caceres et al. 2008; Qiu and Cheng 2007; Fontaine and Smith 2005). In terms of volume data, the concept of using mobile phone data as probes has been explored by various researchers working on simulated frameworks (Fontaine and Smith 2005), as well as in field tests (Bekhor et al. 2008; Höpfner et al. 2007; Thiessenhusen et al. 2003).

In all these cases, traffic volume data is associated with cell phone transit through a boundary area using processes related to mobility management, detecting boundary crossing rates either at inter-cell boundary level (handover) or at location area boundary level (LU procedure).

Most of these studies focus on the handover[3] event detecting phone transit through boundaries between two cells. However, these studies concluded that accurate vehicle flows could not be obtained directly from mobile phone data due to the characteristics of this data source.

The main question is how to correlate the number of phones crossing with the real number of vehicles crossing. Volume data on inter-cell boundaries provided by mobile phones does not yield information on the complete set of vehicles crossing a boundary, but only a statistical sample of all travelling vehicles.

According to these findings, more accurate estimates for the number of vehicles can be obtained by means of appropriate processing to relate both measures (phone counts and vehicle counts) (Caceres et al. 2012).

Although studies in this area show promising results, the attempt to establish a "direct" link between phone calls and the number of people or trips comes up against some major limitations.

[3] Handover refers to the process of transferring an ongoing call or data session from one antenna to another. It, therefore, provides information on the movement of mobile phone users through the network.

To begin with, the use of the mobile phone depends on age, gender, profession, time and activities (Aguiléra et al. 2009), and it is difficult to take into account the possible cross effects: there are so many different situations that it is almost impossible to reach a conclusion on a purely quantitative basis derived solely from the mobile phone data.

This is particularly important if we want to use mobile phone data for urban investigations with the aim of planning the provision of personal services, for which statistical data are needed.

Next, long term effects may diverge from short term effects, in particular because when individuals acquire familiarity with these technologies, they may start to combine them, or because the equipment rate increases and the available applications change rapidly, as has been the case with mobile phones. Moreover, the correct measurement scale is not necessarily that of the individual.

2.2 The Social Positioning Method and Its Possible Applications

Social Positioning Method by Ahas and Mark (2005) studies social flows in time and space by analysing the location of mobile phones and the social identification of people carrying them. Mobile positioning data use different sources: "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. 2010a, p. 46). In doing so, Social Positioning Method uses location coordinates of mobile phones and social identification of the people carrying them for purpose of studying space-time behaviour and commuters' space-time movements. Therefore, this mobile survey saves a lot of time and resources compared to traditional data collection such as paper survey, questionnaires, and it supplies not only location information, but also the characteristics of the phone users. SPM offers more precise information than can be obtained from travel diaries and questionnaires according to the large number of people that can be estimated and the temporal accuracy to observe time changes in urban space use. Compared with tracking data (GPS, mobile drive, travel diaries…) mobile positioning data have some advantages (Ahas et al. 2010a, p. 53):

- Mobile phones are widespread and popular in developed and developing countries;
- People like to carry mobile phone with them, and they recharge the battery carefully;
- Data are originally digital, free from respondents' memory bias or manual digitalisation errors;
- It is possible to ask respondents extra questions or location-aware questions during a study, using text messages or special environments.

The high quality of positioning data today gives an overview of people's actual locations, as well as the possibility to describe the space-time movement of different social profiles of the users, because mobile data findings are correlated with the characteristics of the mobile phone users (Ahas and Mark 2005). Some conditions make this approach particularly promising also for urban planning, "making planning more human-centered" (Pulselli and Ratti 2005)—as is the case in some Estonian cities,[4] for instance: the SPM data collection system is quite simple[5] and the widespread use of mobile communication, also in poorer countries with wireless networks, is cheaper and easier to construct than wired networks.

In addition to these aspects, there is also a dimension related to the role of the mobile phone in daily living practices: the mobile phone is no longer just a phone, but rather a multifunctional media device with library, mail, which makes it an inseparable part of the contemporary daily lifestyle.

According to Elliot and Urry (2010), mobile phones, like the other technological devices (laptop computers, wireless connections) "enter into the constitution of self and of other novel social patterns" (Elliot and Urry 2010, p. 30) becoming "miniaturized mobilities" that "afford a fundamental liberation from place" (Wellman 2001, p. 238). These "miniaturized mobilities" are part and parcel of a continuous coordination of communications, social networks and the mobile self.

In this way, as suggest by Ahas and Mark (2005), Social Positioning will provide maps with survey of real time data of who is moving, where and how. It will become possible to visualize the social composition of streets and individual premises, to provide data about total numbers of people and their movements. This could also highlight crisis situations such as traffic jams and accidents, and would help to manage problems arising from the movement of people.

In this perspective, Ahas et al. (2010b) developed the "anchor point" model to locate and distinguish an individuals' daily anchor points (i.e. home and work) based on call activities.

The above applications have been the subject of experimentation by the Positium LBS (Location Based Services), one of the first companies to have commercialized the use of mobile data applications for marketing and management planning. Founded in 2001 as an interdisciplinary spin-off of the University of Tartu and supported by the Estonian mobile operators which provide a rich database of user data, Positium LBS has managed, over the years, to promote research of great scientific importance. Among the most important tools supplied by Positium LBS there are tools for geographic analysis of the movement of people and tools serving for observation of tourist flows (for example, the Position Touring Barometer, which is a web-based system that analyses the reports drawn up by tourists).

[4] In Estonia mobile data have been used since 2008 for calculation of the balance of payment travel item of the national central bank (Position LBS 2014).

[5] Persons carrying the mobile phone (possibly anonymous), space coordinates x and y, the third height dimension (will be added in a near feature), and finally time coordinates z.

2.3 Mobile Phone Measures and Population Distribution in Cities

The early research works in the field of mobile phone data include those by MIT SenseableLab,[6] thanks to unprecedented access to aggregate mobile phone data. The products of the research have high innovative value and, at the same time, offer several ways to start the transfer of technology for possible commercial applications.

The researches of the laboratory are mainly based on the use of three types of aggregate data provided by the mobile network: cell phone traffic intensity, traffic migration (handovers) and traces of registered users as they move through the city (Ratti et al. 2006).

The data are used to derive real-time pictures of the flow of people in the urban environment (i.e. Mobile Scape Graz 2005; Real Time Rome 2006; Wiki City Rome 2007) and views of the traffic flow of mobile phone and IP traffic together (i.e. New York City Talk Exchange 2008).

The maps are not only useful visualizations of the movements of people on a cartographic support, but are also suitable as tools for analysis of the variability in time and space of the demand for services that people can generate. In particular, in Real Time Rome (2006), the analysis of pedestrian movements of people, in cross comparison with the supply of public transport, verifies the adequacy of the public transport supply at the urban level.

Depending on the quality and richness of the available information, we can get different results. If in the early works in collaboration with Telecom Italia,[7] the data provided were related to the intensity of traffic (Erlang and handovers data), in projects in partnership with AT&T,[8] the data provided were enriched with the identification code of the telephone area for outgoing and incoming calls (ID of incoming and outgoing calls).

This type of information has revealed the degree of connectivity of a specific place with the rest of the world, expanding and providing analytical elements useful in the study of urban sociology in the globalization processes (Castells 1996; Sassen 2007).

Starting from the research of Senseable City Lab, there are many application tests. Among these are:

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[6] Senseable City Lab is a laboratory at the Massachusetts Institute of Technology, supervised by Carlo Ratti, which took the form of a consortium to collaborate with private and public partners. http://senseable.mit.edu.

[7] Telecom Italia is the leading Italian telecommunications company, supplying Italian and international fixed telephone services, mobile phone services, Internet and cable television.

[8] AT&T Inc. is a phone company based in San Antonio, Texas with head office in the USA.

- Reality Mining MIT MediaLab[9] identifies the collection of environmental data detected by digital tools in order to study the social behaviour of people. In particular, mobile phone data analysis allows for study of the practices of social networking in order to model the people's behaviour through stochastic methods. The laboratory was engaged in a meticulous survey of mobile phone data of 100 people between 2004 and 2005. With collection of more than 350,000 h of recorded data it has been possible to establish a database with information about the evolution of social networks over time, about the ways of living of the people and about the relationship between social networks and proximity;
- Current City[10] applies some of the techniques developed at Senseable City Lab on the methods of data collection to offer services to public and private institutions interested in understanding the spatialization of mobility patterns. The main applications are reporting and management of the emergencies, and the management of urban mobility. The strength of Current City lies in effective modes of representation and communication of data flows through maps in real time.

2.4 The Classification of Urban Spaces According to Mobile Phone Uses

The classification of urban spaces according to their actual use by people is an interesting application of recent georeferenced data and in particular of data derived by mobile phone networks, potentially useful for planners as a tool of investigation of the actual use of the contemporary city, otherwise often unavailable.

Works in this direction are based on the idea that people's behaviour can be a good indicator of the effective urban zoning.

Based on the available data the strategy is often to classify 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. The characterization of places in terms of signatures and consequently the attribution of a place to a certain cluster, leads the definition of the zoning, i.e. the division of the city into areas, sharing some behavioural characteristic.

We can distinguish two different kind of approaches: the first is based on distinct traces of users, the second on aggregated data directly attributed to places.

The first approach characterizes for example the work of Becker et al. (2011), the main focus being on users and their behaviour. A classification of the land is subsequent to the classification of users based on the call detail record data (voice and SMS) of 2 months. The authors try to answer several questions on city dynamics. Firstly they identify what they call the "laboursshed", that is the

[9] http://reality.media.mit.edu by Nathan Eagle.

[10] http://currentcity.org by Euro Beinat, Assaf Biderman, Francesco Calabrese, Filippo Dal Fiore, Carlo Ratti, Andrea Vaccari.

residential areas which contribute workers to Morristown. The analysis is conducted following the traces of those users with frequent mobile phone activity in Morristown during working days. They then use the ZIP code of the billing information associated with the SIM to infer the residence of the users. They compare their results with the census, finding significant similarities. Similarly they study the "partyshed", or the zones of provenience of late night revelers, this time starting with those users captured downtown, the area known for its leisure function. Once again the "shed" is identified by the ZIP codes. Lastly the work proposes a clustering analysis of mobile phone usage patterns in order to characterize people (e.g. "heavy voice users who have heaviest usage during business hours, are a bit less active on the weekend, and have little to no SMS usage"). Seven clusters are analysed (k-means clustering) and the geographical "footprint" of the users of each cluster are considered. The identification of home-work location is a task performed with similar data also in other studies. Similar to this work are those of (Ahas et al. 2010a, b; Bekhor et al. 2011), where the focus is on users' behaviour and in particular on the possibility of finding their home locations from cellular phone traces. Different data sets are analysed and the results compared with census data finding good correlations.

Recently also other different data sources reporting information on people traces have been exploited to infer urban zoning.

The work presented in Yuan et al. (2012) is more properly devoted to the identification of different functions in the city. The study analyses several months of taxi GPS traces, but the same authors suggest the possibility to use mobile phone traces within their analysis framework, and a dataset of points of interest (POIs) in Beijing. The idea is that the only presence of certain types of POIs (e.g. restaurants) cannot determine the kind of function of an urban area, but that the mixed exploitation of POIs and mobility information can help the identification of the land use.

The same kind of data is considered in Qi et al. (2011) where the authors exploit the temporal variation of the geolocalized amount of getting on-off of taxis (from GPS traces) to infer the social function of city regions. "regions with different social function have their distinctive temporal variation patterns". They identify three categories of region: train stations, entertainment districts and scenic spots (tourists) and label a set of training samples (zones). They then perform an agglomerative cluster analysis on the whole set and label the clusters by a majority vote of its training samples.

Coming to the second approach exploiting data directly related to places, we can start with one of the first works on this topic, the well-known article by Reades et al. (2007) where, analyzing cellular network data of Rome, a k-means clustering of a simplified kind of Erlang signature is conducted, arriving at an interesting classification of the city in 5 type of areas, two of which (night time leisure and commuters) are particularly consistent with the actual knowledge of the city. The authors suggest that more sophisticated techniques could ameliorate analyses of this kind. Such is the case of (Sevtsuk 2008), where the author classifies places in Rome by means of their Erlang signatures and explains the population distribution trends through socio-economic characteristics of the areas. More specifically, Sevtsuk clusters the three first eigenvectors (of a Principal Component Analysis) of the Erlang signature of the cellular network cells arriving at a subdivision in 16 clusters. He then analyses the three largest clusters, resulting in a concentric structuring of the city, starting from the peripheral zones and arriving in the city core. Comparing these clusters with socio-economic data the author finds a strong correlation “between areas that resemble in network usage and areas that resemble in demographic and business composition”.

In Horanont and Shibasaki (2009) the authors, besides the presentation of their web-based visualizations of population density predictions based on Erlang data in Bangkok, describe a methodology for land use classification based on Erlang time series. After having chosen four points of known different land use (residence, business, shopping, university) they calculate the respective Erlang signature of these zones (like other authors they consider the mean hourly aggregation), discussing how these can be considered representative of the kind of usage of similar zones.

Telefonica Research, the research and development company of the Spanish telecommunication group Telefonica, started its work on the topic with the seminal work by Froehlichet et al. (2009), which analyses data of usage of bike sharing stations in Barcelona. The authors apply dendrogram clustering (Duda et al. 2000) identifying different clusters of station usage. Besides the direct application of their methodology to predict future bike station usage behaviour, they insightfully suggest how shared temporal trends in station usage can allow to infer attributes about neighborhoods (e.g., residential versus commercial, proximity to downtown). After this work, Telefonica research proposed other works based on cellular network data. In Soto and Frías-Martínez (2011a) the topic is urban zoning analysis by means of mobile phone usage intensity. The authors start with CDR records (1 month in 2009), aggregated in order to obtain an antenna level information, namely the measure of the number of calls in the unit time for the cellular network antennas. A representative time series (of the average values of the single week days in one case, of the mean working day followed by the mean weekend day) of the week is considered the “signature” of the antenna. The authors derive from these signatures, by means of an unsupervised clustering technique—k-means clustering with Euclidean and Dynamic Time Warping distance measures—five clusters that they associate with five main land uses in Madrid: residential areas, office areas, nightlife areas, weekend leisure areas, hybrid land use. They discuss the spatial characterization of these clusters reporting that the results are in accordance with their expert knowledge of the city. They finally use the knowledge extracted from the case of Madrid (the cluster representatives) within a classifier which they experiment to automatically classify the land use in Barcelona. Finally in Soto and Frías-Martínez (2011b) the same authors outline the fact that city areas are generally not characterized by just one specific use, especially in older cities like Madrid, on which they conduct their analysis, and for this reason they introduce the use of c-means, a fuzzy unsupervised clustering technique for land use classification, which shows for each area a certain degree of association with each class. In the same paper fuzziness is then abandoned to favour the identification of areas with a clearly defined use (with a degree of membership to a cluster over a certain threshold). They identify 5 clusters which they associate with five types of districts: industrial parks and offices, commercial and business areas, nightlife areas, leisure and transport hubs, residential areas. They validate the unsupervised classification thanks to their expert knowledge of the city.

We will discuss later, in Sect. 3.2, a different methodology for the classification of urban spaces by means of Erlang data, which, like the approach of (Soto and Frías-Martínez 2011b), takes into account the fact that a single zone can be characterized by different uses.

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Chapter 3
Daily Mobility Practices Through Mobile Phone Data: An Application in Lombardy Region

Abstract Beginning with the results of a research carried out in the Italian region of Lombardy utilising mobile phone data provided by Telecom Italia, this chapter will demonstrate how new maps, based on mobile phone data and better tailored to the dynamic processes taking place, can represent spatialized urban practices and origin-destination flows of daily movements. Three different types of mobile phone data were employed in the analysis of complex temporal and spatial patterns. The first data type concerns the mobile phone traffic registered by the network over the entire Lombardy Region (Northern Italy). Data are expressed in Erlang, a measure of the density of calls. The second typology of data consists in localized and aggregated tracks of anonymized mobile phone users. It is an origin-destination datum derived from the Call Detail Record database. The third type of data refers to the mobile switching centre (MSC), which is the primary service delivery node for GSM, responsible for routing voice calls and text messages. With the maps based on the processing of the three types of mobile phone data, it was possible to offer information on temporary populations and city usage patterns (daily/nightly practices, non-systematic mobility).

Keywords Erlang Data · Origin-Destination matrix · Mobile Switching Center · Treelet decomposition · Geographic analysis · Big Event

The twofold view proposed, on the one hand on the role of mobility as an interpretative tool of urban transformations (Chap. 1) and on the other on the nature of the mobile phone data, as the effect of individual behaviour and habits (Chap. 2), has directed our analytical approach.

The research carried out in the Northern Italian Region of Lombardy, employing mobile phone data provided by Telecom Italia, explores how new maps, based on

Fabio Manfredini is the author of Sects. 3.2.4, 3.4; Paola Pucci is the author of Sect. 3.2.3; Paolo Tagliolato is the author of Sects. 3.2.1, 3.3. Sections 3.1, 3.2.2 were written by the three authors.

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unconventional data sources and better tailored to the dynamic processes taking place, can represent spatialised urban practices and can provide new insights for understanding urban practices and lifestyles.

3.1 Methodology: Operational Impacts of Three Types of Mobile Phone Data

Three different kinds of mobile phone data were employed in the analysis.

The first data type consists of the mobile phone traffic registered by the network over the whole urban region of Milan (Northern Italy).

Data are expressed in Erlang, a dimensionless unit used in telecommunications as a measure of the average number of concurrent contacts in a time unit. In our case, the data concern the amount of Erlang, a measure of mobile phone traffic intensity every 15 minutes. They were supplied by Telecom Italia in spatialized form; starting from the traffic recorded by each cell of the network, the provider distributed the measurements, by means of weighted interpolations, throughout a spatial tessellation of the region in 250 × 250 m^2 areas (pixels) (Fig. 3.1).[1]

The research does not consider the Erlang data directly[2] since it takes into account the ratio between the amount of Erlang in each pixel and the total amount of traffic, at the same moment, in the "universe" (i.e. the sum of Erlang across all the pixels of the entire matrix, in this case representing the Lombardy Region). This relative measure indicates the amount of telephone traffic in a certain spatial region with respect to the total telephone traffic. These data are more likely to provide indirect information about the variation in the number of people. The information was statistically processed for comparison with the variables derived from consolidated data sources (census data, land use). These data were used to evaluate the possible relationships between variations in the intensity of cellular network phone calls and land-use characteristics.

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[1] More formally we can define the Erlang Exj relevant to the pixel x and to the *j*-th quarter of an hour as:

$$\mathrm{E}_{xj} = \frac{1}{15}\int_{15(j-1)}^{15j} N_x(t)dt$$

where Nx(x) is the number of mobile phones using the network within pixel x at time t, hence Exj is the temporal mean over the *j*-th quarter of an hour of the number of mobile phones using the network within pixel x.

[2] Erlang raw data describe the quantity of absolute mobile phone traffic in one pixel at a certain moment.

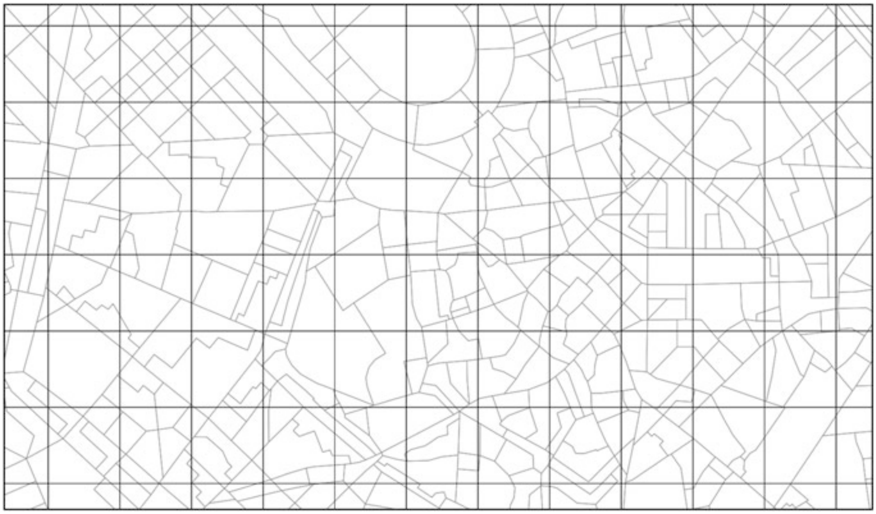

Fig. 3.1 The telephone traffic matrix (in *black*) and the city building blocks (in *grey*): a central area of Milan. This figure shows the mobile phone traffic data spatial resolution superimposed on building blocks, the most detailed statistical unit available for the central area of Milan

This preliminary assessment of data regarding phone call density (Erlang) highlighted some evident limits,[3] together with relevant potentialities for urban studies.

The second data typology consists in localized and aggregated tracks of anonymized mobile phone users. In this second case, an origin-destination datum derived from the Call Detail Record database was provided. Italian privacy legislation severely constrains the use of these data, even for research purposes. In the framework of our research and in collaboration with Telecom Italia (T-Lab), we arrived at a definition of a datum which was free from privacy restrictions, consisting in an aggregation of users' movements based on CDR records. Telecom engineers set up a system for automatic, blind extraction of data of this kind.

The system is fed with the CDR and a tessellation of a geographical region (in the present case the Lombardy Region). The output consists in time series of Origin-Destination matrices (where origin and destination zones are the tessellation tiles), equivalent to a function $F(o, d, t) \rightarrow n$ which, at time t (t varying in the 24 h of a given day), assigns to origin o and destination d the number n of distinct users

[3] These data do not allow us to draw a direct correlation between the density of phone calls (Erlang data) and the number of people present in a cell, also because, as is well-known, cellular telephone use is conditioned by socio-professional user profiles (age, sex, profession).

that performed some mobile phone activity[4] within o at time $t - 1$ and a subsequent activity within d at time t.

The CDR raw data are available at the detail of the antennas which control the activity. The distribution of antennas in space depends on the amount of mobile phone traffic that needs to be handled. In dense urban areas we thus observe a high density of antennas while in the outskirts the density of antennas may be very low. For the positioning of a user within a certain tessellation tile to be reliable, the technical constraint was applied that the tiles should contain at least 13 antennas.

We built three different tessellations which could give us the possibility to map and interpret the main spatial patterns of mobile phone user mobility: the first, obtained with a data-driven process taking into account the spatial distribution of antennas, is more fine-grained; the second and third, even if more coarse, were directly related to administrative boundaries, derived from aggregation of adjacent municipalities' polygons.

We obtained the tessellations as follows (Fig. 3.2):

- Automatic clustering of antennas (526 polygons): each zone is an aggregation of Voronoi cells obtained from the points of location of the antennas. We proceeded by clustering the positions of the antennas applying an agglomerative hierarchical clustering algorithm (complete linkage, Euclidean distance); we first cut the hierarchical tree in order to obtain 100 clusters; we then selected the groups with more than 500 antennas and we cut the corresponding sub-trees using an inconsistency coefficient less than a given threshold (see e.g. Jain and Dubes 1998), obtaining a final sufficiently balanced partition (i.e. with a homogeneous number of antennas per cluster). Finally, for each cluster, we calculated the polygon corresponding to the union of the Voronoi cells of its antennas. By applying this procedure, we obtained the tessellation having these polygons as tiles;
- Automatic aggregation of municipalities (313 polygons): each zone is an aggregation of municipalities and contains no fewer than 13 antennas. An automatic procedure has been created to build new zones in an iterative manner;
- Manual aggregation of municipalities (202 polygons): each zone is the result of a manual aggregation of municipalities based on their geographical and social characteristics.

On these tessellations it was possible to map the direction and intensity of mobile phone user movements on an hourly basis. The dataset was collected on different working days: five Wednesdays respectively in July, August, September, October and November 2011.

Using data on the origin-destination of the traces of cellular phone users we mapped the distribution of aggregated fluxes activated for professional and personal reasons, between hundreds of origins and destinations, at different hours of the day, using a decidedly significant sample of people (more than one million with at least

[4] By mobile phone activity we mean each interaction of the device with the mobile phone network (i.e. calls received or made, SMSs sent or received, internet connections, etc.).

Fig. 3.2 The three tessellations representing Origin-Destination zones: manual aggregation of municipalities (*above*), automatic aggregation of municipalities (*centre*), automatic clustering of antennas (*below*)

8 mobile phone activities per day based on a population of 9.7 million residents in Lombardy Region).

The third type of data refers to the mobile switching centre (MSC), which is the primary service delivery node for GSM, responsible for routing voice calls and text messages. It also records information on the movements of clients by updating the position of mobile devices in the Home Location Register (HLR), which contains all subscriber information. For every hour of two time periods (from 7 to 20 September 2009; from 1 to 30 April 2010) we obtained the number of GSM active clients for each of the Lombardy Region MSC Service Area, distinguished by the nationality of the SIM.

The size of each MSC service area varies according to the number of GSM tower cells served and the quantity of mobile phone traffic generated within it. The number of registered users in each MSC corresponds to the number of users with their phones on and logged on the TIM network in cells served by the MSC on an hourly basis. What makes this specific source of data particularly interesting, despite the low spatial resolution, is the possibility to access information directly related to the number of active phones, which may correspond approximately to the hourly presence of people in the different MSC service areas.

The further possibility to obtain information on the nationality of the SIM of active customers has also led us to assess the potential of these data for monitoring foreign presences in different MSCs. In Sect. 3.4 we will present the main outcomes of the MSC active clients analysis.

One preliminary step was to address the inherent limitations of mobile phone data. In addition to the specific limits of the data (i.e. missing the modal split), establishing a "direct" link between phone calls and the number of people or trips comes up against some major limitations. To begin with, use of the mobile phone depends on age, sex, profession, time and activities; hence it is difficult to take into account the possible cross effects: the vast range of different situations means that it is almost impossible to reach a conclusion on a purely quantitative basis derived solely from mobile phone data. This is particularly important if we wish to use mobile phone data for urban investigations with the aim of planning the provision of personal services, for which statistical data are required. Secondly, long term effects may diverge from short term effects, in particular because, as individuals gain familiarity with technologies, they may begin to combine them, or because the equipment rate increases and available functions change rapidly, as has been the case with mobile phones.

While recognizing the value and limits of the experimental data available, the data processed by the research were used to describe the space-time variability of presences in the Lombardy Region, taking into account traditional statistical sources.[5]

3.2 Erlang Data: Densities of Use of the City in the Milan Urban Region

In order to assess possible correlations between the variability of mobile network call intensity and the urban activities (density of people), our research compared mobile phone traffic data with the traditional statistical variables available.

In this way our research aimed at evaluating if, and if so how mobile phone traffic data could be a useful tool for providing statistically relevant descriptions of

[5] Including O/D flow matrices from the Regione Lombardia (2002) and a qualitative survey by the Provincia di Milano (2006), together with land use maps and demographic census data.

urban activities in terms of real-time monitoring of urban dynamics (during the day, the weekdays, the seasons) as a framework for urban and transport policy and for managing large-scale and special events (inflow, outflow, monitoring).

In this perspective, the methodological approach considered two scales of analysis (Fig. 3.3).

At the macro scale, we explored whether the mobile phone data in Erlang (aggregated to the main cities of Lombardy Region) is correlated with the variation of density of people at a rate of 60 minutes in the same cities. The time series of people density in Lombardy Region was obtained by processing a traditional database (the Lombardia Region Origin-Destination matrix), leading to an estimate of the population reported in any municipality in any hour of a typical weekday.

At the micro scale, we selected similar urban context types—e.g. social housing districts, railway stations, university districts, factory areas, residential districts, business districts, areas of urban sprawl—in order to verify possible correlations between land-use patterns and cell phone activities, in each different selected urban area. Our analysis aimed at evaluating if similar urban context types, in terms of land-use patterns and socio-economic profiles, have recognizable mobile phone trends. In this case, the aim is to propose a functional clustering of the Lombardy Region, starting from the Erlang trends. At the same scale we also examined the variabilities of density before and during a special event like the "Salone del Mobile—International Design Week" in Milan.

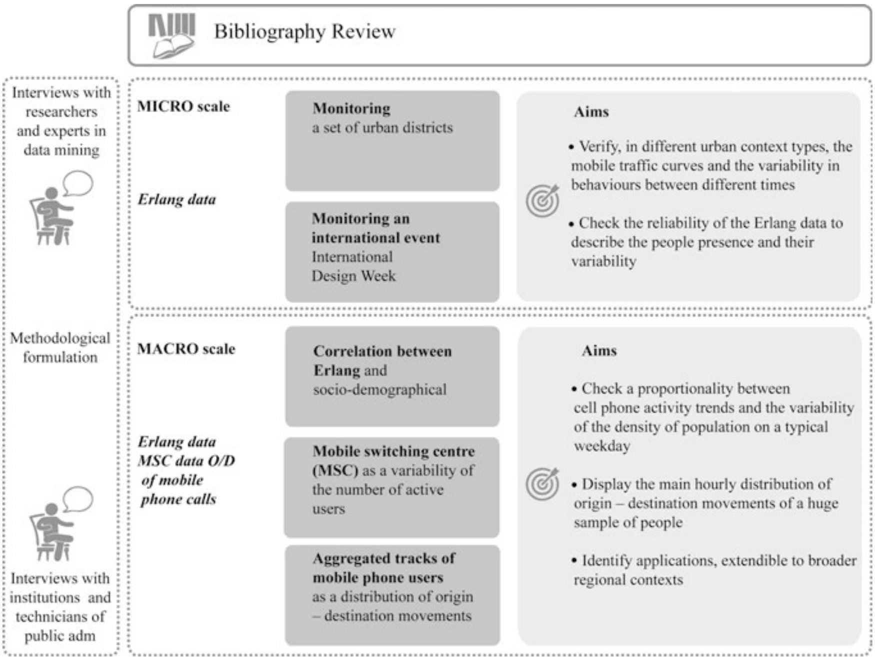

Fig. 3.3 The methodological approach

In macro and micro scales of analysis, statistical correlations between Erlang and the comparable data (land use, density of population, socio-economic trends, commuters flows, mobility surveys…) show that the cell phone activity effectively reflects people's daily activities.

3.2.1 The Macro Scale: Assessing Correlation Between Population Presence and Erlang Values

In the analysis at the macro scale we hypothesize a proportionality between the changeability of the cell-phone activity and the variability of the present population in one representative day. The preliminary results seem to confirm a high level of correlation between these variables.

More precisely we considered the correlation between Erlang measures,[6] aggregated at the municipality scale, and population distribution, for the provincial capitals of the Lombardy Region.

We took as a benchmark the data from an elaboration of the Lombardy Region Origin-Destination matrix (Indagine O/D Regione Lombardia 2002), which consists of a set of time-series of people's presence in the region, one for each municipality, at hourly intervals. Figure 3.4 presents the scatter plots between the two sets of timeseries.

We evaluated the correlations between telephone traffic and people's presence, taking into account some further operations on the time-series, as reported in Table 3.1.

The second column contains the Pearson's correlation coefficient (ρ) of the original time-series. In the third column the correlation was calculated on a smoothing of the original series (moving average of three terms: past, present, future). In the fourth column the same smoothings were considered, but restricting the series to the time range from 7 a.m. to 11 p.m., where the denominator of the telephone series (the Erlang for the whole region) is more continuous than during the night, when lower values, close to zero, and the non-homogeneous use of the cellular network across the region make the curves less reliable.

Correlation values are globally very interesting. While the first comparison leads to high ρ for only a few municipalities, the second presents values mostly around 0.8 and always more than 0.5, with the sole exception of Milan. Filtering the series reduces their local variability, and allows for more reliable evaluation of the trends, as we can clearly observe in Fig. 3.5, where the curves of Milan ($\rho = -0.2$) and their smoothings ($\rho = 0.4$) are plotted. Finally, the third comparison of the daytime part of the time series shows very high correlations for all the municipalities.

[6] We considered once again the ratio between the Erlang measures per pixel of each municipality and that of the entire Lombardy Region.

Table 3.1 Linear correlation between the time-series of cell-phone traffic and those of people's presence in the provincial capitals of Lombardy Region

Municipality	ρ (Pearson's correlation coefficient) —original time series	ρ—moving average (3 terms) smoothing of the time series	ρ—moving average (3 terms) smoothing of the time series, time range 07:00–23:00
BERGAMO	0.817281	0.916167	0.937125
BRESCIA	0.845554	0.941575	0.968859
COMO	0.670492	0.902546	0.930791
CREMONA	0.783395	0.974567	0.986318
LECCO	0.761152	0.891482	0.920895
LODI	0.825717	0.928989	0.982498
MANTOVA	0.483841	0.773677	0.939052
MILANO	−0.269416	0.453118	0.878923
MONZA	−0.321579	0.935640	0.978077
PAVIA	0.292641	0.835625	0.874587
SONDRIO	0.739026	0.862859	0.919483
VARESE	0.895775	0.969681	0.986226

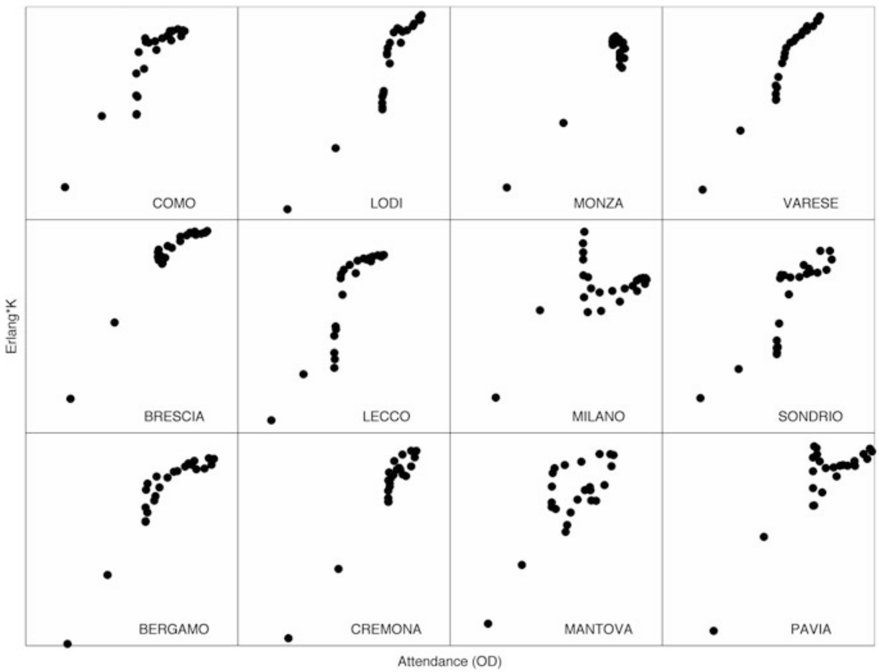

Fig. 3.4 Scatter plot of the time-series (ratio Erlang municipality/region vs. presence of people). Note that isolated points represent mostly night measurements

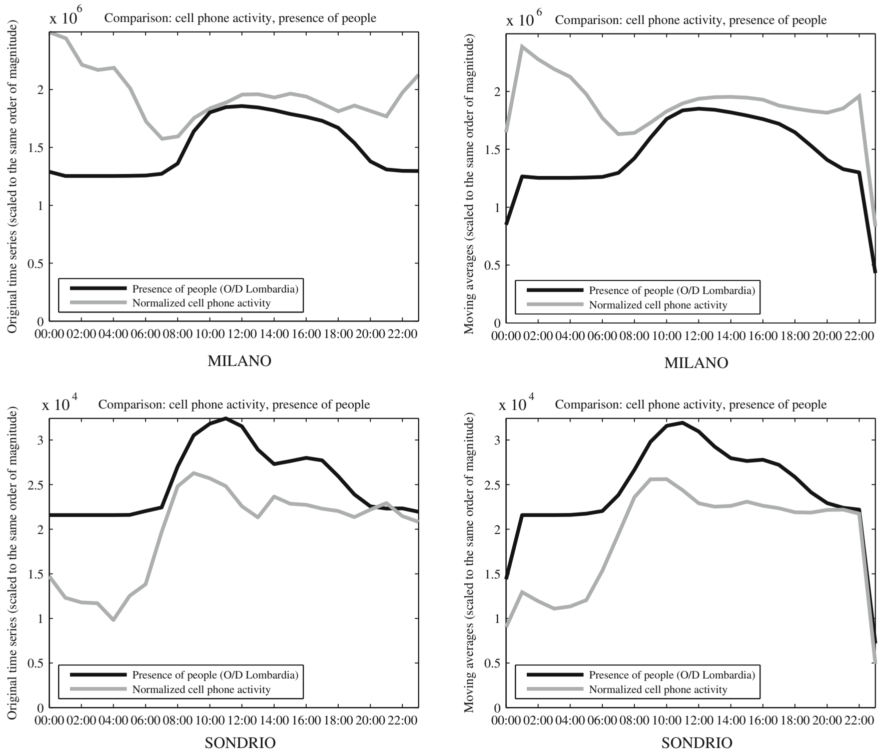

Fig. 3.5 Plot of the time-series for two limit cases: the municipalities of Milan (*top*) and Sondrio (*bottom*). Telephonic activity (*dashed*) is compared to the presence of people (*solid*). The *left side* represents the original time-series, the *right side* the moving average smoothing. For the sake of comparison the cell phone activity trend is scaled to the same order of magnitude of the presence of people trend

These results corroborate the hypothesis that cellular network data can be, at least on the municipality scale, a good indicator of the variability of people's presence (Fig. 3.5).

Besides, reconstructing simple profiles of probability in the use of cell-phone on the basis of the available data, correlations between the Erlang data and the data traceable on the peoples' daily activities in any municipality are verified.

3.2.2 *The Macro Scale: Treelet Decomposition of Erlang Trends*

A promising use of the Erlang data in mapping hidden mobile phone use patterns involved *Treelet analysis* (Lee et al. 2008), in order to verify the potential of this method in explaining spatial urban usage and mobility patterns.

Treelet decomposition is an effective dimension reduction technique for Erlang profiles and, more generally, for data with peculiar functional features, like spikes, periodicity and outliers.

With the Treelet decomposition methodology (Manfredini et al. 2012a, b; Vantini et al. 2012; Manfredini et al. 2015) it is possible to obtain: a reference basis reporting the specific effect of some activities on Erlang data; a set of maps showing the contribution of each activity to the local Erlang signal. In doing so, the Treelet decomposition basis contains different temporal patterns of mobile phone activity (i.e. daily, working day versus week end) that fit with city usage.

Applying the Treelet method in the Milan urban region we produce a set of maps explaining specific patterns both of mobility and of city usages (commuting, nightly activities, distribution of residences, non systematic mobility), comparing them with the main urban facilities and services,[7] in order to test their significance and interpretation of them from an urban analysis and planning perspective.

According to the different city usage profiles, the processed maps illustrate:

- In the Top panel, the basic profile considered: the x-axis represents time, spanning 7 days from Wednesday to Tuesday at an hourly rate. The dotted lines correspond to 2 h while the continuous lines separate the different days of the week; y-axis: Erlang values;
- In the Bottom panel, a map of intensity values: colours show how much the upper profile concurs to explain one place's overall (telephone) use pattern.

Comparing the maps of mobile call density in different hours with the morpho-functional profiles of the urban districts, interesting correlations emerge, describing urban dynamics and temporal profiles of the Milan urban region.

The nightly activities during holidays (Fig. 3.6) and weekdays (Fig. 3.7) reflect very different times and places of use of the city.

With regard to the density of mobile phone activity late at weekday nighttime (in particular from midnight until 8 a.m. (Fig. 3.7), we can observe very high values of the hot spots in the exhibition district in the Northern Western side of the map and in the Fruit and Vegetable Wholesale market in the South Eastern part of the city where a considerable amount of night work is involved in delivering and distributing products that come from the whole of Italy and abroad. The relatively low value in the city centre confirms the absence of significant urban activities during the night.

On the contrary, the high density of call activity during Saturday evening (from 8 p.m. until midnight; Fig. 3.6), focusses on the core city area, as well as in the Navigli District, in the Quartiere Isola and in other leisure spaces (Filaforum Assago in the South of Milan), where many entertainment places, pubs and restaurants animate nightlife.

7 In each map we added infrastructures (railways and main roads), railway stations, Linate city airport, main shopping centres and the fair trade centre.

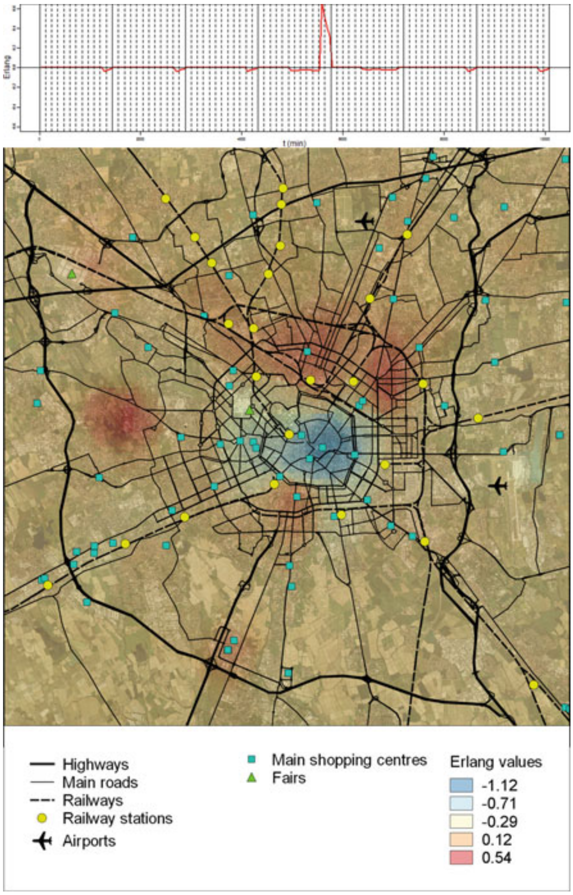

Fig. 3.6 Density of activity during Saturday night (8 p.m. to midnight)

Comparing these two maps only the activities in a continuous cycle such as those of the hospitals are always present. If the Saturday nightlife territories define a geography of densely frequented places completely different from that of night work, these maps suggest diversified policies for different populations at various times, unknowable with traditional sources.

The temporal profile of the city emerges when we consider mobile phone activity during working day evenings (from 8 a.m. until 8 p.m.) and during weekend daytime. Figure 3.8 highlights the main residential districts of the Milan urban region along the second circular ring of the city, where the density of the inhabitants reaches the highest value of Milan, as well as some municipalities with large scale social housing and residential neighborhoods in the South, South-West and in the North (Corsico, Rozzano, Sesto San Giovanni). The city centre of Milan appears as a void, due to the gradual replacement of the dwellings with offices, services and retail spaces over the last few decades.

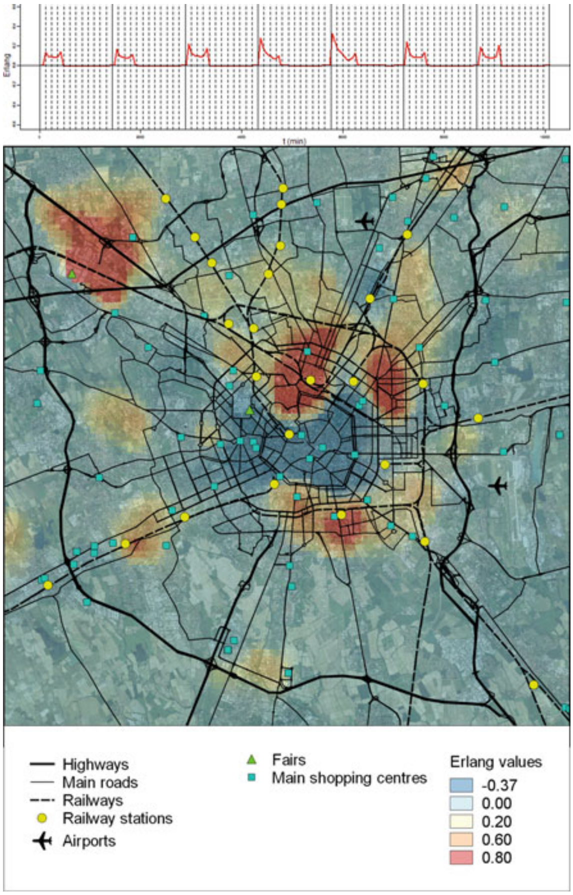

Fig. 3.7 Night activity. Hot spots highlight the presence of night work

The concentration of shopping and leisure activity in the Milan city centre is confirmed by the map of the density of mobile phone calls on Saturdays, from 10 a.m. to 8 p.m. (Fig. 3.9).

This map highlights shopping and leisure activities, difficult to capture with a traditional database, although they contribute significantly to the even more complex mobility patterns. In fact, in the Milan urban region a considerable concentration of mobile phone traffic can be observed corresponding to the distribution of shopping centres, shopping streets and, in general, cultural and leisure activities, inside and outside the city.

With the calculations performed it is possible to map the shopping, leisure and entertainment areas, bringing out the importance not only of the Milan city centre, but also of the western urban sector, rather than the large trade centres along the ring roads, counter-intuitively much less significant in Saturday shopping practices.

The catchment area of these centres, involving large amounts of city users, covers a vast territory, going far beyond the administrative boundaries of Milan city.

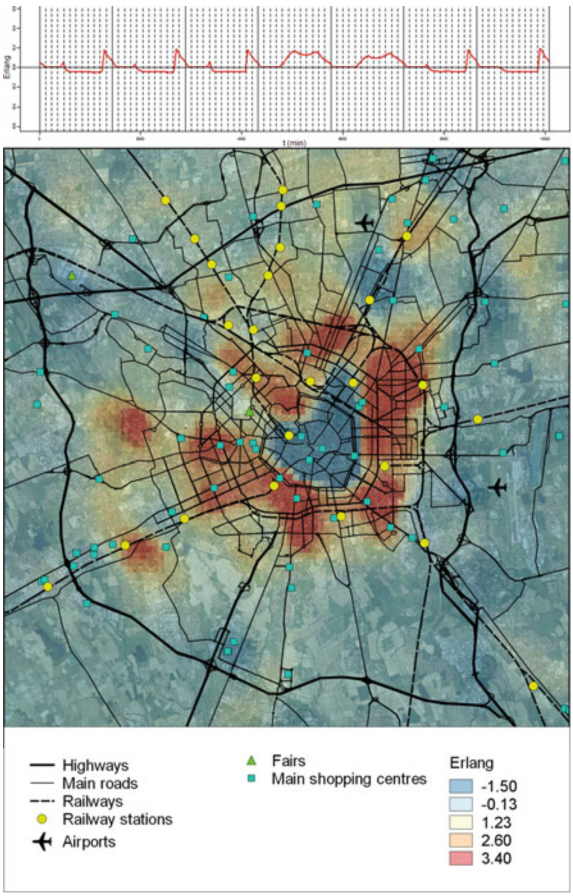

Fig. 3.8 Concentration of activities during working day evenings and daytime (from 8 a.m. until 8 p.m.) in the week end: residential districts of the Milan urban region

Treelet decomposition of the Erlang measures offers insight into different aspects of the urban area, and analysis of them can be developed with various scopes: segmentation of the area into districts characterized by homogeneous telephone patterns; identification of a set of "reference signals" able to describe the different patterns of utilization of the mobile phone network in time; description of the influence of each telephone pattern detected in each site of the grid.

The Treelet approach shows the ability of mobile phone data to reflect the space-time variability of use of urban spaces, not necessarily due to the functional features, to land-use or to the times of the activities, but to the ways in which people frequent some of these spaces.

In doing so, it is possible to describe the "urban rhythms" generated by practices, rather than defined by opening/closing of activities.

This is important information in proposing more effective urban policies, able to manage the actual uses of the urban spaces and services, as proposed in Chap. 5.

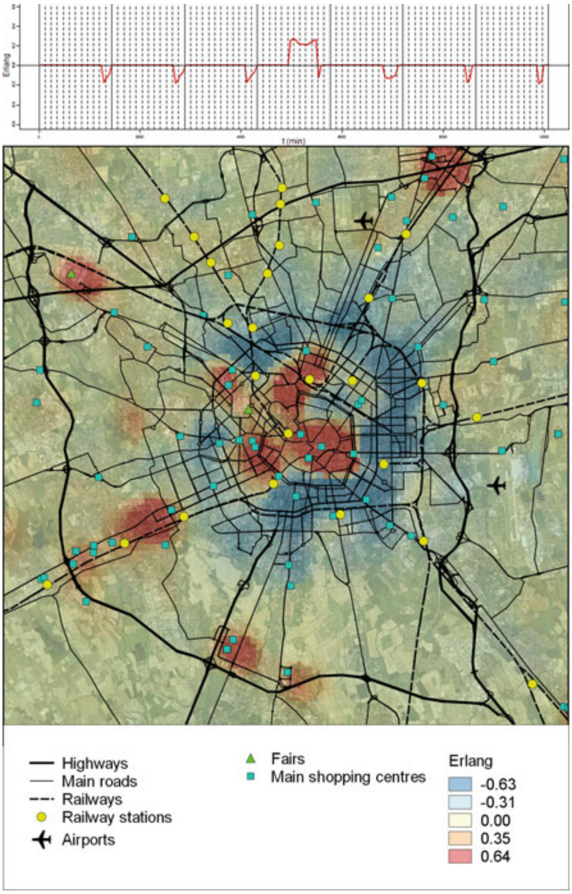

Fig. 3.9 Density of activity on Saturday (10 a.m.–8 p.m.): shopping and leisure activity

3.2.3 The Micro Scale Analysis and Its Relevance

The aim of the micro scale analysis is to evaluate the Erlang trends in similar context types in terms of land-use patterns and socio-economic profiles, as well as to verify possible correlations between land-use maps and mobile phone activities, in order to provide a functional clustering of the territory.

In this way, the micro-scale analysis identifies similar urban contexts, selected on the basis of recognizable and well known land-use patterns, density of population or activities and socio-economic patterns.

Viewing each selected case territory, which was chosen based on some similarities and grouped by clusters (such as social housing districts, railway stations, university districts, factory ambits, residential districts, business districts, areas of urban sprawl), it is possible to verify if in each group there is actually a similarity in the time and practices of use (Fig. 3.10).

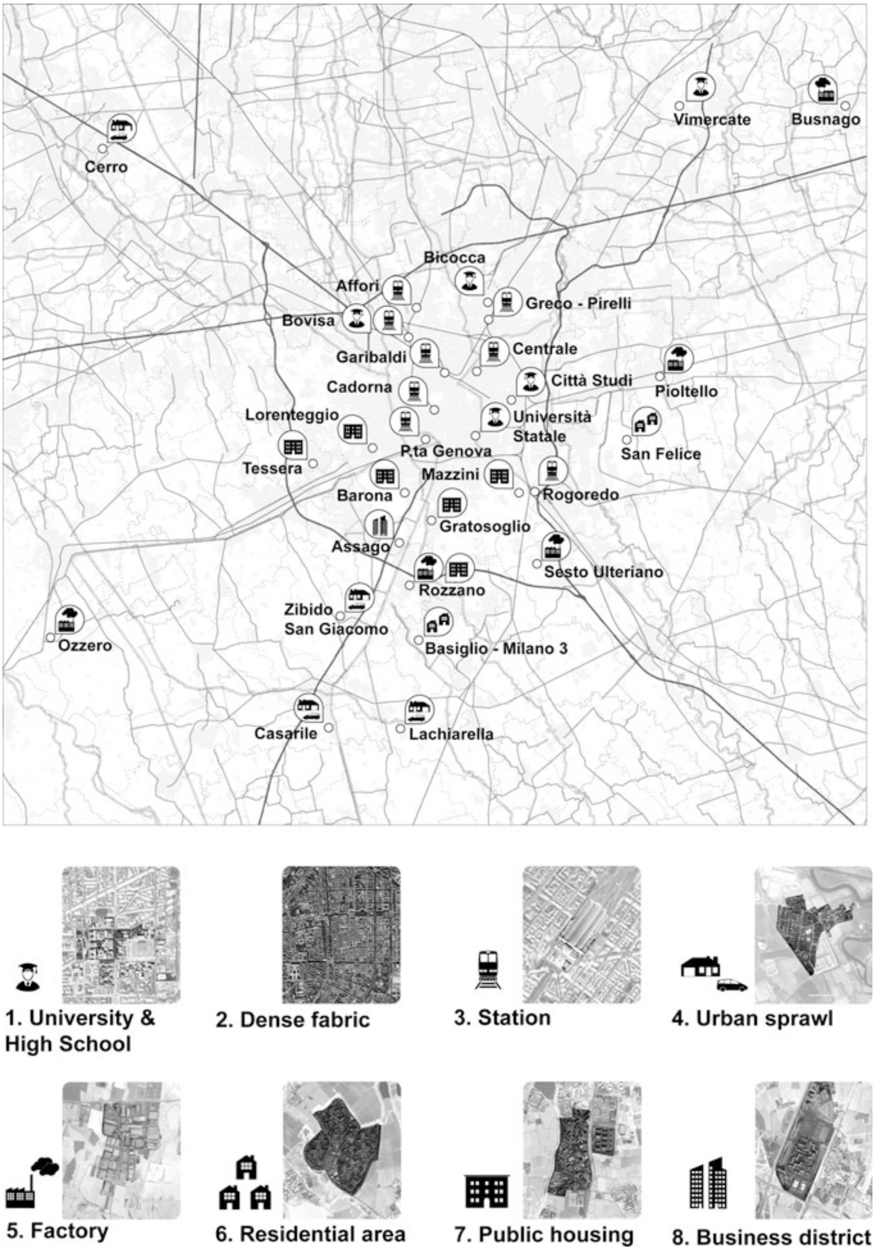

Fig. 3.10 Mapping the selected urban situations

Comparison with demographic and socio-economic data also allowed us to analyse the “anomalies” in the Erlang curves, recorded in the same urban districts, and to recognize the significant socio-economic indicators useful in explaining the correlation between statistical data and mobile phone trends.

Thus, the first step of this analysis was to elaborate the typical daily curves of mobile phone activity (Erlang from January to October 2009) to verify whether urban districts with similar socio-economic profiles showed similar cell phone activity trends. In addition, we examined the variability of trends on working days and during holidays for the same urban context type (Fig. 3.11).

Reconstruction of correlations between the smoothed data expressed in Erlang (from 9.00 a.m. to 10.15 p.m.) in the selected areas shows (Fig. 3.12):

- homogeneous patterns of telephone traffic within the majority of urban situations considered (in particular within the industrial plots and the social housing districts);
- the presence of areas belonging to different urban situations, which are characterized by similar profiles of cell phone use, a trend that suggests similarities in the practices of use of mobile phones for some urban situations, such as productive plots and universities;
- the presence of different cell phone traffic trends in similar urban district types, such as railway stations and urban sprawl areas.

These situations (different mobile phone traffic trends in similar urban context types) were analysed in depth, with demographic and socio-economic data, in order to recognize the significant variables able to account for the anomalies.

In particular, we observed, for the railway stations, a linear correlation between mobile phone traffic intensity and the quantity of people getting on and off during the whole day. This is due to the different profile and role played by each station for the local passenger traffic in the Milan Urban Region.[8]

Considering, as an example, two different profiles of stations, such as Milan Central Station—the main station for national and international railway connections—and Milan Cadorna, the commuter train station with an important role for the regional railway links (Fig. 3.13), we can observe that during weekdays the Central Station (grey line in Fig. 3.13) presents less telephone traffic than Cadorna Station (black line), while the opposite situation characterizes holidays.[9]

This confirms the prevailing role of Milan Central Station: rather a station for middle/long journeys, than one used by commuters. On the contrary, the considerable rise in telephone traffic registered for Cadorna Station during working days is

[8] These stations, located in Milan, play different roles related to their transport supply: regional stations for commuter flows such as Porta Genova, Bovisa, Affori, Rogoredo, Cadorna, Greco-Bicocca and nodes of national relations (Milano Centrale and Porta Garibaldi).

[9] The Wednesday peak in the Central Station from 5 a.m. to 7 a.m. can be explained with the corresponding low value of the denominator of the ratio station Erlang/Lombardy Erlang. When the total amount of telephone traffic is low (0 a.m.–6 a.m.), Erlang Lombardy curves are not very reliable.

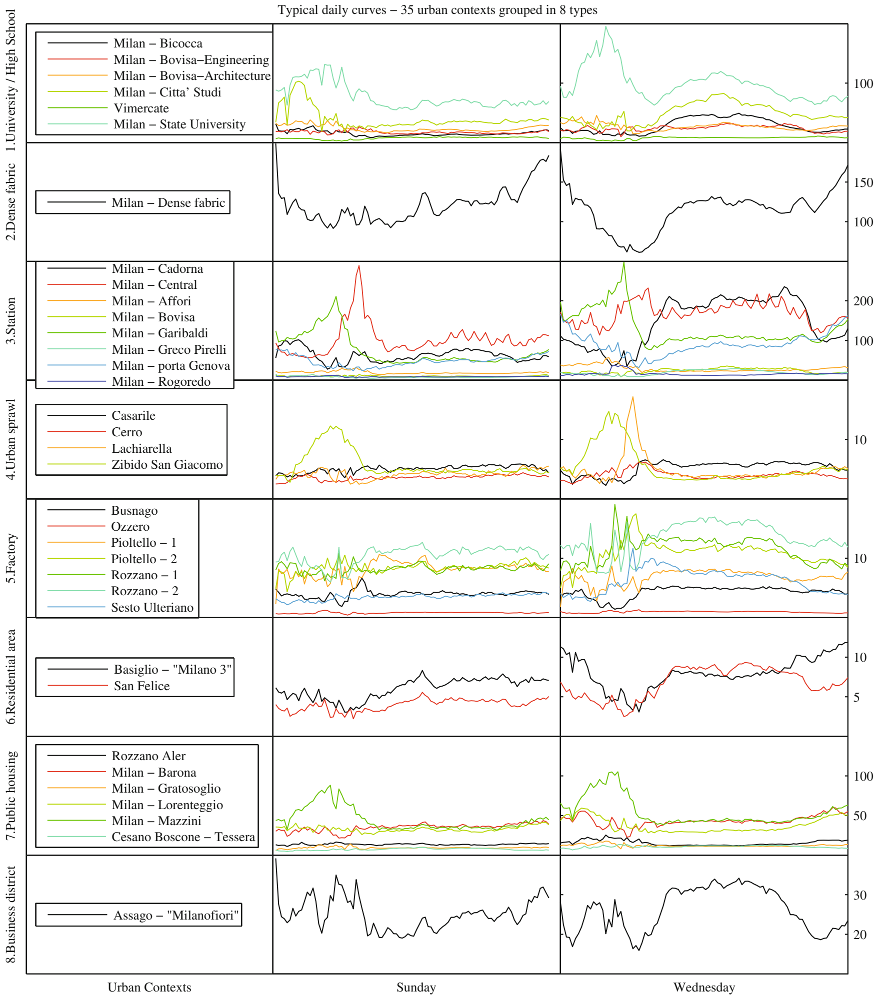

Fig. 3.11 Typical daily curves (Sundays on the *left*, Wednesday on the *right*) for 35 urban districts grouped in 8 urban context types

consistent with the data on people getting on and off, and corresponds to the key role of this station for the commuter flows. Considering other stations, the distribution of telephone traffic is more regular and is characterized by a greater intensity in weekdays than in holidays.

In the areas of urban sprawl, characterized by marked functional specialization (residency), often accompanied by few or no services and by a standardized time of use, comparison of the Erlang data between weekdays and holidays shows different

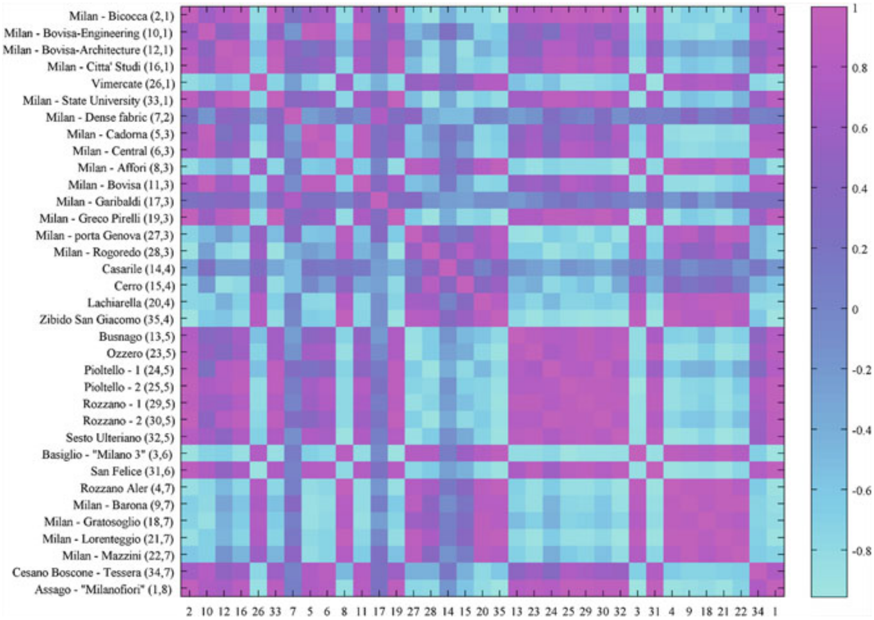

Fig. 3.12 Correlation matrix among different urban context types. Row labels represent: urban district name, id of the district (from 1 to 35, the same used for columns), id of the context type (1: university; 2: dense urban fabric; 3: railway station; 4: areas of urban sprawl; 5: factories; 6: residential districts; 7: social housing districts; 8: business district). The 35 urban districts analysed are ordered by type. *Pink squared blocks* along the principal diagonal of the matrix (correlation values near 1.0) show a marked homogeneity in the density of calls throughout urban contexts of the same type. The presence of *blue* pixels (correlation values near −1.0) along the diagonal reveals that some contexts does not behave in the same way as the other contexts of the same type. *Pink blocks* far from the diagonal, by contrast, indicate some “telephonic” analogy among urban districts of different types

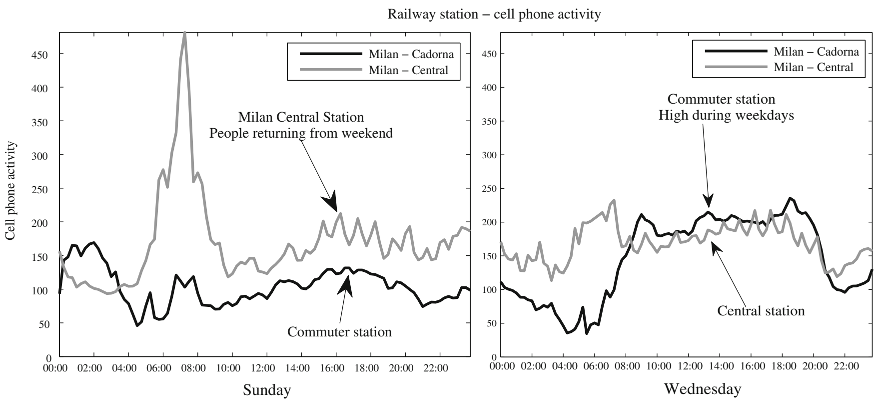

Fig. 3.13 Milan railway stations on Sunday (*left*) and Wednesday (*right*)

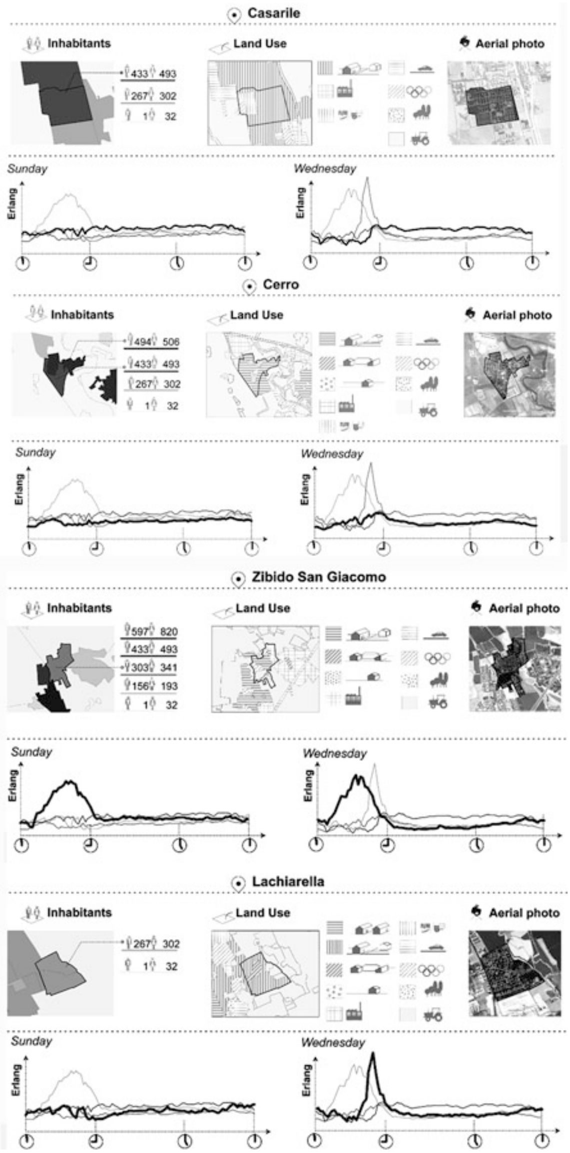

Fig. 3.14 Areas of urban sprawl

behaviours on Sunday relative to Wednesday, in line with the profile of these areas, almost exclusively residential and with a high percentage of working population[10] (Fig. 3.14).

[10] During the day, the people generally move to the workplace or school, to come back in different times, according to age.

In the Sunday curves higher values of cell phone traffic are found, distributed fairly regularly throughout the day, although not related to the density of settlement. In fact, comparing Erlang and statistical data[11] we see two interesting and "extreme" situations.

The least populous area among those considered (Zibido) is one that has a density of mobile phone traffic peaking on Sunday and significantly falling on Wednesday. This trend may be related to the profile of this area, characterized more significantly than other areas, by the presence of young population, by an equally high percentage of the population under 14 years, as compared to residents over 55 years, under-represented. The commuter flow data are the most significant among the areas considered (79.7 % of all journeys are out of the district). The opposite situation—Cerro—is represented by the highest residential density in the urban context type considered, but with less significant cell phone traffic both on Sunday and on Wednesday.

These trends can also be traced back to the age profiles of residents (high density of population over 55 years) and to the component of outflow (69.2 %), conditions that account for the working day Erlang trend, similar to that of less populated areas.

Proceeding with analysis of the urban situations, we can draw some conclusions from research findings.

Beginning with *Railway Stations* it is, first of all, possible to identify, through the Erlang trends, different types of stations: a correlation was found between the intensity and amount of telephone traffic during the day (when presumably people use rail services more intensively) and the role of each station (hierarchy, size, number of trains per day, etc.). Secondly, with comparison of Erlang data for weekdays/holidays we can see the different profiles and roles stations play in the city. For instance, it can be seen if some stations are more used during weekends because they mainly serve railway connections over medium-long distances, whereas others are more used during morning hours when there are more regional trains and thus more commuters. The Erlang data also help to bring out the relationship between flows and utilities, which may improve services at train station. Significant socio-economic variables useful for stations classification and estimation of ways of use are: number of entrances and exits on each station; number of entrances and exits during time slot from 0 a.m. to 9 a.m.; hourly estimation of entrances and exits.

The *University Districts and High School* chosen are four Milan University campuses located in dense urban fabric and a specialized high school with less marked presence of other assets. In this case, the presence of young students, between the age of 14 and 18, who use mainly text messages instead of calls for communication, has represented a field test for the validation of Erlang trends.

Useful to consider socio-economic parameter for constructing a profile of such districts are the following: number of employees, number of students enrolled, number of employed and professional profile.

[11] The socio-economic data for comparison with Erlang data, are: inhabitants by sex and age; socio-professional profile of population; foreign population; commuter flows; employees and economical activities.

The result showed the presence of intense telephone traffic between 7 a.m. and 7 p.m. with a high correlation between curves of mobile phone traffic and presence of people around university campuses[12] (students enrolled as well as staff in each university and school structure). Decrease of activities during weekends shows cluster uniformity and, thus, if there is an exceptionally large presence of people it can be an indicator of mixed use of the neighbourhood.

Public housing neighbourhood characterized by a relatively poor endowment of services. The choice of this kind of study areas was due to their dense residential fabric and absence of services; additionally neighbourhoods of this type are mainly populated by people over 60 and immigrants. Erlang trends, on a weekday and on a holiday, show a substantial similarity among the public housing districts selected, in spite of a low correlation between Erlang date and some socio-economic data useful for analysis. Among these are: resident population by gender and age, socio-professional profile of occupied population, foreign residents, daily trips out and in municipality, employees and local units.

The density of population does not account for the Erlang trends, nor are there correlations between age of the population and propensity to mobile phone use (the neighbourhoods where there are high percentages of the population over 70 years and low percentages of population under 25 years are those in which call density is more intense).

Areas of urban sprawl. These areas are interesting due to their marked functional specialization, which is residence, often accompanied by a weak range of services. Here we can find high correlations between the Erlang trends and some socio-economic variables. Useful socio-economic identifiers are: resident population by gender and age, socio-professional occupation profile, foreign population, daily journeys inside and outside municipality, employees and local units.

Comparison of the Erlang weekday and holiday data shows very different trends on Saturday and on Wednesday, confirming the profile of these areas: residential areas with a high percentage of the workers going out of the area studied in the morning hours and returning in the evening. On working days higher values of phone traffic are found, with regular distributed throughout the day, although not correlated to the density of settlement. In these cases, socio-economic data are a useful key to understand some anomalies and peculiarities: the presence of aged population and population under 14 plays an important role because it affects the habits of phone use, confirming the characteristics of each sprawl area.

[12] With comparison of trends between 7.00 a.m. and 7.00 p.m. on a representative weekday correspondence can be observed between the datum of the number of students enrolled as well as staff in each university and school structure and the intensity of telephone traffic: the “Università Statale di Milano”, which shows the greatest density of telephone traffic, is also the structure which concentrates the greatest quantity of students and staff. Città studi-Leonardo, albeit showing a number of students enrolled and staff only slightly higher than Bicocca University, displays a higher density of telephone traffic in Erlang. This trend could be associated with the significantly higher proportion of students enrolled at Città studi-Leonardo who are more likely to use cell phones than the staff, who have access to landline telephones in the workplace.

Industrial plots. Productive settlements are often the result of the unified territorial planning, formed by strong functional plots (mainly industries), and services are limited in the area. Socio-economic variables for comparison with Erlang data are the following: employees, local units, typology of businesses set up, socio-professional profiles of occupied population, foreign resident population, daily journeys inside and outside municipality. An indicator[13] has been built to quantify the presence of population during workdays with the least error possible. The main trends observed in this typology show a decrease of calling activity during weekends in comparison with work days, which confirms that these areas are used mainly for work activities. The considerable difference in time use of mobile phones among the industrial plots can be accounted for with different production profiles characterizing the industrial areas selected.

The outcomes lead us to consider two relevant research perspectives, finalized:

- to propose a land-use classification, on the large scale, starting from the same kind of Erlang curves as a "signature" of each urban context type, chosen from the specific functional profile; in this case, since the mobile phone data would allow a functional description of the space, without the burden of a direct survey;
- to experiment a spatial clustering of Erlang data, finalized to identify some urban contexts characterized by homogeneous telephone patterns, considered proxies of areas that are used in the same way by the population.

3.2.4 An International Event Transforming the Use of the City: The Milan International Design Week

The approach proposed applying micro scale analysis is useful not only to have a broader view of a particular urban, as described above, but also helps to understand flows of tourists in specific areas, to identify and measure the attractiveness of the areas and, moreover, to monitor events taking place in the city.

The Milan International Design Week represents an interesting case study for evaluating the potentiality of mobile phone network data for analysis of the spatial and temporal variability of urban space uses by temporary populations.

It is, in fact, at the same time a large-scale event—called the "Salone Internazionale del Mobile"—which takes place in a specific part of Milan—the Rho-Pero exhibition district—and a "distributed" event, as it is also characterized by various initiatives—going under the name of "Fuorisalone"—carried out in different parts of the city of Milan.[14]

[13] The indicator is calculated as: employees + resident population − commuter outflows.

[14] The 49th edition of the "Salone Internazionale del Mobile", which lasted from 14 to 19 April 2010 at the Rho-Pero exhibition district, has attracted 298,000 visitors, including 166,000 foreigners (*Source* www.cosmit.it).

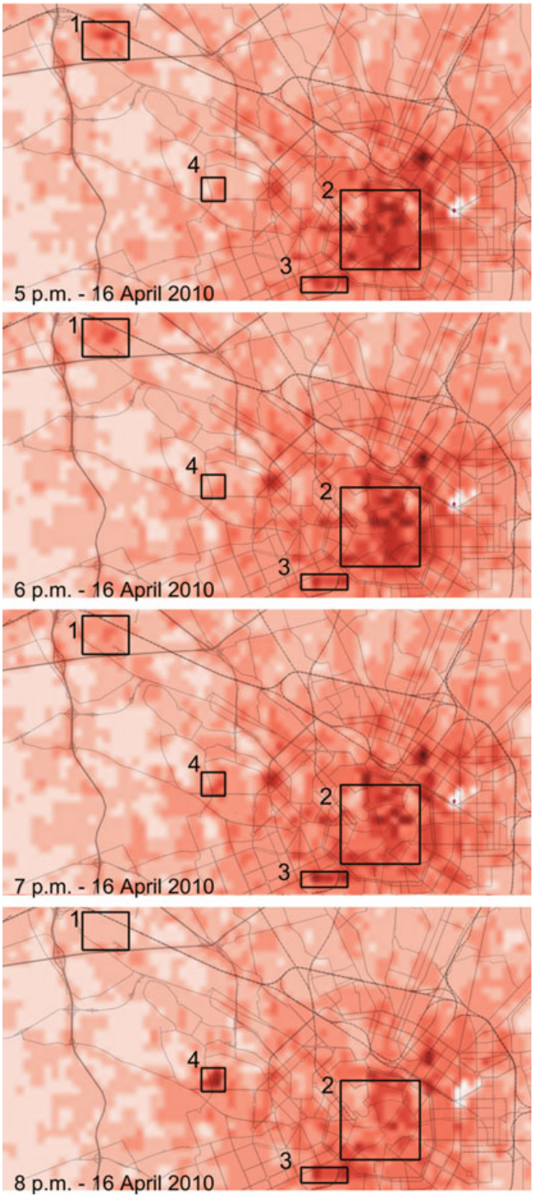

Fig. 3.15 The sequence of maps shows the cell phone traffic on 16 April 2010 from 5 p.m. to 8 p.m. Increasing intensity of *red colour* corresponds to higher cell phone traffic in some urban areas where phone activity is high, largely due to the International Design Week activities. Numbered boxes in the *top-left* frame highlight areas of particular interest: *1* Exhibition District; *2* Milan city centre; *3* Tortona District; *4* San Siro Stadium

The event attracted temporary populations who interacted and interfered with the usual temporal and spatial patterns of the city.

It is difficult, if it not impossible, to measure with traditional data and surveys an event like the International Design Week. It is therefore clearly useful to look for

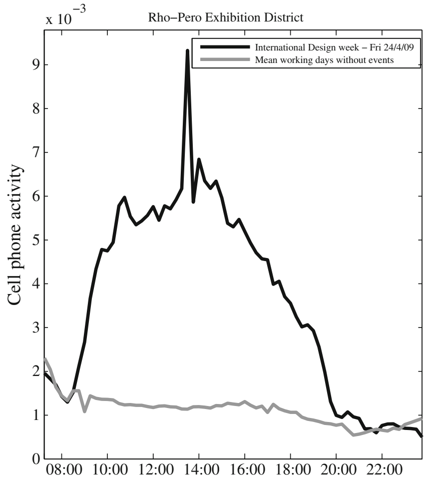

Fig. 3.16 Variability of cell phone traffic (Erlang) normalized by the total Lombardy Region value at the Rho-Pero Exhibition District during the 2009 International Design Week (*black*) and in a typical weekday, without events (*gray*)

other sources that can describe in real time the variation of people presence in cities and urban spaces.

Thus analysis of mobile phone data during the 2009 and 2010 International Design Week—a major international event that lasts 5 days and concentrates its activities in the Rho-Pero Exhibition District and in hundreds of places within and outside the city (Fuori Salone)—consituted an opportunity to quantify the consequences of a specific event on the whole urban system, to assess its impact on mobility, tourism and temporary population attractiveness and to offer guidance for future decisions on the provision of new urban services (Manfredini et al. 2012b).

The International Design Week (presentations, exhibitions, pre-opening previews) modified, even quite substantially, the ways and times in which some Milan urban districts were used by tourists, city users and temporary populations. The main design pavilions, located in Rho Fiera, are evident places for concentrations of people, whereas other areas are more difficult to identify. It was known, for example, that the Tortona and Savona streets are the second most visited area of the city during the event, but also the Lambrate district or other areas clearly emerged from the Erlang distribution maps.

Using Erlang data we performed processing along various lines for the period of the Milan International Design Week with the aim of mapping the spatial configuration of mobile phone traffic during the event as well as identifying which parts of the city show a significant concentration of activity, comparing the days when the event occurred with other days without events.

We then performed several analyses to evaluate the potential contribution of Erlang data to describing, representing and managing an event, from the beginning until its conclusion. In doing so, we defined a set of significant spatial operations between Erlang matrices with the aim of highlighting the territorial effects of the event on a wider scale and in different temporal intervals.

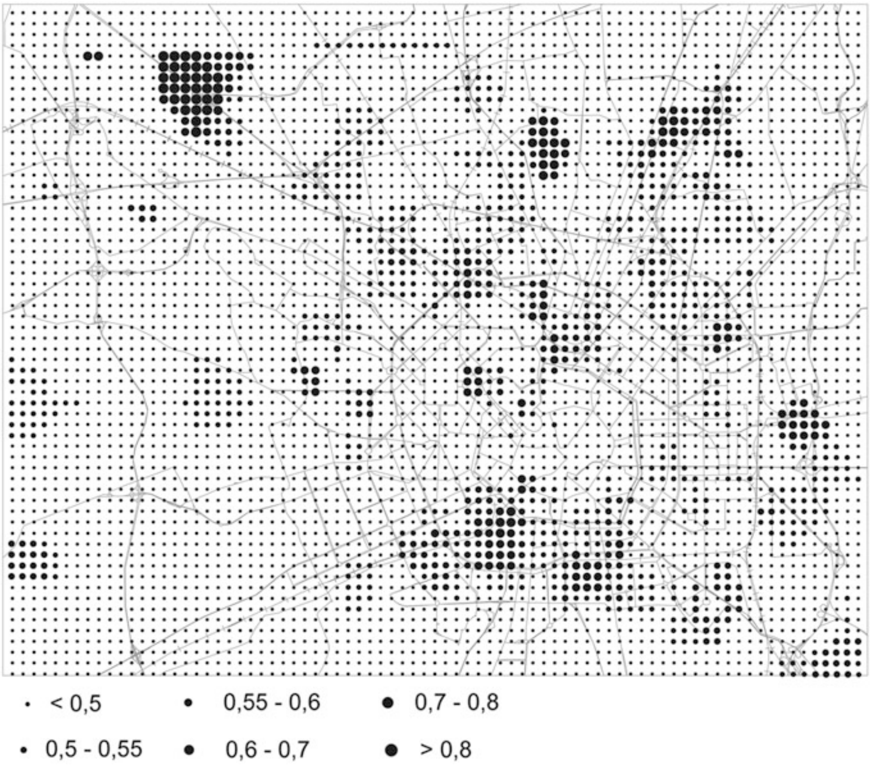

Fig. 3.17 Night/day cell phone traffic activity ratio during weekend in the period of the 2009 International Design Week

The maps, representing the spatial configuration of cell phone traffic at different hours of the day, can be divided into two main groups:

- "Static" maps, which show cell phone traffic intensity at different hours of the day in which the event occurs. They represent the variation in urban uses by temporary population over time;
- "Complex" maps, which compare two matrices of cell phone traffic, such as ratio between night-time and day-time mobile phone activity, ratio between weekdays and holidays, ratio between days with event and days without events, with the aim of showing the spatial concentration of mobile phone activity.

Analysing in detail the change in cell phone traffic activity during Friday 16 April 2010—the day when, in addition to the exhibition in the Rho-Pero District in the Northern-Western side of Milan (box 1), dozens of formal and informal activities (presentations, inaugurations, etc.) occurred in several areas of Milan—a distinct and substantial modification in density of use of the city is found, reflecting the time-frame of the different events (Fig. 3.15). The centre of Milan empties

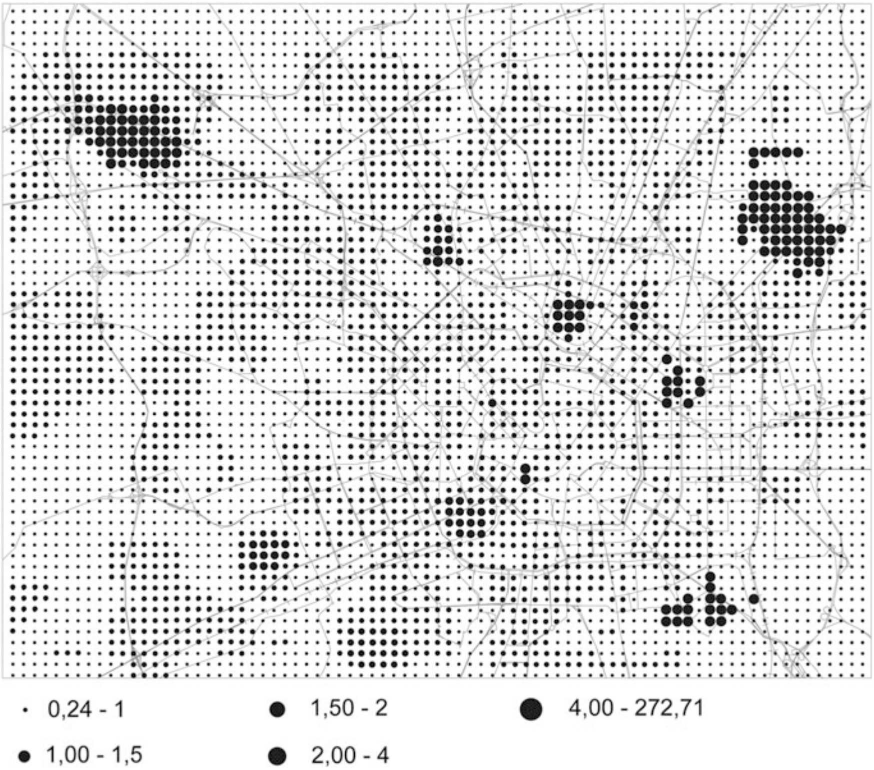

Fig. 3.18 Ratio between 24 and April 2009 cell phone traffic. The map highlights the parts of the city where the activity, during the International Design Week (April 24), was greater than during a typical weekday (April 29)

gradually during the afternoon (box 2), while the Tortona district, on the southwest side (box 3), where the main "Fuorisalone" activities were organized, remains crowded until late evening. During the evening, the San Siro stadium area (box 4) is stands out because of the major football match held there that day.

These trends related to an increase in temporary population and tourists during the International Design Week are confirmed on observing the variability of cell phone traffic (Fig. 3.16), which increases compared to a typical weekday, as well as in different hours of the day (Figs. 3.17 and 3.18).

If interpretation of maps like those presented is facilitated with specific information on the activities established in the territory and by integration with traditional databases (land use/land cover maps, transport networks, etc.), they can provide a new picture of urban dynamics with far greater spatial and temporal resolution than is possible with maps using traditional data sources.

The maps suggested a close correspondence between the variability of cell phone traffic and the distribution of activities and initiatives in the Milan urban areas during the period of the International Design Week.

These data can therefore enhance our understanding of the variability in the intensity of urban space use by the population present, allowing us to propose a descriptive and interpretative model of events through analysis and mapping of cell phone traffic data. This model can take into account what happens when the event occurs, even in real time, comparing it to typical spatial patterns.

Interpreted along the appropriate line, this type of information may well prove useful in evaluating the spatial and temporal effects of a specific event on the entire urban system in terms of concentration of people and mobility.

3.3 Aggregated Tracks of Mobile Phone Users: The Experiential Dimensions of Commuting Rhythms

For the purposes of mobility analysis and definition of public transport policies, origin-destination (OD) flows matrices are considered the classical source. These matrices are extremely expensive to obtain by means of large-scale surveys, and are consequently seldom commissioned. Hence mobility policies generally rely on non-recent information. In the Lombardy region, for example, the most recent OD matrix was produced in the context of the Survey on Mobility (2002) (Regione Lombardia, Direzione Generale Infrastrutture e mobilità, 2002), a second source on commuter mobility being the Census data (2001) which dates back to 2001.[15]

In recent years, several studies have begun to analyse the possibility to exploit mobile phone data, and in particular Call Detail Records (CDR), for vehicular traffic estimation (Bolla and Davoli 2000; Caceres et al. 2008, 2012; Cayford and Johnson 2003) and for computing OD matrices (Bekhor et al. 2011; Calabrese et al. 2011).

The perspective opened by mobile phone data in this field is particularly interesting if we consider, for example, the situation in the Lombardy Region depicted in the Table 3.2 and focus on the following points:

- the spatial resolution of mobile phone data is, in urban areas, much finer than that of traditional surveys. Mobility practices, then, can be better visualized and studied;
- Mobile phone data are continuously collected and their temporal resolution is very high; it could be possible to monitor different practices over time on an hourly, daily or seasonal basis;
- the transport mode is lacking from mobile phone data, which means that only indirect indications can be obtained for traffic on the main roads;

[15] The present work could not take into account the last census data on commuter mobility, relative to the year 2011, being it published in August 2014 after the preparation of this book.

Table 3.2 Comparison of the available sources on mobility in Lombardy

	Survey on mobility (OD) Lombardy Region 2002	Census (on commuting) ISTAT 2001	Mobile phone data (Aggregated O/D tracks)
Sample	750 K interviews	All residents	Mobile phone users $\sim$1.5 M per day
Type of movement	All	Study and work	All
Reference Period	"Typical" working day of 2002 (one Wednesday)	One working day of October 2001	Every day
Updates	No	Census 2011 (results not yet available)	Continuous
Information on vehicle	Yes	Yes	No
Spatial resolution	Municipalities, aggregation of minor municipal districts, subdivision of major municipalities	Municipalities	Variable aggregation of cells
Temporal resolution	24 h	7 a.m.–10 a.m.	Hourly or sub-hourly
Cost	Expensive	Very expensive	Not known

- we may reasonably assume that when information derived from mobile phone data becomes available on the market it will cost rather less than the outlay needed for conventional surveys, the mobile phone data having already been collected for accounting and for network monitoring.

In Italy the law imposes very strict constraints on the use of Call Detail Records. It is therefore unfeasible to employ CDR directly, as suggested by several recent studies, for example the research by (Bekhor et al. 2011) in which an evaluation of OD matrices is performed, exploiting tracks of a selected sample of cell-phone users. We were, however, able to make use of an aggregated derivation of CDR, namely Origin-Destination counts, with no reference to the individual users generating them. An example will make the differences between the two kind of data clearer: with CDR data it is possible to infer the "work" and "home" position of a specific user (even if anonymized) on the evidence of, respectively, the most recurrent position of a SIM card during weekdays and night. Subsequently it is possible to aggregate this information obtaining the number of users who live in city O and commute daily to city D; starting with aggregated OD counts this is not possible: what we do know is that a certain number of users moved from city O' to city D' in the course of an hour, while we cannot say if O' is residence of the users counted or if D' is their final destination. We just know the flow.

In the following pages we will present some applications of these "legal constraint free" Origin-Destination data, showing how, despite the aforementioned

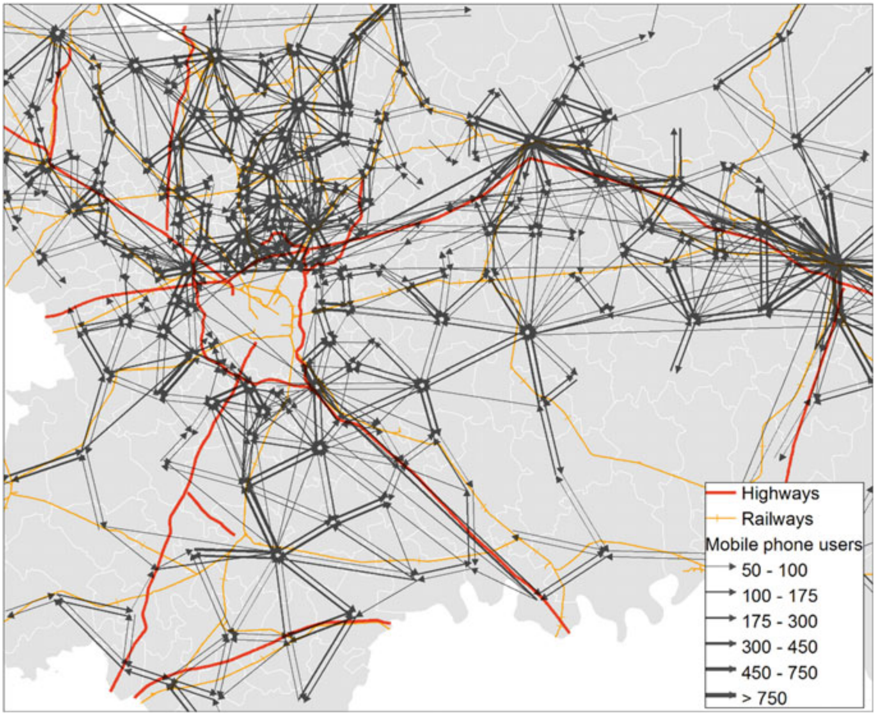

Fig. 3.19 Origin destination flows of mobile phone users: 8 a.m., 19-10-2011

apparent limitations, they have much to offer for investigations into mobility and for urban analysis (Manfredini et al. 2013).

We dealt with data derived from call detail records of a huge sample of people (more than one million per day). The data constitute a network of directed connections among the zones of a tessellation, labelled with the number of users traced in each hour of the days considered.

In Fig. 3.19 we provide a representation of this network for 19 October 2011 at 8 a.m.; Figure 3.20 represents 5 p.m. of the same day. The 313 zones tessellation was used for these maps, where only flows of more than 100 users are shown by oriented arrows connecting the centroids of the origin and the destination zone. Flows having Milan as the origin or the destination were filtered out to let a better visualization of the overall patterns of mobility in the region.

Figure 3.19 shows significant flows towards some of the major cities of the Lombardy Region (Bergamo, Brescia), but also some interesting patterns in the Northern Milan area.

Along some important infrastructural corridors (e.g. the Sempione road in the north-western side of the region and along the highway in the western side of the map between Bergamo and Brescia) we can observe many interconnected centres with relatively short distance relations. The density of flows at 5 p.m. (Fig. 3.20)

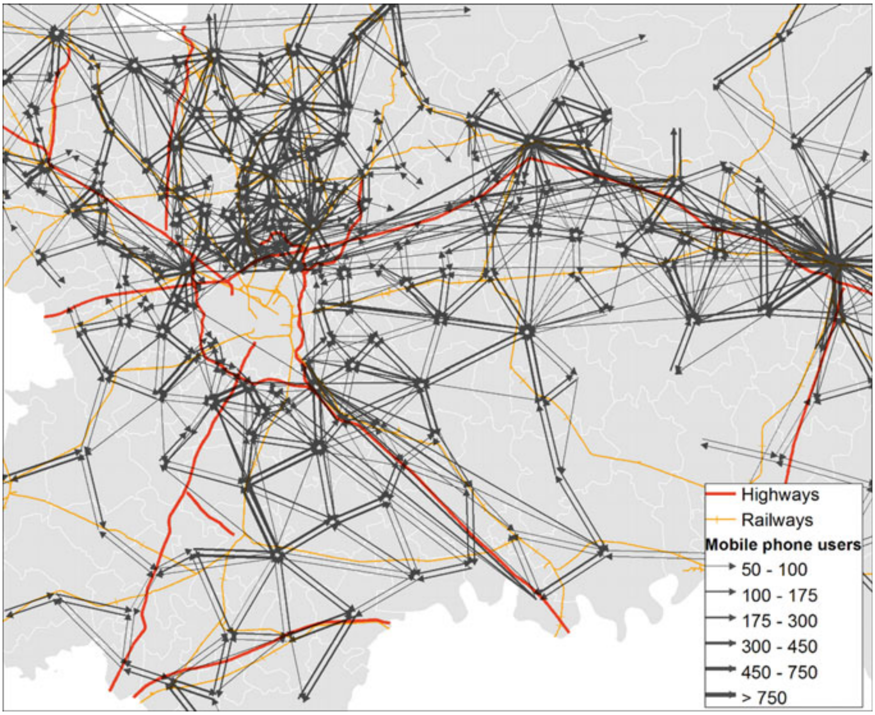

Fig. 3.20 Origin-destination flows of mobile phone users: 5 p.m., 19-10-2011

reflects not only the return home, but also the unsystematic mobility related to individual habits as an effect of the diversified uses of the Milan urban region.

These maps show how complex daily mobility patterns modify the hierarchical structure of the cities where traditionally the physical relationship between jobs and homes was the main reason for mobility.

In order to provide a more essential picture our proposal is to consider "prevalent flows" of mobility during the hours of a typical working day. The prevalent flow is defined as the sum vector of all the flows of people moving from each zone. More precisely, let each origin-destination flow be represented by the vector (two dimensional in an appropriate projection and reference system) applied to the centroid of the origin tile and directed towards the centroid of the destination tile, having its magnitude determined by the value in the cell of the OD matrix corresponding to the related origin and destination. If we consider now each tile, it is possible to sum all the vectors applied to its centroid obtaining the sum vector, which is representable in two dimensions: the magnitude, a function of the magnitudes of the original vectors, and the angle, which expresses the prevalent direction of the flow.

We produced (Tagliolato et al. 2013) a set of maps of the sum vectors during a typical working day (19 October 2011) in order to highlight the main mobility

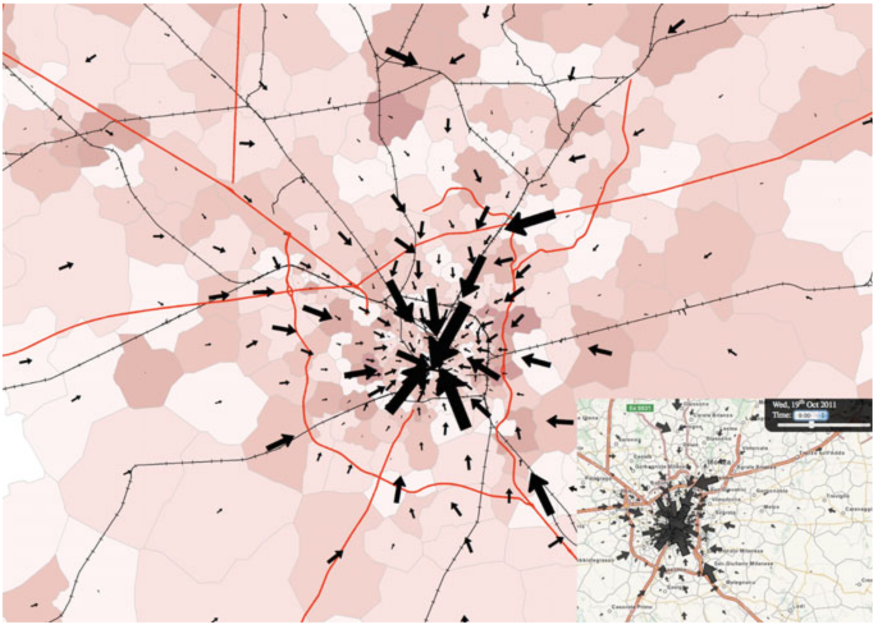

Fig. 3.21 Interactive visualization of "prevalent flows of mobility" in Lombardy Region derived from aggregated flows of mobile phone users: 9 a.m., 19-10-2011

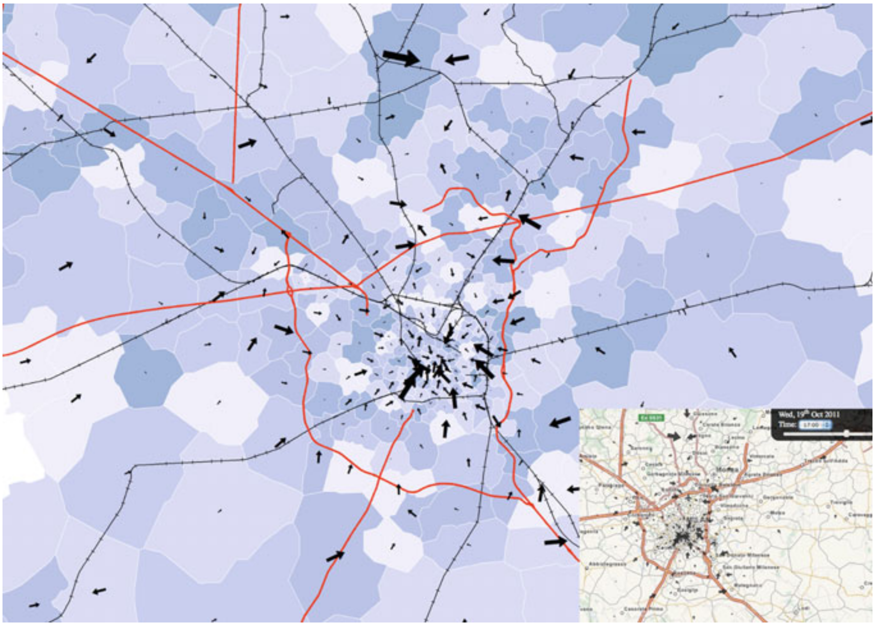

Fig. 3.22 Interactive visualization of "prevalent flows of mobility" in Lombardy Region derived from aggregated flows of mobile phone users: 5 p.m., 19-10-2011

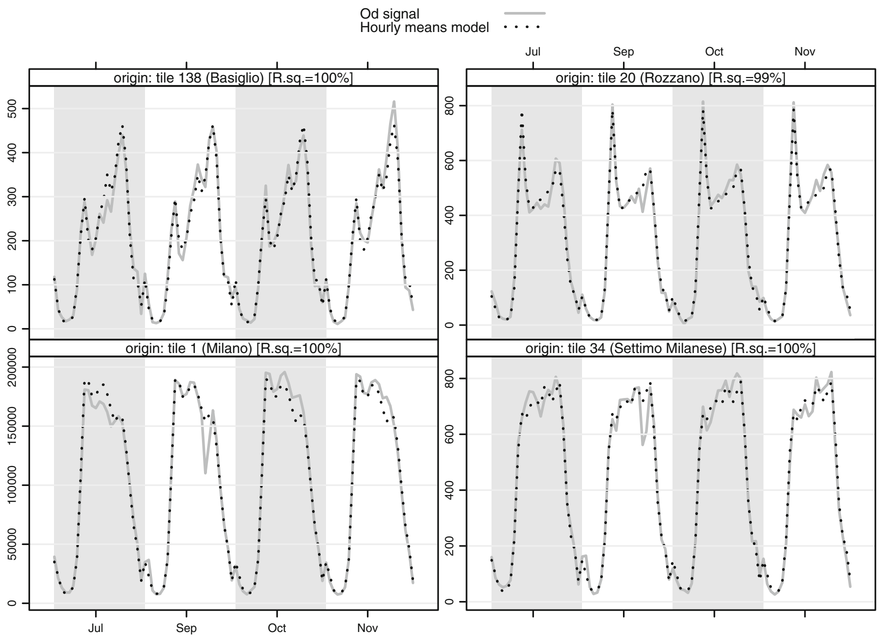

Fig. 3.23 Examples of OD flows directed towards Milan (*solid lines*) and fit of the seasonal means model (*dashed lines*). The four best fitted curves (sorted from *bottom left* to *top right* according to R2). Sampling rate is 1 h. Each *coloured* region in tones of *gray* represents 1 day of data, each day being one Wednesday in a different month of the year 2011

patterns. An interactive version was realized[16] too, where the user can see the evolution of the “mobility field” hour by hour (Figs. 3.21 and 3.22).

This visualization could be a useful tool for monitoring the use of infrastructural networks and urban spaces, and is able to show the variability of phenomena that conventional data sources, such as census data, cannot give for a typical day.

The regularity of people movements is a topic of interest. In this perspective, the work of Gonzales, Hidalgo and Barabasi, which examined the tracked positions of individuals, proved that “human trajectories show a high degree of temporal and spatial regularity” (Gonzalez et al. 2008). We can study, by the OD matrices of aggregated cell phone tracks at our disposal, recurrent mobility practices in a different way: instead of focusing on individual people and observing their movements through places, we can focus on places and observe the flow of people passing through them.

Public transport policies could benefit from the identification of regular mobility practices: it could offer an insight into the actual catchment area of an urban

[16] http://www.ladec.polimi.it/maps/od/fluxes.html.

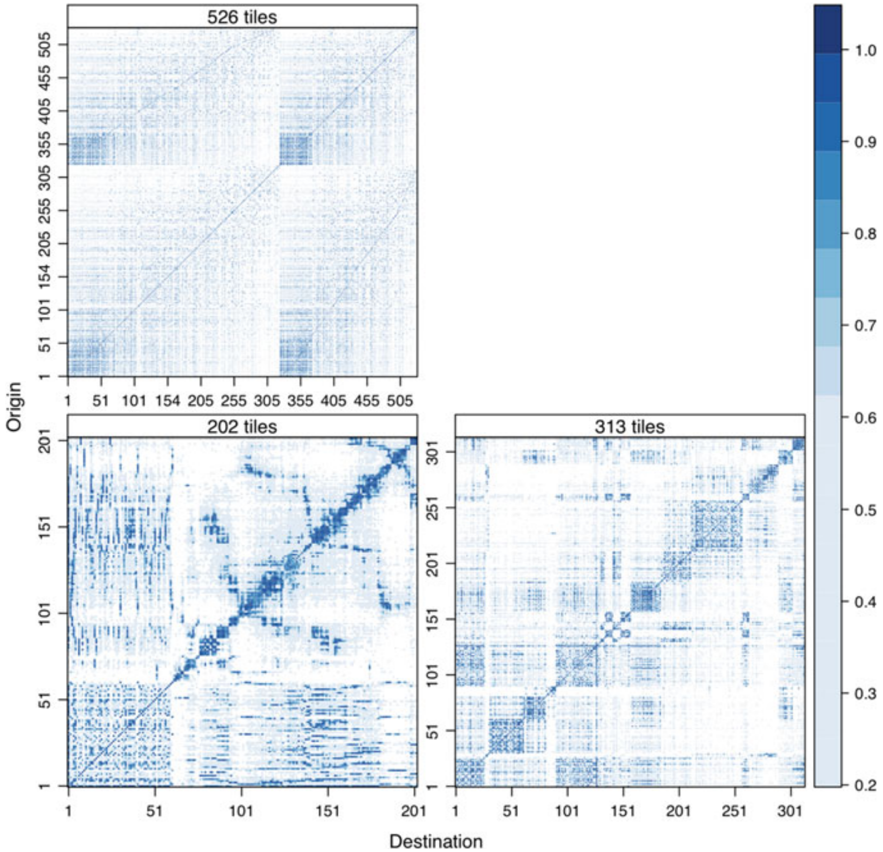

Fig. 3.24 R squared values of the fit of each origin-destination signal to the seasonal means model

context, to which regulation measures and appropriate rates of the public transport service should correspond.

We want to identify the pairs of zones for which a high degree of regularity of movements between them emerges. We analysed (Tagliolato et al. 2014), for different tessellations of the Lombardy Region, the time dependent sequence of OD flow matrices of aggregated cell phone tracks. We considered the time-varying functions F_{od}(time), defined for each (origin, destination) pair and whose domain is the juxtaposition of four out of the five days at our disposal (excluding August, the main holiday in Italy): in this way the time is represented by an integer varying on the set of numbers from 1 to 96 (24 h for 4 Wednesday).

The hypothesis is that regularity should be denoted by cyclical signals having a period of one day.

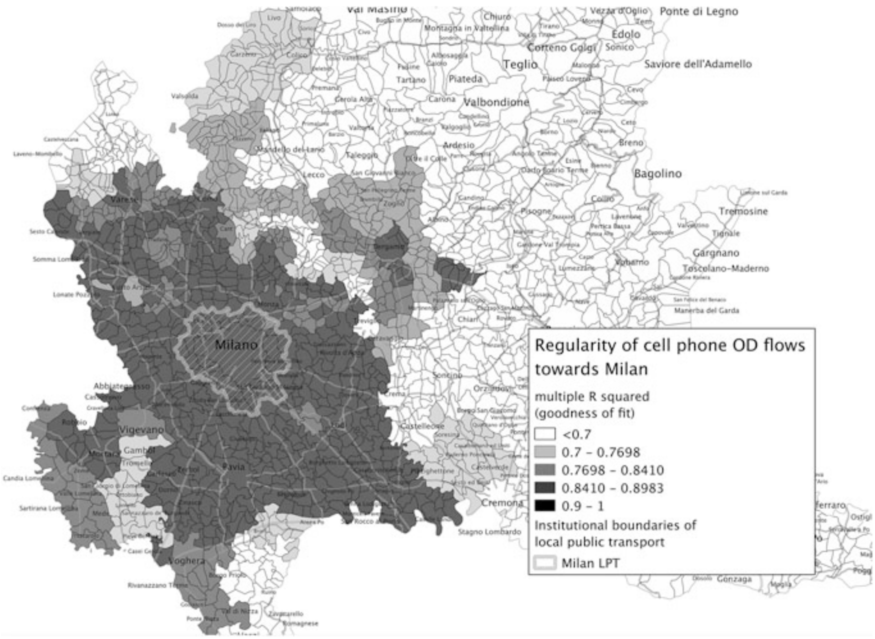

Fig. 3.25 Regularity of flows directed towards Milan: pap of the R squared values for the 202 zones tessellation of the Lombardy Region. The perimeter of the institutional boundaries of the management of the local public transport is superimposed

For each origin-destination (od) pair, we consider the seasonal process

$$\boldsymbol{\Phi}_{\mathrm{od}}(\mathrm{t}) = \Sigma \beta_{\mathrm{i}} \mathrm{D}_{\mathrm{i}}(\mathrm{t}) + \varepsilon(\mathrm{t})$$

where the sums are taken on i varying in {1,…,24} and the $\mathrm{D_i}$ are seasonal (i.e. hourly) indicator variables, and we calculate the coefficient of determination (multiple R^2) that results from fitting $\boldsymbol{\Phi}od$ to F_{od}.

R^2 measures the quality of the model fit: we take it as a synthetic indication of the regularity of the signal.

We can look at some example in Fig. 3.23, where four origin-destination pairs are presented, all having the Lombardy Region capital, Milan, as the destination. More specifically they are the first four best fitted curves. The bottom left chart represents the pair Milan-Milan: the regional capital internal flows.

Levelplot in Fig. 3.24 represents the values of R^2 for all the origin-destination pairs. All the three tessellations (resp. 202, 313 and 526 tiles) are considered. It is clear the emergence of symmetric patterns of R^2: when a pair of zones presents regularities of movement in one direction, it is also likely that regularity characterizes the movements in the opposite direction.

The choropleth map in Fig. 3.25 represents the R^2 values of the flows toward Milan of the areas of Lombardy Region (here the 202 OD zones tessellation is considered): it can be regarded as the map version of matrix column, in the preceding figure, relative to the regional capital. The institutional boundaries for the management of the Local Public Transport (LPT) are superimposed on the map: the comparison of the areas of high regularity with the LPT perimeter let us clearly observe how theoretical these boundaries prove.

A broader political debate concerns how public institution should deal with policy demands generated by temporary populations: one of the subjects is the inadequacy of the institutional boundaries in the Milan Urban Region as well as in other urban regions in the whole Italy. It is a problem of equity and efficiency (Pucci et al. 2013; Pucci 2014): the impact on the budget of the Municipality due to groups of people that are part of its economic jurisdiction but at the same time are neither voters nor tax-payers is not negligible. The net cost of these populations incurred by the Milan municipality is estimated at 295.52 M euros (Bernareggi 2013). Identification of the *actual* boundaries of the provenience of these populations could contribute to definition of fairer and more efficient policies (Pucci et al. 2014), as explained in Chap. 5.

3.4 MSC: Monitoring Visitors and Tourists Through Mobile Phone Data

Mobile Switching Centre data are used to monitor the variability of visitors and tourists in the Lombardy Region. Since the data were initially available in the form of cell tower localization, each of them belonging to a MSC, we created a bounded Voronoi polygon in order to obtain a polygon layer representing the different MSC serving areas.

The dimension of the MSC service areas depends on the amount of traffic to be served. They are relatively small in dense urban areas (dozens of square kilometers) but they can be very large in less populated suburban areas (even thousands of square kilometers).

Despite their very variable sizes, the geography of the MSC serving areas appears to be very interesting in terms of urban dynamics and land use.

The central area of Milan is divided into two MSC service areas; other important cities like Bergamo and Brescia are defined by a single MSC service area. The sparse and mountainous northern side of the region is also divided into two big MSC service areas. The dynamic northern side of Milan is shared by 3 MSC service areas (Fig. 3.26).

The data at our disposal were, for every hour of two time periods (from 7 to 20 September 2009, from 1 to 30 April 2010), the number of active and registered clients (UMTS and GSM) for each MSC Service Area of the Lombardy Region, distinguished by the nationality of the SIM connected. We carried out data analysis on the variations of active users in each MSC area for the two periods with the aim of determining whether and if so how these data might provide new and useful

Fig. 3.26 Map of Lombardy region's MSC service area

understanding of urban temporary population dynamics on working days, on holidays and also over longer periods (week, month, year).

For better comparison of the results of our analysis, we used the density of telephone contacts (active customers per square km) instead of the absolute number of contacts, which does not take into account the substantial differences in size between the MSC areas.

We then performed several analyses on active client variations over time in the Lombardy Region MSC service areas (Manfredini et al. 2011).

For the dense urban Milan MSC service areas, the variability of active clients during working days highlights the attractive role of the city in terms of jobs and services. In fact, during working days Milan attracts a great number of people from a vast territory that extends beyond the municipal boundaries of the city. This phenomenon is related to daily mobility patterns.

We show (Fig. 3.27) this result by comparing, on an hourly basis, the quantity of active clients during a Wednesday and a Saturday in the central area of Milan. We observe that the Wednesday/Saturday ratio increases sharply during the early hours of the day until 8 a.m. (marked in black), after which the number of contacts shows no particular variation. After 4 p.m. the number of active clients decreases very slowly, until it reaches the same value as the morning.

The number of contacts during Wednesday is more than half that of Saturday. The Milan municipality's official tell us that every working day nearly 600,000 people enter Milan, a value compatible with the evidence of MSC service area statistics.

Figure 3.28 represents the hourly variation of active clients in the MSC service area corresponding to the Milan city centre for the period 1 April 2010–30 April 2010.

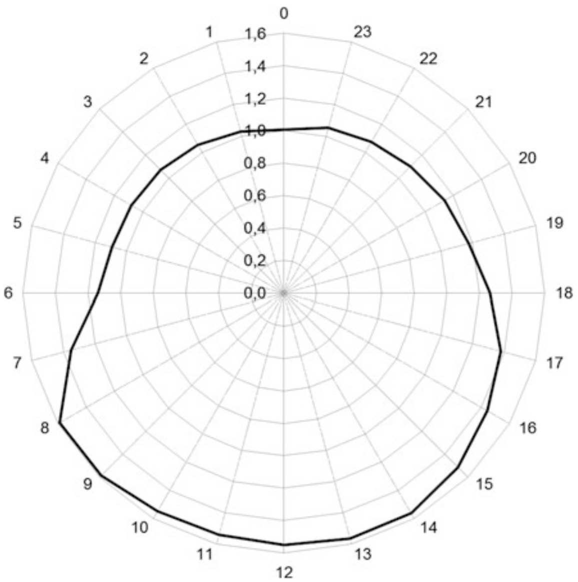

Fig. 3.27 Hourly Active clients during a working day (Wednesday) and Saturday ratio in the MSC service area central Milan. Values close to one mean that the Wednesday number of active clients is equal to the Saturday number of active clients (during the night). Values greater than 1 mean that the Wednesday number of active clients is higher than the Saturday active clients (from early morning until late evening)

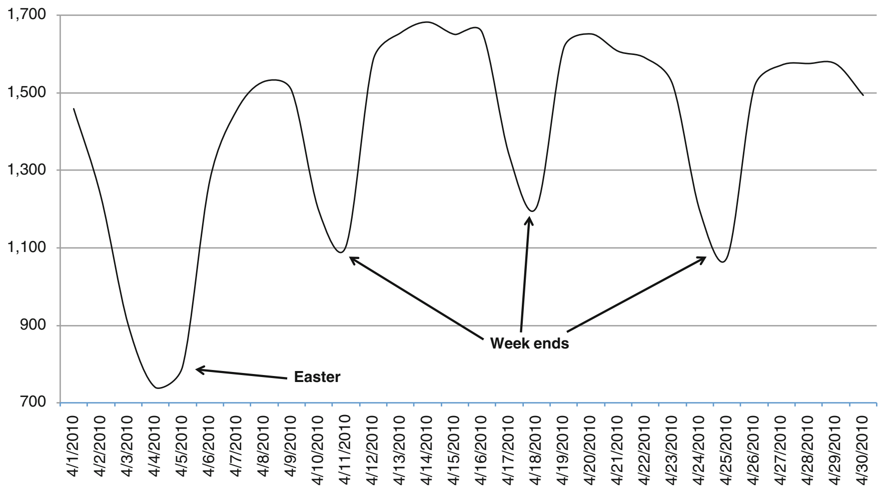

Fig. 3.28 Active client density in the MSC service area of Milano during the period 1–30 April (2010)

We observe a very sharp decrease of active clients during the following weekends (10–11 April, 17–18 April, 24–25 April) due to the reduction in journeys for work and study.

Moreover, for the Easter holiday period, Saturday and Monday April 4 and 5, we observe an even greater fall than recorded for the other April weekends. In this case, there is a significant reduction of active clients, related to the long Easter weekend, when many inhabitants of Milan leave the city. On Easter Sunday, the active clients come to about one third less than on the subsequent Sunday. This indirect measure of the temporal variation of presences in the city illustrates the great potential of these data, relevant for policy and decision-makers, always on the look-out for new methods to quantify the variability of urban populations.

3.4.1 Foreigners' Trends and Evidence

MSC counters register the nationality of the SIM connected to the mobile phone network. For that reason, we decided to study the variability of foreign visitors in Lombardy Region MSC service areas during the periods for which we had data with the intention to determine the potential of this information for monitoring foreign tourists and visitors.

First, we verified that the data on MSC active clients provided different information from that obtainable through conventional statistical sources by comparing the proportion of the top ten most numerous foreign resident nationalities obtained from official statistics, with those obtained from data on active clients in the Lombardy Region MSC service areas (Table 3.3).

Table 3.3 The 10 most numerous nationalities in the Lombardy Region from 2009 official statistics (left) and from MSC Register during the 7–21 September 2009 period (right)

Nationality	Percentage (residents) (%)	Nationality	Percentage (active clients) (%)
Romanian	35.5	German	22.9
Moroccan	29.5	Swiss	15.1
Albanian	27.1	English	6.9
Egyptian	15.9	French	6.4
Filipino	12.3	Romanian	5.9
Chinese	11.3	Polish	5.8
Indian	11.1	Spanish	4.3
Ecuador	10.8	Dutch	2.7
Peruvian	10.0	Czech Republic	2.2
Ukrainian	8.7	Austrian	2.1

While the immigrants are mainly from Northern Africa, Eastern Europe, Asia and Southern America, the active clients are primarily from Western European countries. Germany, Switzerland, the United Kingdom and France account for 50 % of the total active clients in the period studied.

Comparing the data, it thus becomes clear that the active clients are mainly accounted for by temporary foreign visitors and tourists. Official tourist statistics on the occupancy of collective tourist accommodation refer to the number of arrivals (at accommodation establishments) and the number of nights spent by residents and non-residents, separated into establishment type or region; annual and monthly statistical series are available on the provincial spatial scale.

A large number of temporary visitors who do not make use of official facilities is therefore excluded. It is estimated that in Milan there are about 500,000 visitors per year who are not counted by statistics because they spend the nights in accommodation provided by friends or informal touristic structures (Observatory of Tourism—Milan).

On the other hand, relevant urban stakeholders, such as municipalities, public agencies, industry and trade organizations, interested in enhancing the attractiveness of urban regions, show a great need to know the real dimension of tourism in order to provide new services targeted to this type of temporary population (tourists, business people, city users).

Focusing on German visitors, we observed that the highest concentration of Germans is in the big MSC service area covering the western side of the Lombardy Region plain and lake Garda—one of the main tourist attractions in inland Northern Italy, in particular for the German population. The trend during September 2009 is clearly due to the presence of German tourists in the Lake Garda area for the summer.

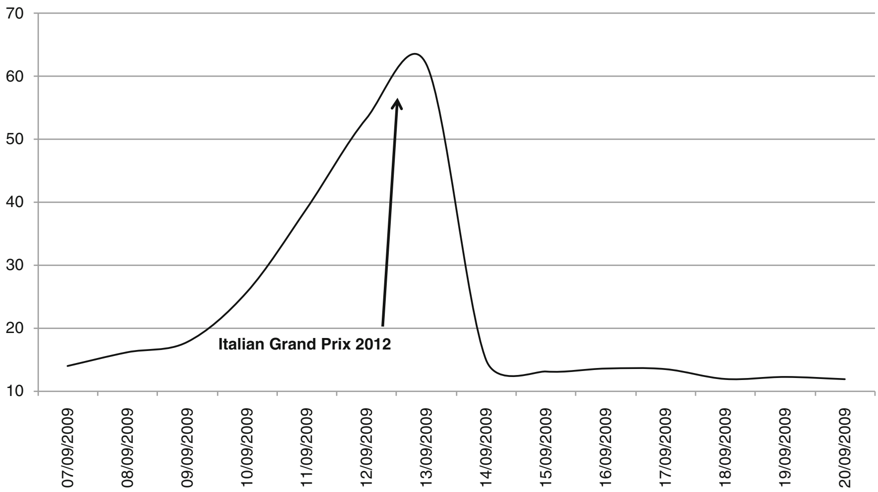

Fig. 3.29 Average hourly number of foreign active clients in the Monza and Brianza area-September 2009

The National Statistic survey on Tourism indicates, for September 2008, the presence of about 915,000 tourists in the province of Brescia, the majority (82 %) being concentrated in the lake and the mountain areas, entirely within one MSC service area. In the same year, Germans scored more than 2,000,000 admissions, representing 41 % of total foreign tourists and 25 % of the total. Although the two data sources differ in level of detail, period and nature of the data, it seems that the data on the variability of active MSC clients can effectively reflect the dynamics of tourist arrivals.

Americans are mainly concentrated in the centre of Milan and show a growing trend on working days, from Monday onwards, and a subsequent decrease in the weekend—a pattern that seems to be compatible with business travel rather than tourism.

Finally, we may point out the presence of a spike of foreign visitors during the weekend of 12–13 September 2009, in one MSC service area, covering the central part of the Monza and Brianza Province, certainly linked to the Formula 1 Italian Grand Prix, which took place in those days (Manfredini et al. 2014). The average presence of foreigners during the Grand Prix period is more than five times the average September value (Fig. 3.29).

The composition of nationalities within the same MSC service area, in the same period, shows the presence of British (15 % of total), Swiss (13 %), German (13 %) and French (7 %). Such detailed information is not available through traditional data sources.

3.4.2 Monitoring Visitors During a Big Event

We performed specific investigation regarding the period of the Milan International Design Week[17] (14–19 April 2010), a major event that takes place in the Rho-Pero Exhibition District and in dozens of places in the city where art galleries and museums, shops, industrial areas and showrooms host events and exhibitions, parties and special initiatives (named "Fuorisalone").

We measured through active client data the level of attractiveness of the event for foreigners, and which nationalities were more present, in order to verify if and how these data can be used for monitoring foreign visitors during a major event.

For a better understanding of foreign dynamics, Italians were excluded from the analysis. The foreign active clients trend appears to be closely related with the International Design Week development. In fact, from the day before the beginning of the Event (13 April), the number of foreigners increases sharply to peak on Saturday 17 April. Afterwards the curve decreases slowly and reaches a more typical course (Fig. 3.30).

[17] The 2010 edition registered about 300,000 visitors, more than half being foreigners (Cosmit).

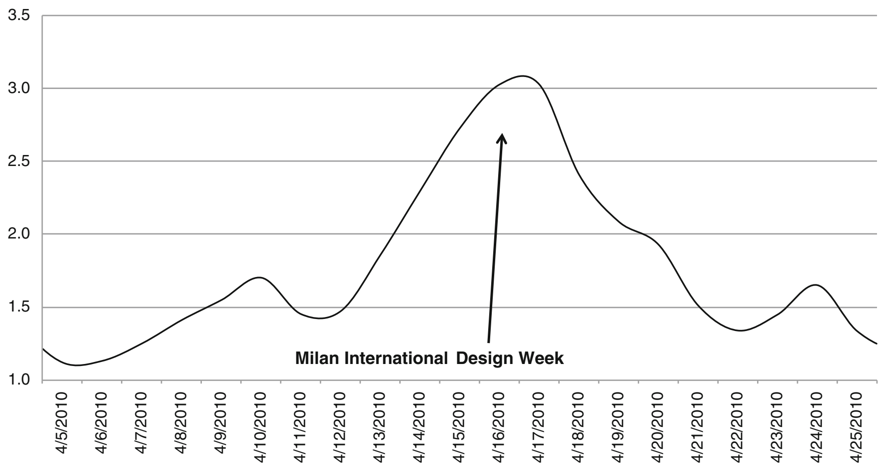

Fig. 3.30 Foreign active client density in the MSC service area of Milano during the period 5–25 April 2010. The International Design Week was held from 14 to 19 April 2010

Table 3.4 The most numerous nationalities in the Milan area during the 2010 International Design Week

Nationality	Percentage (%)
French	9.8
Swiss	9.2
United Kingdom	8.7
Spain	8.0
German	7.5
Russian Federation	5.6
USA	4.0

Of the more than one hundred nationalities registered, the most represented were France, Switzerland, the United Kingdom, Spain, Germany, the Russian Federation and the USA, accounting for more than the 50 % of the total foreigners (Table 3.4).

The attendances spikes occurred during Thursday and Friday for all the nationalities except for the Swiss, in which case the peak was on Sunday.

Particularly interesting is the evidence for the same period (14–19 April 2010) of the Brianza region, indicating a peak of foreigners in the MSC service area.

This trend may be related to the Brianza wood furniture district, one of the most important in Italy, showing very important quantitative and qualitative performance in terms of number of workers and enterprises (mainly medium-sized), in terms of ample range of products (industrial design) and in terms of exportation worldwide. In our opinion, many visitors to the Milan International Design Week went on to visit the enterprises specialized in the production of wood furniture for contacts and to draw up commercial contracts (Fig. 3.31).

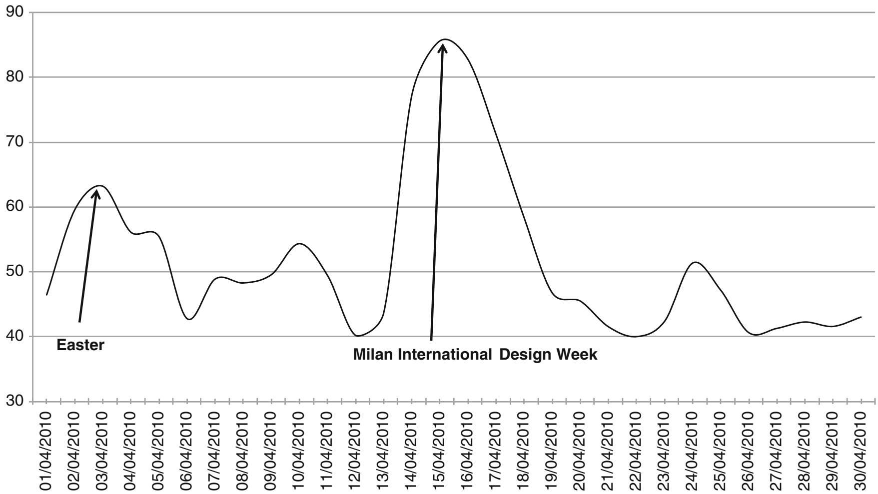

Fig. 3.31 Average hourly number of foreign active clients in Brianza region—April 2010

Despite the dimensions of the MSC service area, the data were able to capture the foreign trends as a phenomenon visible on the urban scale. For major events, active client figures can provide an important tool for monitoring visitors and tourists, for evaluating the attractiveness of a big event, for evaluating its economic impact and for providing new tourist and business services (e.g. side event organization, translations, etc.) targeting specific nationalities.

There is a great need for up-to-date information about urban attractiveness, a major component of global city competition which is hardly reflected by standard surveys. Innovative methods are therefore required for measuring and monitoring tourist and visitor attendance on the different urban scales.

MSC active client data seems to be promising for visitor and tourist monitoring because it provides information that institutional sources do not currently offer.

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Chapter 4
Implications for Traditional Data Sources

Abstract This chapter focuses on the differences between mobile and conventional data sources and illustrates how the former open new implications for the urban research community which needs to elaborate new strategies to integrate user-generated data with traditional data to achieve a better understanding of urban usages, in time and in space. In particular, the main differences lie in the characteristics of the data and the dimension of the samples: conventional data are public and refer to the "universe" of population, mobile phone data are collected by private companies and refer to a subsample of the overall mobile phone subscriptions (i.e. active users). Official statistics are necessary to interact with these new data sources in order to evaluate if, and if so how mobile phone data can be used as new sources, able to describe phenomena for which official statistics do not collect data, as additional sources to be used as complement to conventional data sources or as alternative sources able to replace conventional ones. In this general context, the real challenge for urban studies is integration of the available databases together with an innovative use of traditional sources, in order to capture the variety of changes in urban practices.

Keywords Conventional data · Mobile phone data · Official statistics · New urban research agenda

In the previous chapters, we demonstrated that the different types of cell-phone data employed in our research, i.e. Erlang measures, aggregated OD tracks and MSC active user counts, can provide new knowledge about urban dynamics, which can be used in practical terms.

In particular, these data can be used for many purposes such as monitoring and managing large-scale events, for analysing the spatial and temporal variations in the densities of populations, for evaluating how different parts of the cities are used by temporary populations, for studying mobility practices and patterns and for monitoring tourists and visitors, just to mention some of the potential uses of mobile phone data explored in our research.

Fabio Manfredini is the author of this chapter.

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Table 4.1 Comparison between conventional data sources and mobile phone data

	Conventional data sources (municipal statistical offices)	Conventional data sources ISTAT Census	Mobile phone data (Erlang)
Sample	All residents	All residents	Mobile phone active users
Spatial resolution	Urban blocks	Municipality boundaries (very variable), urban blocks	Pixel size 250 mt × 250 mt
Reference Period	Yearly	2011 (Census)	Every day
Updates	Yes (yearly)	Every 10 years (Census)	Continuous
Available information	Number of inhabitants, sex, age, nationality	Number of inhabitants, sex, age, nationality, workers, education, employees, etc.	No
Temporal resolution	Yearly	Yearly	Hourly or sub-hourly
Data ownership	Public	Public	Private
Cost for the production	Expensive	Very expensive	Not known, cheap
Cost for the public	Free	Free	Not known, not free

The topics covered in the present work can hardly be reflected through conventional data sources. Each of the experiments carried out opened up new questions and research perspectives, related to the relationships between this new source and the conventional data source traditionally used in urban studies.

This opens new implications for the urban research community that needs to elaborate new strategies to integrate traditional data with user-generated data, such as mobile phone activity, in order to achieve a better comprehension of urban usages, in time and in space.

Is it worthwhile to profile and describe a region using cell phone data? What do we gain from using these data instead of conventional data sources?

In fact, conventional data sources and mobile phone data show many differences that we need to understand in order to make the urban studies research community and the policy-makers aware of the potential of mobile phone data in providing new information on the cities and the ways in which mobile populations actually shape the cities.

A comparative table on the different characteristics of Erlang mobile phone data and conventional data sources can help in defining the limitations and the potential of each data source and finding an appropriate use for each (Table 4.1).

The main difference lies in the characteristics and dimensions of the data sample.

Conventional data refer to the "universe" of the population (for example if we consider census data) or to a statistically significant sample which corresponds to the overall population in terms of age distribution and sex, and is based on direct surveys or interviews.

Moreover, the public authorities provide conventional data used in urban analysis and planning. The data are generated for purposes of general interest (policy, urban and spatial management, etc.) and, above all, are public. The open data philosophy in the last few years has been acquired by many public institutions that have through the world wide web started to share their statistical and geographical data using open licenses (such as creative commons or other such forms).

This process has increased the availability and the quality of conventional data sources for many sectors including urban analysis and planning.

Mobile phone data and, in general, user generated data are of a completely different nature.

They can be considered “big data”, since they are generated in real time, are huge in volume, and have high spatial and temporal resolution (Kitchin 2013). Handling, analysing and interpreting such data is a proposition very different to dealing with a census every 10 years or a survey of a few hundred or thousand respondents.

Big data are characterized by being generated continuously, seeking to be exhaustive and fine-grained in scope, flexible and scalable in their production (Kitchin 2014).

The data refer to active mobile phone users of one single telecommunication company that owns the data and decides on which conditions and in which format distribute them on the basis of the company’s interests and priorities.

According to a recent survey (Istat 2013), in Italy 93.8 % of overall all families own a mobile phone and 43.9 % of the families have a cellular phone with internet access. There is a penetration rate around 150 % (i.e. there are 150 devices every 100 inhabitants).

Nonetheless, there are differences in the use of mobile phones among inhabitants. In fact, according to the most recent statistics available, gaps in cellular use are observed among sex, age, working position and place of residence.

This issue will be even more important for the research community since other data sources (social media data, data generated by active digital populations) are becoming massively available and refer to a sample of population which is even more specific than that of mobile phone users.

It is therefore important to bear in mind all these elements to achieve better use of mobile phone datasets, especially if we collaborate with public institutions that are used to working with conventional data sources.

In the case of the Erlang data at our disposal, the information was collected at the level of cell phone towers, and was afterwards transformed into a regular georeferenced grid, with a spatial resolution of 250 × 250 m, according to the land cover of the area, the spatial distribution of cell phone towers and the intensity of the signal.

This is just to underline that the original raw data are acquired automatically by the network, processed directly by the company and finally provided to the scientific community in different formats, at different spatial and temporal resolutions. It is not always possible to obtain precise information on the methodology used for producing the data.

These data are "private" and therefore not available to larger academic communities for repeated analysis. It is not possible to verify and re-test the data and to replicate the methodologies available in literature.

No technical and scientific collaboration between mobile phone companies for research exists, nor does it seem likely in the near future. The sample of population depends therefore also on the market share of each company, which changes in time and in space. Data on the spatial distribution of market share are not available because it is business sensitive information. In our experience, the number of TIM subscriptions was about one third of overall subscription on the national scale, but it is evident that this market share changes according to different factors (advertising, offers, coverage), which can lead to even great differences in the sample size of the available data and in the overall results of the elaborations.

The data refer to mobile phone activities, i.e. the number of interactions between the device and the network (calls, SMS, etc.). Therefore, the number of active users is lower than the number of mobile phone subscriptions. In our research, we experienced that in Lombardy region the number of mobile phone users with more than 8 activities per day exceeded 1 million which is anyway a value greater than the dimension of a standard statistical sample defined in the framework of a survey.

Despite the limitations to the quality and nature of the data, it is important to stress that the sample size is comparable, if not greater, than that of many conventional surveys based on interviews.

Therefore we are dealing with a complex kind of data that must be communicated and explained to the policy makers and to the general public in the most simple terms by clarifying the dimension of the sample, the spatial and temporal resolutions and other information about the quality and the characteristics of the data (called metadata).

There is a trade-off between the completeness of the sample achievable with census data versus the variability of the number of active users in mobile phone data. There is also another trade-off in the spatial and the temporal resolution of mobile phone data, measurable respectively in hundreds of meters and in minutes/hours, in comparison with the spatial and temporal resolution of conventional data, measurable respectively according to the dimensions of administrative or statistical units and in years.

By choosing one source rather than another, we lose some information, we gain some other, and the researcher has the responsibility to explain the limitations and the advantages to final users and urban stakeholders.

The census data output is usually coarse in resolution (e.g. local areas or counties rather than individuals or households). Moreover, the methods used to generate them are quite inflexible (for example, once a census is being implemented it is impossible to add/remove questions). Whereas the census seeks to be exhaustive, enumerating all the people living in a country, most surveys and other forms of data generation are samples, seeking to be representative of a population.

In urban research, the recognition of the "right" geographical scale for observing urban phenomena is not always easy. The re-scaling of data sources requires more flexible data and tools able to intercept urban phenomena in their correct spatial dimension. It clashes with the traditional data collection, because urban and regional data are normally available at the level of statistical subdivisions that correspond to municipal and administrative ambits and not to the geographic dimension of processes and urban transformations.

Mobile phone data have a very fine spatial and temporal resolution and have very flexible. It is therefore feasible to analyse customized areas depending on the aims of the research (urban blocks, linear infrastructures, etc.). The precise spatial accuracy is therefore one relevant aspect that creates greater possibilities for detailed research.

Another point to stress is that mobile phone data must be interpreted, even with the help of conventional cartographic data sources. This is important because, thanks to a map of activities, land cover or urban facilities, it is possible to attribute a sense to concentrations and hot spots of mobile phone activity or anomalies in specific hours of the day, days of the weeks, seasons.

Mobile phone data are therefore important as corroborating evidence in explaining patterns of usage of the city by urban populations.

Statisticians, social scientists, urban planners and geographers should take advantage of this new data source. Due to their complexity an intersection between different competences is needed in order to fully exploit the potential of 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.

Official statistics are therefore required to interact, in some way, with big data, i.e. with mobile phone data.

Further investigations are needed in order to evaluate if, and if so how mobile phone data can be used as new sources, able to describe phenomena for which official statistics do not collect data, as additional sources to be used as complement to conventional data sources or as alternative sources able to replace conventional ones (Barcaroli et al. 2014).

The visualization of complex phenomena, such as those described by user generated data, is another key issue. It is necessary to present urban spaces through visual approaches that are able to capture their flows in the form of static or dynamic images (Ciuccarelli et al. 2014).

How can we represent time? How can we explain the meaning of the data? What is the utility of the analysis carried out? Specific attention should be paid to clarity and to the understanding of the output.

In other words, the visualization of complex processes and the communication of the results obtained by the analysis of mobile phone data are relevant in order to gain new insights from mobile phone data analysis.

Analysing the spatial and temporal usage of cities in their contemporary daily-life practices requires an integration between traditional data (land cover, town plans, spatial distribution of activities, etc.) and new sources of information, closer to users such as mobile phone data activity or geolocated digital traces, with the aim of identifying the complexity and multiplicity of individual behaviours. Through the new data we can define who we are by the places we go to, overcoming some limitations due to characteristics of traditional sources of data in describing contemporary city dynamics.

In this context, the real challenge for urban studies is the integration of available databases together with an innovative use of traditional sources, in order to capture the variety of changes in urban practices.

Research outputs such as maps, tables or reports could provide information for policy makers and urban planners useful in understanding showing time dependent spatial patterns and information not available elsewhere. This field of research is rapidly evolving and there is now the need to consolidate some of its major findings in specific urban contexts in order to test the capacity of these new data in answering real knowledge questions raised by public or private stakeholders and to evaluate the data capability in supporting new urban policies.

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Chapter 5
Implications for Urban and Mobility Policy

Abstract This chapter illustrates the potentiality of mobile phone traffic data for improving the effectiveness of urban policies. Mobile phone traffic data, as the effect of individual behaviour and habits, help in formulating policies more in keeping with the molecular daily practices and emerging demands being made by diverse populations using the city and its services, at varying rhythms and intensities. By offering new maps of site practices and information on temporary populations, the processing of mobile phone data has an important role to play in both the analytical and the normative dimensions of urban policies, within two different perspectives. The first regards the opportunity to use a real-time knowledge of mobility needs, possible through a more widespread use of networked technologies, as a framework for area-wide implementation of innovative urban policy and transport supply. The second perspective concerns the valuable support offered by mobile phone data in "re-scaling" urban policy and assisting in the construction of geographies of partnerships between different stakeholders.

Keywords Urban and transport policy · Temporary population · Soft spaces · Fuzzy boundaries · City usage patterns

Our research focused on the longitudinal activity patterns of network cells, rather than individual users. This implies consideration of mobile phone traffic data as the effect of individual behaviour and habits. These data provide information about the characteristics of a territory, its intrinsic property, which varies over time. In this perspective, the maps and the processing play an important role for both the analytical and normative dimensions: producing knowledge about mobility patterns and behaviours, we produce an analytical framework taking into account contemporary urban practices and mobility processes, crucial for urban planners and designers in two different perspectives.

The first is related to the opportunity to apply a real-time knowledge of mobility needs, possible through a more widespread use of networked technologies, as a framework for area-wide implementations of innovative urban policy and transport

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supply. According to Jensen (2015), the objectives of transport efficiency, safety and security as well as environmental and urban aspects which address economic efficiency and sustainability of investments could be more easily achieved through the use of networked technologies. "First because they are simply "out there working": networked technologies are as much a part of the city as its more traditional features. Any designer or planner concerned with the city should therefore mobilize an interest in these technologies if they claim to know the city. Secondly, the technologies at work are producing data on the city that urban planners and designers may well make use of in their attempts to monitor and track the city and its dynamics (setting aside the at times rather subtle legal issues involved). Thirdly, and this may appeal to many process-oriented planners, these technologies offer new opportunities for engaging with the public, to facilitate new public participation processes and involve segments of the city's population that are not normally very vocal in urban planning processes" (Jensen 2015, p. 230).

In our research we have shown how the maps of mobile phone data, describing the trends of use of the urban spaces, provide important information for mobility policies. The outcomes permit a visualisation of the density of use and a spatial distribution of mobility flows with a high temporal and spatial resolution.

In order to analyse the differences between specific hourly, daily and weekly distributions of mobile phone density (using Erlang data), the team specified a statistical processing (spatial clustering) focused on recursive trends over the period considered and containing different temporal patterns of mobile phone activity (i.e. daily, workday versus weekend) (Pucci et al. 2014; Manfredini et al. 2012; Manfredini Pucci and Tagliolato 2012). This model produced a selection of maps of the spatial distribution of mobile phone traffic. This information was superimposed over a mapping of the primary facilities of each urban area (infrastructures, large shopping centres, railway and underground stations, trade centres) with the purpose of interpreting the concentrations in densities, also in relation to key activities and urban supplies.

In particular, it is possible to observe differences in the spaces of mobility during morning and evening rush hours in the urban region of Milan.

Using accurate place-time information, our findings describe a trend discussed in the literature regarding the non-coincidence between mobility practices during peak morning and afternoon hours, when the chains of displacements, generated by the same populations, are more articulated and complex (Fig. 5.1). Comparing these two maps (Fig. 5.1) it is possible to deduce that those commuting between 8:00 a.m. and 9:00 a.m. (morning rush hour) become city users between 5:00 p.m. and 7:00 p.m.

The map of evening rush hour mobility patterns (5:00 p.m.–7:00 p.m.) describes in detail places linked to social practices (leisure activities, shopping, picking up a family member or friends).

The result is a dense and widespread use of the territory that traditional sources fail to capture, with consequences on infrastructural networks and demands for public transport. In our opinion, these maps effectively represent the mobility patterns of those working in the city as they return home, but also the places where

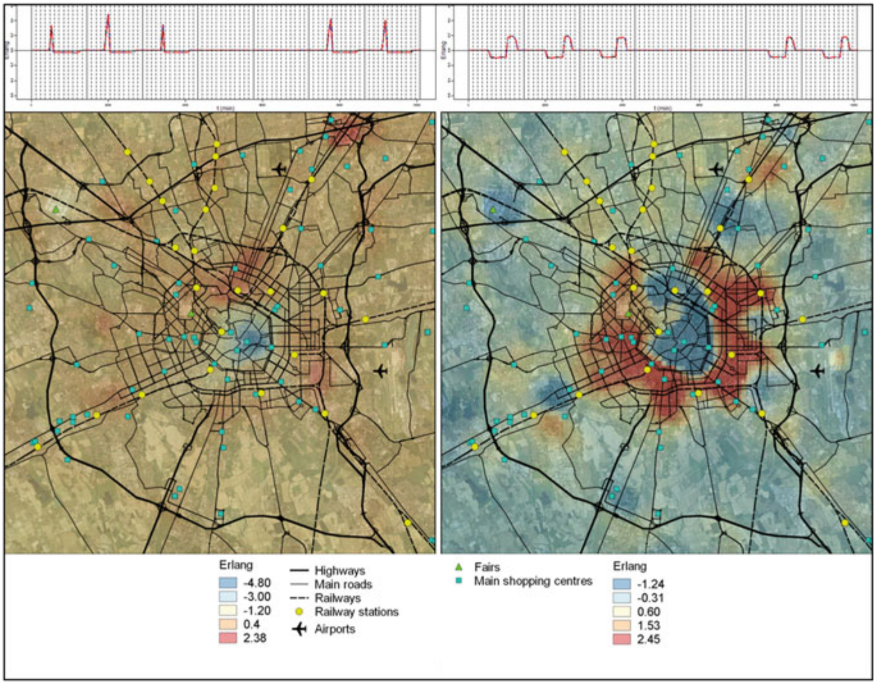

Fig. 5.1 Daily mobility spaces: morning rush hour map (*left*), evening rush hour map (*right*). *Source* processing by DAStU (Dipartimento di Architettura e Studi Urbani) and MOX (Laboratorio di Modellistica e Calcolo Scientifico)—Politecnico di Milano, on Telecom Italia data

these practices are occurring recursively. It is this feature (repetitiveness) that allows us to speak of "communities of practice" or "mobile communities".[1]

The mobile phone data and methodology presented were able to explore a much finer and more extensive pattern of distribution of urban activities than that allowed by traditional travel surveys. The same data raise questions about particular theoretical interpretations of the "erratic and nomadic behaviour of metropolitan populations"[2] that characterise urban practices, already confirmed by well-known

[1] This approach is complementary to existing methods proposed in the literature, also with respect to the use of tracking technologies and/or other digital data. The individual traces of a sample detected using tracking technologies (i.e. GPS, SMS) offer a more precise result because it is possible to record the origin and destination track of individual movements. On the other hand, this means a greater cost for data processing and the need to build a statistical sample of users. Moreover, problems related to individual privacy raised several ethical questions for this type of research. Instead, the use of aggregated data collected from the network (mainly cell towers) allows research to move away from the individual level, focusing on the emergence of complex urban dynamics related to the places that people use and frequent (Gonzalez et al. 2008).

[2] For example, in the influential work of Deleuze and Guattari (1980), or Virilio's (1997) texts on dromology.

studies (Song et al. 2010). Indeed, while the data confirm the remarkable density of daily movements, the same data also show a strong recursion path: while we move a lot during the day, we tend to do so along familiar and habitual paths.

The second perspective is related to the valuable support offered by mobile phone data, to "re-scale" urban policy and assist with the construction of geographies of partnerships between different stakeholders.

Interpretations of mobility trends through mobile phone data, by offering new maps of site practices and information on temporary populations and city usage patterns (daily/nightly practices, non-systematic mobility), made it possible to "re-scale" the hierarchies of intervention, and thus the governance of dynamic processes, in relation to public transport policies too (Pucci 2014).

The maps—produced with mobile phone data—represent the territories made by communities of practice detected by mobile phone data, which generate contingent boundaries with a relational and variable value, due to the dynamics we plan to capture and regulate.

These practices, deforming institutional boundaries, are proposed as a tool for supporting and increasing the efficiency of urban policies and mobility services.

This is what emerges from our experiments.

The processing maps on origin/destination mobile traffic flows (Chap. 3) describe phenomena—movements carried out for both work and personal reasons—with temporal continuity throughout the day, and with high space-time resolution. These data bring out a rich variety of places of use in accordance with the temporal organisation of a day, linked not only to fixed events (employment), but also with other activities. These places define new geographies that call into question the perimeters of the institutional policies.

If the information derived from the continuous mapping of flows represents an important basis for reading the effective dynamics and impact of spatial mobility, their variability constitutes important information for more efficient and fairer management of urban transport and supplies as shown with a real-time mapping of a daily mobility catchment area of Milan, proposed in our research.[3]

Superimposing the perimeters of the institutional management of local public transport in Milan over the boundaries, varying in time, of mobility practices obtained from mobile phone data (Fig. 3.25 in Chap. 3) reveals how "the profound structural effects (or destructuring) of spatial mobility on institutional boundaries"[4] (Estèbe 2008, p. 6) expose a clear discrepancy between fixed jurisdictions and "mobile factors".

This map provides considerable indications with respect to the effective catchment area of Milan, to which regulation measures and appropriate costs of public transport services should correspond. In the urban area of Milan, 8.5 % of the

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[3] An interactive map is available at: www.ladec.polimi.it/maps/od/fluxes.html.

[4] Our translation from "les effets profondément structurants (ou déstructurants) de la mobilité des personnes sur les territoires politiques" (Estèbe 2008, p. 6).

municipal budget is intended to cover the costs of supplying urban services (Pola and Ferri 2012), with public transport accounting for a significant share.

The "political price" of a public transport ticket in Milan benefits not only the inhabitants, but also the city users, tourists and commuters making intensive use of Milan's public transport network. However, these temporary populations do not contribute to covering the real costs of public transport; as non-residents, they are not subject to local taxation. Conversely, temporary populations make use of urban services, governed by local Authorities in a city (Milan) where they do not live and do not vote. This condition is summed up by Martinotti (1993, p. 163) as the "paradox of voting".

In this case, the availability of data capable of describing the variability of Milan's sphere of influence is an important prerequisite not only to improve the supply of public services, but also to legitimise interventions focused on re-modulating pricing policies for public transport services, which may currently be considered unfair (tariff policies, public transport services supply etc.) (Pucci 2013; Pucci 2014).

The search for relevant boundaries in addressing the variability of social and spatial relationships and with the multi-scalar dimension of urban practices, is at the core of Spatial Planning debates, for years, because "all territorial governments exist in a condition of permanent dissociation between citizens, inhabitants and city users" (Estèbe 2008, p. 17).

While there is a consensus, in the specific literature, on the need to build relevant boundaries as a resource of institutional capital through which new initiatives can be pursued rapidly and legitimately (Healey 1998, p. 1531), questions are being asked about the practical impact of this shift.

From a project-oriented viewpoint, developing tools for identifying what and where borders are, how they function in different settings, with what consequences and for whose benefit, means generating new frameworks, necessary for institutional innovation in Spatial Planning.

This is also because boundaries "are complicated and historically contingent phenomena that are concomitantly both contextual social institutions and symbols and are constituted on spatial scales on various institutional practices and discourses" (Paasi 2010, p. 679).

At the same time, the spatial organization and the institutional boundaries affect the spatial behaviours by interfering with the intensity and the nature of the practices.

If reorganising skills and resources to improve the regulation of practices calls for the identification of variable boundaries, the challenge is posed in terms of interpretive tools able to recognise "soft spaces" (such as transversal spaces) and "fuzzy boundaries" (such as fluid perimeters). There is also a need for an operational understanding of the effects on what Haughton et al. (2009, p. 52) refers to as "formal hard spaces of governmental activity".

These notions are gaining consensus, thanks largely to their fundamental characteristics (Haugthon and Allmendinger 2008), which express "the new post-devolution spaces of planning" (Haughton et al. 2009). Less obvious is the operational impact in terms of relationships with institutional perimeters corresponding with powers and strengthened responsibilities.

In the relationship between fuzzy boundaries, built on "communities of practice", and institutional spaces, problems related to the temporal variability of the practices at the origin of the fuzzy perimeters, such as the mechanisms of political representation of communities of practice, remain unresolved.

Nonetheless, the "informal boundaries" defined by these practices may become part of an 'institutional landscape', generating new models of public involvement and actions capable of intercepting and responding more effectively to the emerging social demands that can be read from these practices. Therefore, the possibility to "re-scale" offered by the boundaries defined by mobile communities may assist in the construction of geographies of partnerships between different stakeholders. They may also promote forms of cooperation, not necessarily and forcibly linked to institutional frameworks.

In this perspective, the processing of mobile phone data, by offering new maps of site practices containing information on temporary populations and city usage patterns, can be considered a valuable support for tracing fuzzy boundaries as perimeters of practices, useful for re-territorialisation of urban policies.

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