Toward a Systemic Use of Manifold Cell Phone Network Data for Urban Analysis and Planning

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Introduction

The Province of Monza and Brianza is a densely populated area located in the Lombardy Region of Northern Italy. (See Figure 1.) Monza and Brianza is characterized by the presence of several medium sized cities, huge urban sprawl, and an economy specializing in wood, furniture, and high-tech productions. (It is one of the richest Italian region in terms of GDP).

Composed of 55 municipalities (860,700 inhabitants with a population density of 2.112,5 inh/km^2), the Province of Monza and Brianza can be divided into three main areas with different socioeconomic trends and specific urban settlements:

- Monza, which is a tertiary sector center, has a metropolitan role in relation with other urban centers in Brianza. It represents a gateway integrated with the city of Milan in relation to global networks.
- The area of Vimercate in the eastern part, is characterized by high quality productive activities (goods and services) with a high intensity of technology and human capital, resulting from a network of small and medium-sized enterprises and supply services.
- Western-Central Brianza, a densely urbanized area, organized around some large urban centers (Desio, Seregno, Meda), is the site of a well-known

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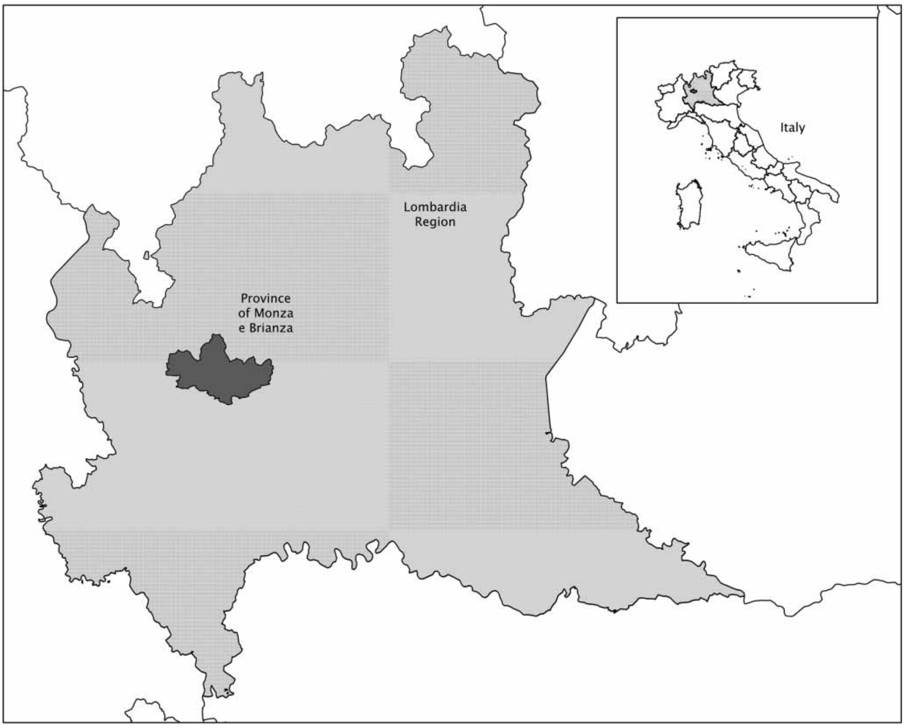

Figure 1: Province of Monza e Brianza, Lombardy Region, Northern Italy

productive district specializing in furniture production, and it is characterized by a high density of commercial spaces that create, for our purposes, relevant mobility patterns.

In this territory, during the last 20 years, the growth of urbanized areas and the consolidation of the process of urban sprawl, changed the settlement structure and the overall mobility trends: daily mobility patterns are more complex than in the past when the network of cities was hierarchically organized and the physical relation between jobs and homes was the main reason for mobility.[1] Monza and Brianza presents significant internal fluxes that define a non-hierarchical system, due to the spatial distribution of work places, leisure, and residences. The commuter flows describe only a minor part of the overall urban movements (about 29 percent, excluding returning home). This mobility has no adequate response in the networks' infrastructure (rail and roads), which is organized radially, converging towards the city of Milan. The radial organization of the network of infrastructures is an important source of congestion and remains actually unchanged, except for the amplification or the duplication of existing roads and for the construction of ring roads. This synthetic framework highlights the importance of this case study to test the usefulness of mobile phone data in describing complex land use dynamics.

In order to analyze the complex temporal and spatial patterns of this peculiar spatial context, we used several mobile phone traffic data (namely Erlang measures, SMS counts, counts of active MSC clients), provided by Telecom Italia, the main Italian operator, covering two time slots in 2009 and 2010. We started with time series analyses of the overall mobile phone traffic in the area, in order to study its trend and its coherence with population behaviors at an hourly and daily base. We used Erlang and SMS data to evaluate their distribution in time and in space within the region, comparing different days and hours of the week; we analyzed cell phone activity, comparing diurnal and night traffic, working days and non-working days. We had the possibility to integrate mobile phone data with traditional spatial databases on land cover, infrastructures, distribution of activities, in order to identify and to correctly interpret emerging spatial patterns.

We then focused on temporary urban populations. We were able to distinguish nationalities by using specific data on mobile active clients at the Mobile Switching Center (MSC) service area level to evaluate and to understand dynamics of present population and of foreigners within the region. The Mobile Switching Center (MSC) is the central element of a mobile telecommunication network, that carries out call switching and mobility management functions for mobile phones roaming on the network of base stations. Each MSC provides service to mobile stations located within a specific geographic area, defined as a MSC service area.

The reference to urban populations (Martinotti, 1993), permits the recognition of the space-time variability of the roles of individuals, who may belong to different communities of practices (Wenger, 1998) that use urban spaces according to their preferences and projects. If time-related changes in the city can be described through the concept of "temporary populations," an urban population can no longer be regarded as a collection of residents forced to move within the boundaries of the city. 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: 148).

These data, then, offer the potential of identifying different urban populations. The identification of temporary urban populations through mobile phone data is not has only a heuristic purpose, focused on describing new urban dynamics and time-dependent patterns in the use of urban spaces, but also can be seen as a tool for learning about new claims and urban demands, in favor of more efficient and less costly urban policies (Pucci, 2014).

Why and How to Integrate Traditional Data Sources with Mobile Phone Data

The work presented here is part of a project carried out for the Monza and Brianza Province aimed at understanding, through conventional data sources (statistics and surveys), the overall mobility practices and their relationships with the distribution of main activities, i.e. large traffic attractors and generators, within the region (Pucci, 2009).

In this context, we used mobile phone data to assess whether they are useful to fill gaps of information related to traditional data sources (Manfredini et al., 2012) and, therefore, whether their use could provide benefits to the urban planning community and to urban decision makers. In fact, in urban research and practice, there is a wide and growing concern about the inability of conventional data sources to describe adequately city dynamics and time-dependent variations in intensity of use of urban spaces by temporary populations. Knowing this variability of daily practices can be used to promote a fair and effective range of services. Many authors (Ahas and Mark, 2005; Ratti et al., 2006; Kwan, 2007; Ahas et al., 2010) indicate passive and anonymous monitoring of mobile phone activity as a valid alternative or complement to traditional methods. Cellular network information can be easily retrieved in real time, and it is available at a high spatial and temporal resolution. Emerging disciplines (Mobile positioning, Space-time movement studies, life-map geography) are involved in the analysis, visualization, and interpretation of people's presence and movements in urban spaces. Mobile phone traffic data are promising sources for large-scale surveys due to the ubiquity of cellular phones in contemporary societies. According to the most recent International Telecommunication Union (ITU) statistics, Italy has over 150 mobile phone subscriptions per 100 inhabitants (ITU, 2012). Moreover, since they are automatically generated from the telecommunication networks, there is no need for huge investments such as those necessary for the acquisition of conventional data banks. In the present case, the availability of direct measurements, performed with traditional methods of urban surveys, offered a useful framework to test whether mobile phone data trends and maps were illustrative of known spatial dynamics and processes but also to investigate their capability to highlight new trends and dynamics, difficult to detect through conventional sources.

We investigated, on the one hand, whether the outcomes of different mobile phone data (Erlang, SMS, MSC) provide reliable dynamics or, at least, verifiable trends, with available conventional data (census, O/D mobility matrix) and with specific surveys (distribution of the most important urban functions, performance of each function, number of potential users, opening hours) within the Monza and Brianza area. On the other hand, our work was aimed at verifying the possibility of integrating traditional data sources, which have some known limitations for urban and mobility investigations with new sources of data, characterized by a high spatial and temporal resolution. Both aims are linked to the need to seek new interpretative tools for the identification of mobility practices that traditional data sources are unable to provide with continuity.

Among the limitations of traditional data sources, we cite the high cost of surveys, the difficulty of data updating, the difficulty of describing city dynamics, and time-dependent variations in intensity of the use of urban spaces by temporary populations at different scales. In the Monza and Brianza area new forms of mobility are emerging; they are close to the daily mobility and are characterized both by being based on the use of transportation systems, and by the efficient appropriation of information technologies (Internet, mobile phone). These new forms of daily mobility, linked to a diversification of the social time and to a weakening of the institutional ties (schedules of job, schools, public services, and public exercises), use the urban space very differently from commuting (Kaufmann, 2002; Lyons and Urry, 2005; Sheller and Urry, 2006).

In the Monza and Brianza Province, travel for personal reasons, related to free time, shopping, visiting friends and family, or to carry out personal activities, represent 39.1 percent of daily trips (Regione Lombardy, Direzione Generale Infrastrutture e Mobilità, 2002) and contribute to enhancing multidirectional mobility, drawing a more complex network of movements than in the past. In these new mobility practices, time plays a more significant role than distance: the time needed for the recurrent (work and school related) displacement, around which personal time is organized, has a decreasing relevance. Traveling for personal reasons, instead, becomes more relevant, even for the consequences on infrastructure networks. In fact, these movements are distributed throughout the day and they draw a non-hierarchical system of visited places, especially in the more dynamic municipalities, putting in evidence problems of inadequate mobility networks and of public transport supplies. The clustering of activities (Karlsson, 2007) in different parts of urban areas is at the same time cause and consequence of the new mobility practices which now define a broader area than in the past. In a context where the chain of daily trips becomes more complex, in which the peak hours dilate, in which the average time of displacement increases due to growing road congestion, new data sources capable of describing these dynamics are essential. On the contrary, available data are not able to provide information about these new daily practices. Such information could help decision makers in defining effective urban policies and in measuring the effects of such policies. So, for example, the provision of public transport services is still heavily dependent on a Fordist idea of the city, now completely obsolete, producing a deficit in transport supply and also generally high government spending. The consequences of these mobility practices create urban spaces defined as "archipelagos" of places and relationships. "The variable shape and dynamic," of such places quickly turn on and off, and are not easily captured by traditional data available in Italy. The interpretation that leads to this definition of the contemporary city could have consequences in terms of contribution to direct urban policies, only if supported by empirical evidence, capable of quantifying, even summarily, the variability of the density of use of places by urban populations. In this context—as indeed it has long been recognized—aggregated and anonymous mobile phone network data are considered a promising source (Reades et al., 2007; Ahas et al., 2010; Järv et al., 2012).

However, despite the positive results related to the use of the new methodology, additional evidence is needed to show how mobile network signals correlate with the actual presence of people in the city, how they can be used to characterize and map different urban domains and their occupants, and how this tool could support urban planning and urban policies. Towards this goal, we focused primarily on the possibility of establishing a coherence between mobile telephone traffic and the presence of people in an urban context, since it represents a relevant and necessary condition for exploiting mobile phone network data, and also for surveying the density of people's presence. This would be extremely useful for the implementation of policies concerning the supply of services that are more effective in responding to different needs.

Furthermore, the survey on the telecom data allowed us to assess the requirements of different applications and to identify ways in which to process the data to obtain outcomes, with a traditionally unavailable space-time resolution useful for urban studies. The analysis and the interpretation of telephone traffic data focused on three main applications:

- describing the intensity of the use of the city (during the day, weekdays/holidays, seasons) linked to the differences in the distribution of urban activities at different hours, days, and weeks, as a tool to define urban policies oriented toward offering services for the individual behaviors
- managing large and special events (inflow, outflow, monitoring), also estimating population density
- monitoring temporary populations and foreigners dynamically over time.

Available Data

For the present research we had the opportunity to use three kinds of data derived from the anonymous monitoring of the Telecom Italia mobile phone network:

(1) Matrices of mobile phone traffic expressed in Erlang, i.e. the average number of concurrent contacts in a time unit: this measure of traffic is anonymously recorded every 15 minutes by each cell of the network. Telecom Italia elaborated these measurements obtaining their distribution, by means of weighted interpolations, throughout a tessellation of the territory into areas measuring 250 meters × 250 meters ("pixels"). The data are characterized by a high spatial and temporal resolution and they show the *intensity of telephone traffic* per unit of time, but it is worth noting that they do not directly represent the number of users generating that traffic. It is known that the modes of mobile phone use change according to the age and socio-professional condition of the users. In addition, the Telecom Italia cell traffic is a part of overall Italian mobile phone traffic, as Telecom users are about 40 percent of the market on a national scale, and of these, only those who generate traffic are recorded by Erlang data.

(2) Matrices of Short Messages (SMS) traffic: the number of generated and received short messages is recorded by each cell of the network at an hourly rate and distributed over the same spatial grid previously described. This kind of cellular network traffic is referable in particular to specific segments of population, namely to people of an age range from 15 to 24: hence the study of spatio-temporal distribution of SMS leads directly to the individuation of areas where young people are concentrated.

(3) Data of the Mobile Switching Center (MSC): for every hour, the number of GSM active clients (i.e. the number of switched-on cell phones) for each of the Lombardy region MSC Service Area, distinguished by the nationality of the SIM, has been extracted. These data are very interesting, because they are directly related to users, but on the other hand their spatial resolution is less fine and less regular with respect to the former data presented in (1) and (2): the service area of each MSC has a variable size depending on the number of served GSM tower cells and on the intensity of mobile phone traffic generated inside it. In the present study we considered trends of data generated inside the MSC service areas having non-empty intersections with the area of the province of our interest. We took into account the variability of presence during weekdays and holidays. On one hand, we examined the whole population; on the other, we extrapolated the trends distinguished by the SIM's nationality, in order to evaluate the degree of attractiveness of the provincial territory for visitors and tourists (Manfredini et al., 2011). We related this information with the calendar of local events during the studied period (September 2009, April 2010).

Data Analysis and Outcomes

Let us introduce the data by examining some time series of the cell phone traffic. The first two figures (See Figures 2 and 3) show the graphs of the overall traffic expressed in Erlang, generated in the province of Monza and Brianza in two periods: from March to June 2009, and during September 2009.

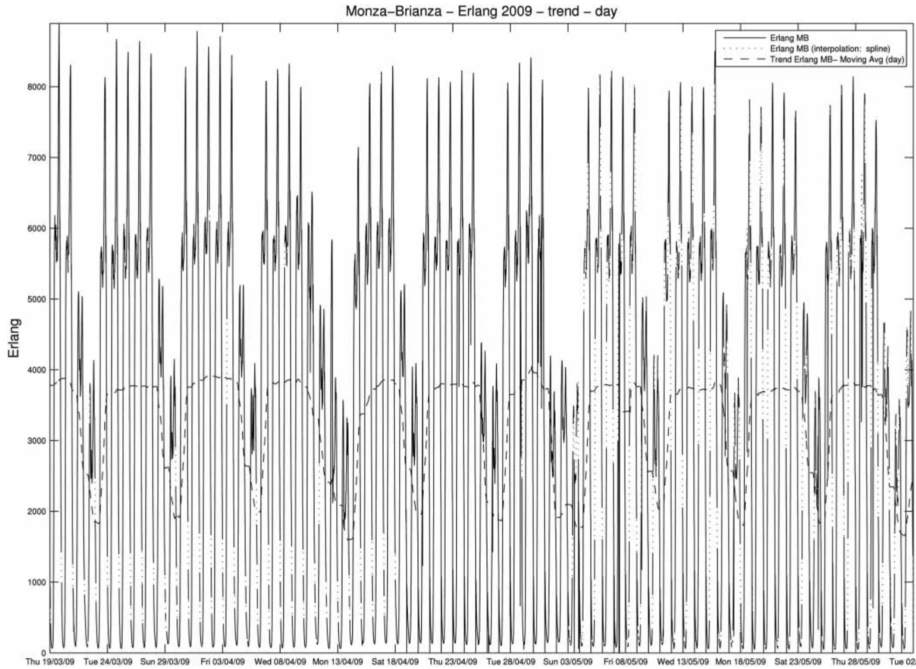

Figure 2: Telecom Italia mobile phone network activity (Monza e Brianza, March–June 2009). Overall Erlang traffic (green); daily trend (red).

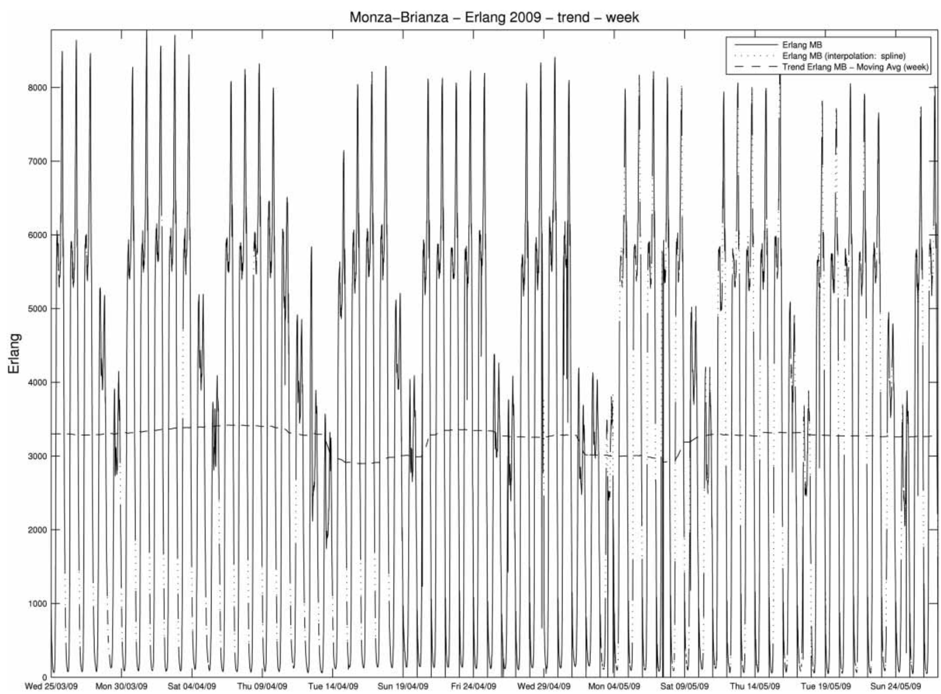

Figure 3: Telecom Italia mobile phone network activity (Monza e Brianza, March–June 2009). Overall Erlang traffic (green); weekly trend (red).

Figure 2 represents the average daily traffic from March to June 2009. Erlang traffic, with missing values filled through a spline interpolation, is depicted in dotted line. Some regular patterns are clearly recognizable: every day is an oscillation with a prominent peak in the graph. It is evident that the week is roughly identified as a sequence of five peaks of comparable magnitude, followed by two other peaks representing the weekend. The trend, calculated as the daily moving average, is represented by the dashed line: it shows well the weekly periodicity (weekdays-weekends) during the first data set of approximately four months. From here you can also find some anomalous weeks coinciding with major holidays (Easter, April 25–May 1). The two holidays of the period are again well visible in Figure 3, where the trend is calculated on a weekly basis. In this case, the weeks in which the behavior of the phone is "regular" have a substantially flat curve, while the holidays are recognizable as the two troughs.

Similar considerations apply in the case of Figure 4 (left), which covers the telephone traffic expressed in Erlang of two weeks of September 2009. In particular, we may note that after the start of school (September 13) Erlang traffic is higher than that in the previous week. The right side of Figure 4 shows the SMS traffic over the same period, showing how SMS have more activity than phone calls between Friday night and Saturday, presumably because of youth activities. It can also be observed that SMS traffic is less influenced by the weekend than Erlang traffic, and that it is characterized by a lower deviation from the mean.

Mobile Phone Data Intensity Maps

We defined a set of spatial operations between Erlang matrices aimed at underlining the spatial and temporal dynamics of the uses of urban spaces uses within the study area. The maps, therefore, represent the spatial configuration of mobile phone traffic at different hours of the day and can be divided into two main categories:

- "snapshot" maps that show mobile phone traffic intensity at different significant temporal intervals. They represent the variation in urban uses by temporary population over time:
    - average daylight mobile phone traffic during working days: Monday to Friday, from 8 to 20 (See Figure 5);
    - average daylight mobile phone traffic during holidays: Saturday, Sunday, from 8 to 20 (See Figure 6);
    - average night mobile phone traffic during working days: Monday to Thursday from 20 to 24, Monday to Friday from 24 to 8 (See Figure 7);
    - Average night mobile phone traffic during weekend: Friday from 20 to 24, Saturday and Sunday from 24 to 8 and from 20 to 24 (See Figure 8). The representation of the average intensity allows the evaluation of the spatial distribution of telephone traffic and highlights the hotspots in the different time intervals considered.
- "complex" maps that display the relationship between two matrices of mobile phone traffic:
    - Working days/holidays ratio (See Figure 9);
    - Night-time working days/Night-time weekend days (See Figure 10).

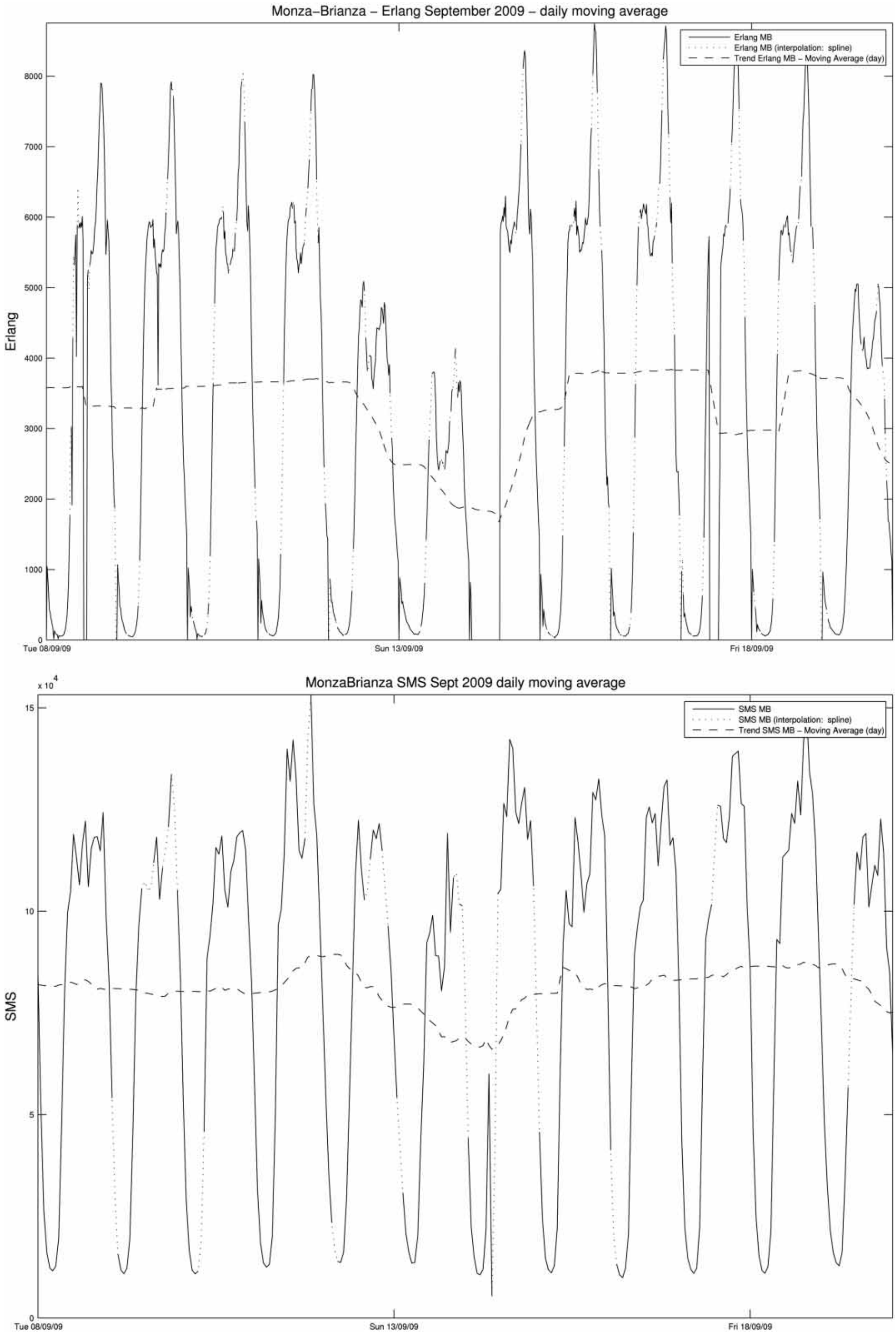

Figure 4: Telecom Italia mobile phone network activity (Monza e Brianza, September 2009). Upper: overall voice traffic (Erlang); lower: overall SMS traffic. Daily trends in red.

The representation of the relationship between different time interval maps allows us to point out the specific characteristics of mobile phone traffic and to highlight the places where mobile phone activity is particularly

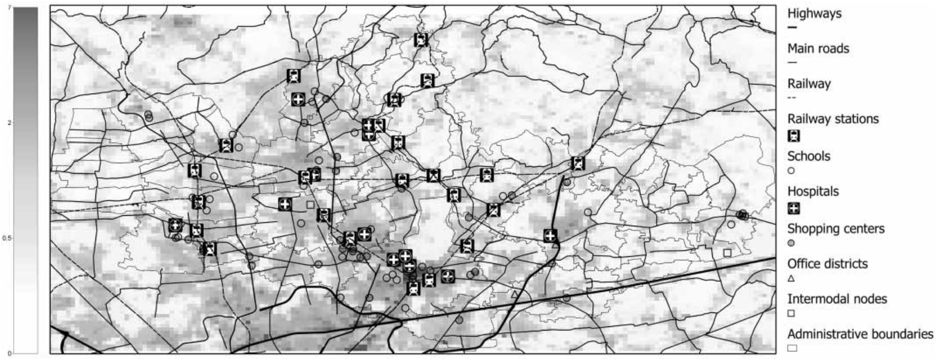

Figure 5: Mobile phone activity (Erlang) on the average working day (September 2009).

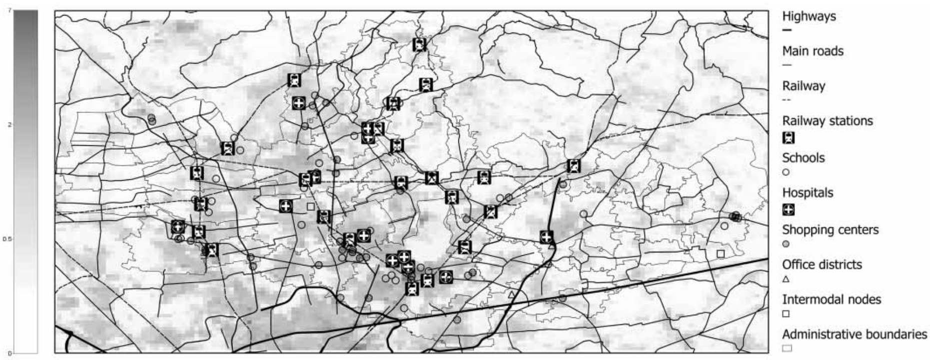

Figure 6: Mobile phone activity (Erlang) on the average weekend day (September 2009).

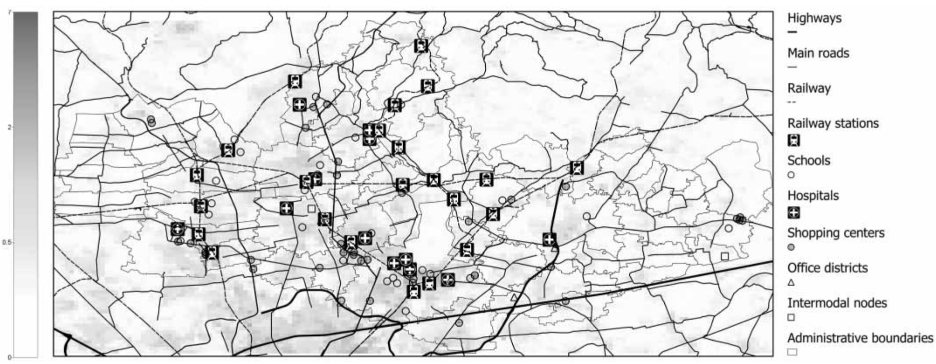

Figure 7: Mobile phone activity (Erlang) on the night of the average working day (September 2009).

relevant according to the mobile phone users' practices, and to the located activities.

Snapshots Maps

The four mobile phone maps (average working day, average weekend day, average night working day, average night weekend day) provide very different

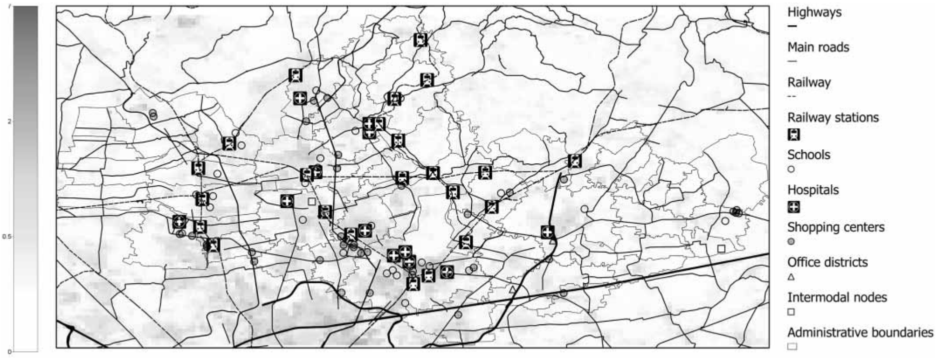

Figure 8: Mobile phone activity (Erlang) on the average weekend night (September 2009).

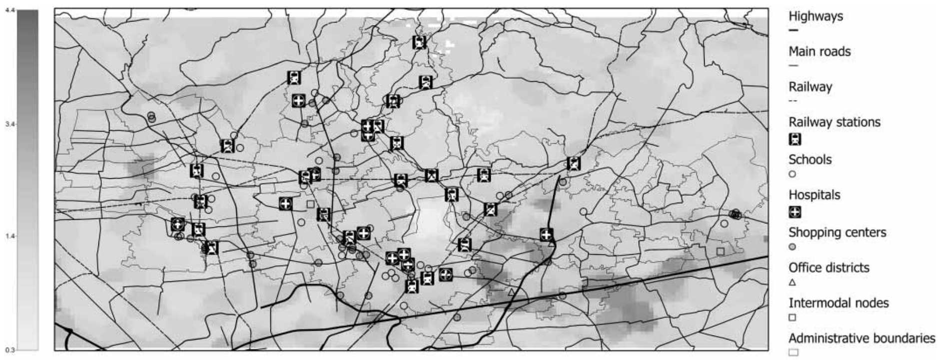

Figure 9: Working days/Weekend days ratio (September 2009).

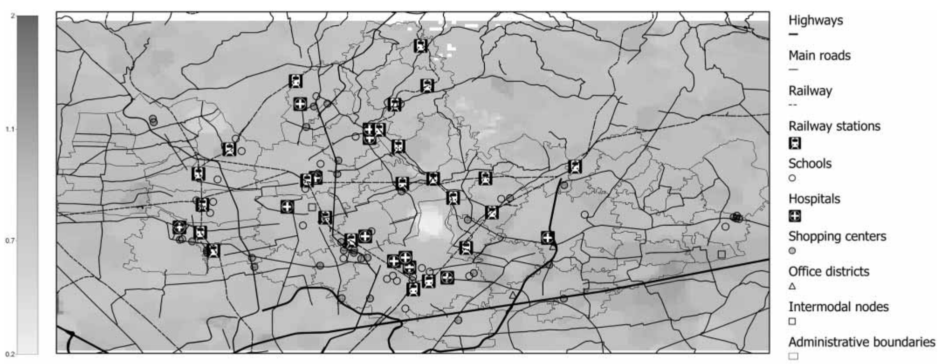

Figure 10: Night-time working days/Night-time weekend days (September 2009).

images of the region. The activity considerably changes, primarily in its maximum and average values (See Table 1).

During working days, the average traffic is almost double that during the weekend, while it is more than four times higher than during the night-time. Moreover, the data variability is much higher than during the other time intervals.

Table 1: General statistics for the mobile phone traffic maps (September 2009).

	Min (Erlang)	Max (Erlang)	Max−Min (Erlang)	Average (Erlang)	Standard deviation (Erlang)	Sum (Erlang)
Average working day	0.005	6.94	6.94	0.37	0.46	5808
Average weekend day	0.003	2.91	2.91	0.21	0.25	3322
Average Night working day	0.001	1.42	1.42	0.09	0.11	1428
Average Night weekend day	0.001	1.44	1.44	0.08	0.1	1338

On each map we superimposed infrastructures (railways and main roads) and main mobility attractors (shopping centers, high schools, hospitals, railway stations) in order to facilitate the interpretation of emerging spatial patterns. Indeed, the analysis and the interpretation of mobile phone traffic maps is facilitated by a specific knowledge about the activities established in the territory and by an integration with conventional databases used in urban and regional studies (land use and land cover maps, transport networks, etc.). Therefore maps such as those obtained can provide new knowledge about urban dynamics at a spatial and temporal resolution not comparable with maps achievable by conventional data sources.

Daylight Mobile Phone Traffic. Figure 5 shows high mobile phone activity in the main urban areas of the region (in particular Monza, and in the other main centers, with less intensity; Lissone, Desio, Seregno in the western side of the territory and Vimercate, Agrate Brianza in the eastern side).

We observe a variety of situations and contexts where it is possible to read a relation between a diffused presence of attractors (mobility generators) and the density of mobile phone traffic. In other situations the mobile phone traffic can be related to the presence of huge manufacture platforms such as in Desio, Seregno, or along the highway passing by the southern side of the region.

As expected, Figure 6 shows how during the average day of the weekend the intensity of mobile phone traffic is lower than that of the average working day (2/3 less). The spatial distribution of the telephone traffic is, however, similar to that of the weekdays, albeit with reduced overall intensity. There emerges an interconnected system of high telephone activity areas between the municipalities of Monza and Desio, along the Valassina, an important infrastructure directed toward the northwestern side of the province. The western and eastern portions of the area, characterized by a very low population density and by lack of services, have a very limited density of mobile phone traffic. The same phenomenon happens along the Lambro Valley. In general we observe a morphology of areas where the intensity strongly depends on the settlements density and on the spatial distribution of the attractors.

Night Mobile Phone Traffic. Night maps, both of weekdays (See Figure 7) and of holidays (See Figure 8), present instead a far more fluid and smooth behavior. We do not observe significant concentrations of telephone traffic, except in Monza and in the main towns along the New Valassina road. Weekend nights are substantially similar to working days nights.

Complex Maps

The relation between matrices of telephone traffic allows a comparison of different time-dependent situations (working day vs weekend days, night-time vs daylight time) and to relate the spatial distribution of mobile phone traffic to specific activities, actually located in the territory.

Working Days/Holidays Ratio. Figure 9 represents the variation in the use of phones between weekdays and weekend. When the ratio is high (over 1), diurnal working-day mobile phone traffic is over that of holiday traffic and this is primarily due to the presence of working-day activities.

In particular, along the A4 highway which is placed in the southern side of the region, we observe a great increase in working-day traffic, due to the spatial distribution of important productive activities characterized by a high number of employees. The same phenomenon happens in the northwestern side, in correspondence to a very dynamic area where other relevant productive activities are located.

If we concentrate on the areas with an opposite behavior, the Monza Public Park emerges, i.e., it is characterized by a huge mobile phone traffic during weekend days. This dynamic is attributable both to more intense and frequent use of the park on holidays, but especially to the Formula 1 Monza Grand Prix, which was held on the weekend of 12−13 September 2009 and was therefore included in the period of analysis.

The observed trends, from a qualitative and an interpretative point of view, allowed us to discriminate specific parts of the region characterized by an intense mobile phone activity, which can be caused by the distribution of productive and commercial activities.

Night-time Working Days/Night-Time Weekend Days. Overall, the ratio is almost in the entire province, close to 1, i.e. there are no significant differences between the density of use at weekdays and at holidays (See Figure 10).

In the Park of Monza, the night traffic of the weekend is much higher than that of working days, because of the Monza Grand Prix and of the presence of a temporary camp site in the northern portion of the park.

Equally interesting are also two areas where many pubs and discos are located that are characterized by intense telephone traffic during weekend nights. But along the A4 highway and in the western side of the region, we find situations with high mobile phone traffic during weekday nights, that can be explained by the presence of huge manufacturing firms with 24/7 production cycles.

SMS Maps

Still experimental are the first findings of the SMS—Short Message Text—traffic data analysis. SMS is the main messaging technology used by young people, and it is the most effective way of reaching this target group of the population.

The hypothesis is that the spatial distribution of text message services can provide an indication of the presence of young people in the area.

In this section, we present a preliminary comparison between the average mobile phone traffic activity (voice) and SMS traffic. These two dimensions are not directly comparable because mobile phone traffic is recorded every 15 minutes and is expressed in Erlang while SMS traffic, sampled every hour, is expressed as the number of messages exchanged in the unit of time considered (one hour).

The comparison between the two sizes is established, for each pixel, as the linear correlation coefficient, which is an independent measure, between a sequence of scan times for a set of days.

In the resulting maps (See Figures 11 and 12), increasing values in intensity of blue color correspond to a positive correlation between the two time series (SMS and Erlang), i.e., the profiles of the two curves are increasingly similar while the value approaches to 1. In contrast, negative values indicate negative correlation; for value equal to -1 the two curves have opposite behavior (i.e. when the Erlang traffic increases, SMS numbers decrease or vice versa). Areas of strong negative correlation, therefore, indicate that the two types of mobile phone services are disjointed. This may, for example, indicate the alternate presence of young people or adults, who have different propensities to use mobile devices and services. It is worth noting that on a typical working day, many high activity areas located near high schools emerge. Productive districts are characterized by low values of the correlation index both on working days and on weekend days, a situation that can be explained by the different use of voice mobile phone traffic and SMS.

MSC Area Analysis

The data analysis has been carried out on the variability of the number of active users in one MSC, covering the central part of the Monza and Brianza Province (See Figure 13), for two periods of time (September 7–20, 2009; April 1–30, 2010) and it was aimed at determining whether and how these data might provide new and useful understanding of urban temporary population dynamics on working days, on holidays, and in correspondence to big events (Formula 1 Grand Prix, Milan International Design Week), and also over longer periods

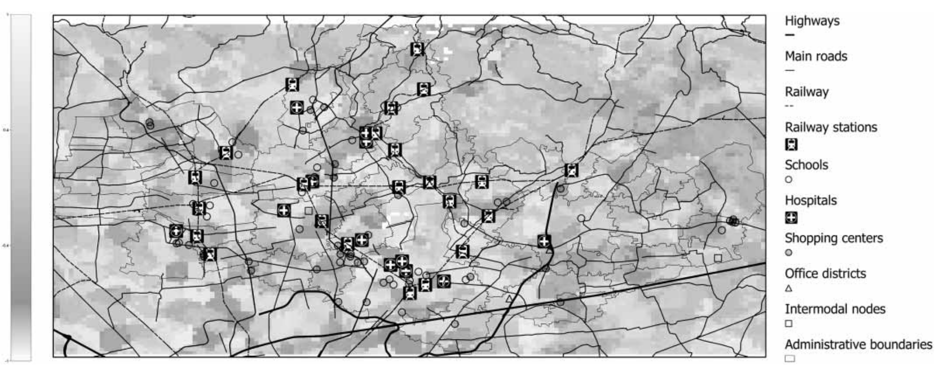

Figure 11: Linear correlation coefficient between SMS and Erlang: Tuesday.

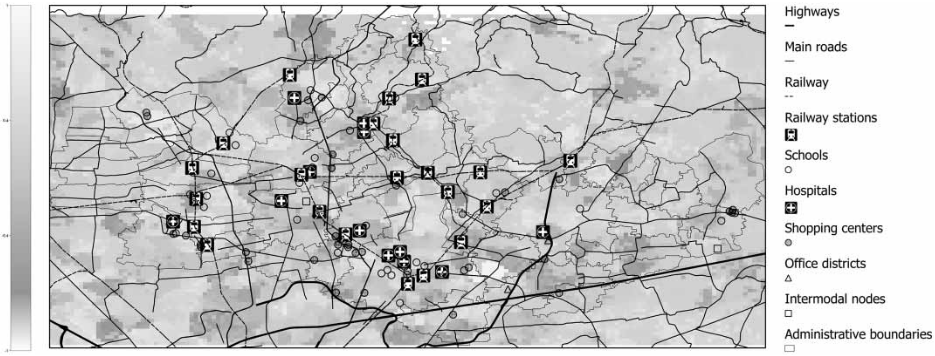

Figure 12: Linear correlation coefficient between SMS and Erlang: Sunday.

(week, month, year). Data at our disposal were, for every hour of the two considered time periods, the number of active and registered clients (UMTS and GSM), distinguished by the nationality of the connected SIM.

The interest in this type of information, despite its low spatial resolution, is due to the possibility of having access to data directly related to the number of active phones, which may correspond approximately to the hourly people presence in the different MSC service areas. The further possibility of knowing the nationality of the SIM of active customers has also suggested an evaluation be made of the potential of this data for monitoring foreign presences in the study area.

Nowadays, tourism statistics are related to capacity and occupancy in collective tourist accommodations, and they are collected via surveys filled in by accommodation establishments. Statistics on the occupancy of collective tourist accommodations 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.

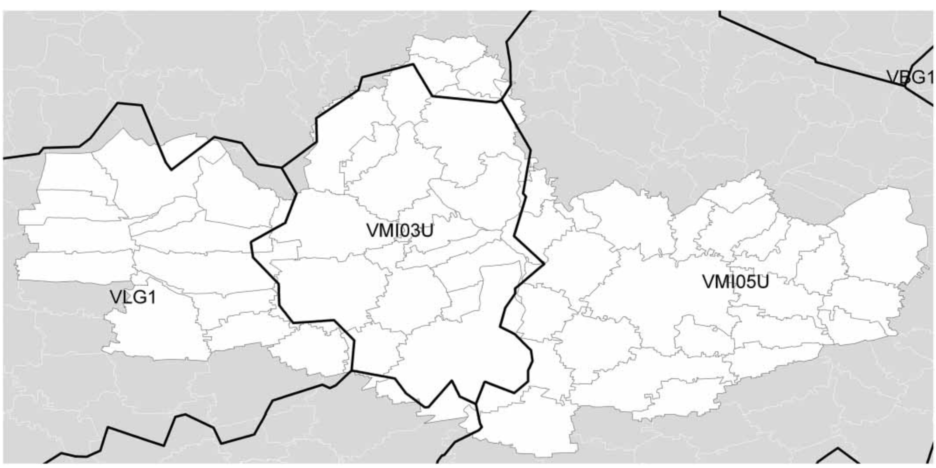

Figure 13: Boundaries of the MSC service area covering the central part of the Brianza region.

This information is available at the provincial spatial scale and underestimates the dimension of phenomena, because it considers only tourists or visitors who go to official structures. A large proportion of temporary visitors are, therefore, excluded. On the other hand, a strong need to know the dimension of tourism is expressed by several urban stakeholders, such as municipalities, public agencies, and industry and trade organizations: they are interested in increasing the attractiveness of urban regions in order to provide new services and activities targeted for this type of temporary population (tourists, business people, etc.).

September 2009

The hourly variability of Italian GSM active clients during the period 7–20 September 2009 (See Figure 14) highlights two different phenomena. During the first week, we observe an increasing number of MSC users, returning home after the end of the August holidays.

In the second week, the average hourly trend is more regular (more than 80,000 users in the working days and a subsequent reduction in the weekend days, due to the attractive role of the Brianza main city, Monza, offering jobs and services).

Focusing on foreigners (See Figure 15), the trend is quite different. In fact we point out the presence of a spike of foreign visitors, during the weekend of September 12–13 and in the former days, certainly linked to the Formula 1 Monza Grand Prix, which took place in those days. The average presence of foreigners during the Grand Prix period is more than five times the September average value.

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

April 2010

The April 2010 trend is shown in Figure 16. The graph highlights different temporal patterns of Italian daily population:

- Working days vs week-end days
- Easter vs holidays

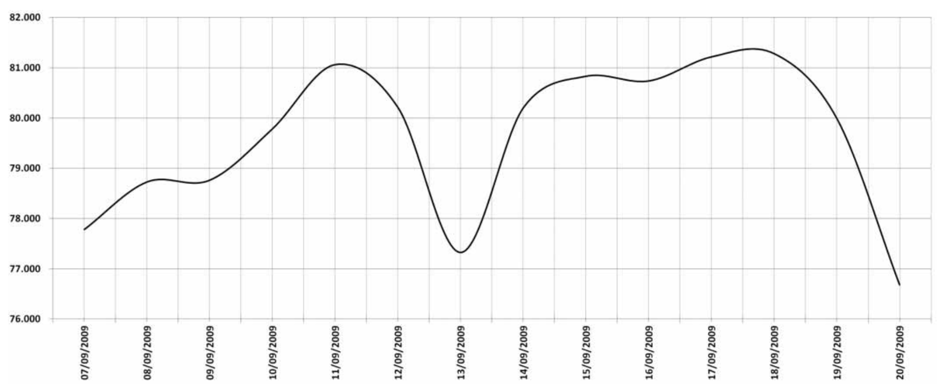

Figure 14: Italian active clients in the MSC service area covering the study area—September 2009.

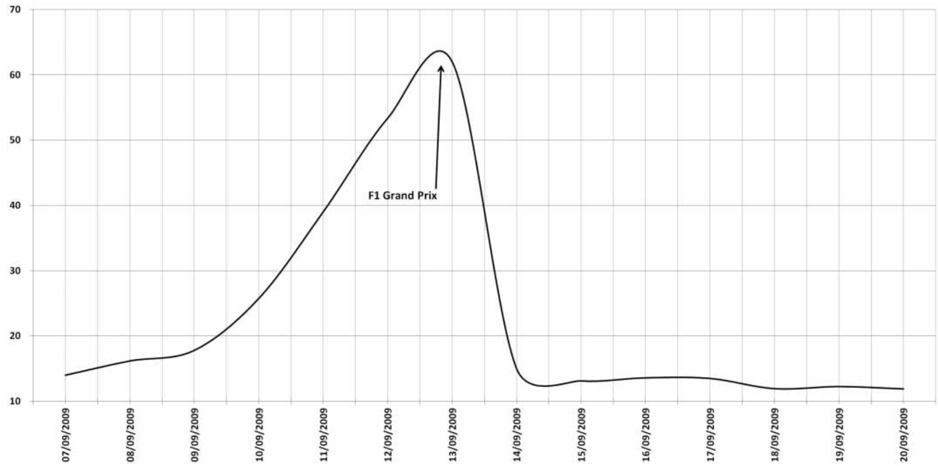

Figure 15: Average hourly number of foreign active clients—September 2009.

We observe a decrease of active clients during the weekend, in particular on Saturday and on Sunday due to the reduction of job and study travels.

Moreover, the Easter period, Sunday and Monday April 4–5, presents an inflection even more pronounced than that of other April weekends. In this case there is a significant reduction of active clients, related to the long Easter weekend, when many inhabitants of the area left the city. On Easter Sunday, there are about one-fourth fewer active clients than in the subsequent Sunday. The possibility of obtaining an indirect measure of the temporal variation of presences in the city is a great value of these data, relevant for policy and decision makers.

Contrary to the behavior of Italians, foreign visitors' trend (See Figure 17) shows that the central area of Brianza (VMI03U) is strongly attractive during the holidays, especially at Easter, when the intensity is approximately 16.2 percent higher than other Sundays. Particularly interesting is what emerges in the period April 14–19, 2010, when there is a peak of foreigners in the MSC service area.

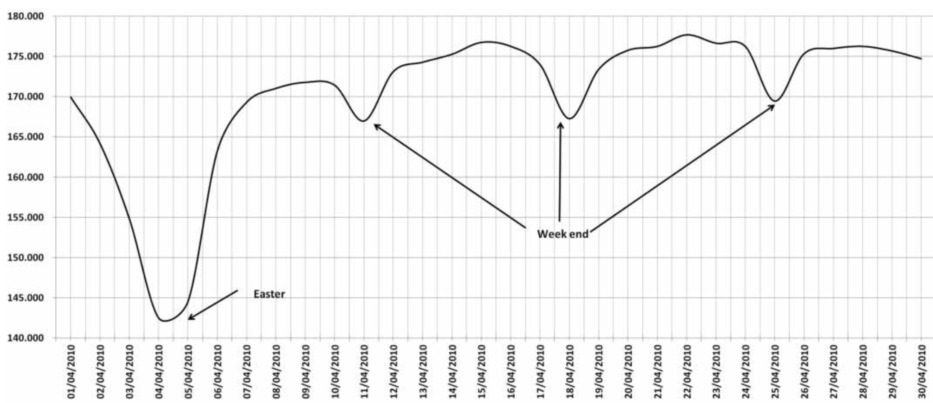

Figure 16: Average hourly number of Italian active clients—April 2010.

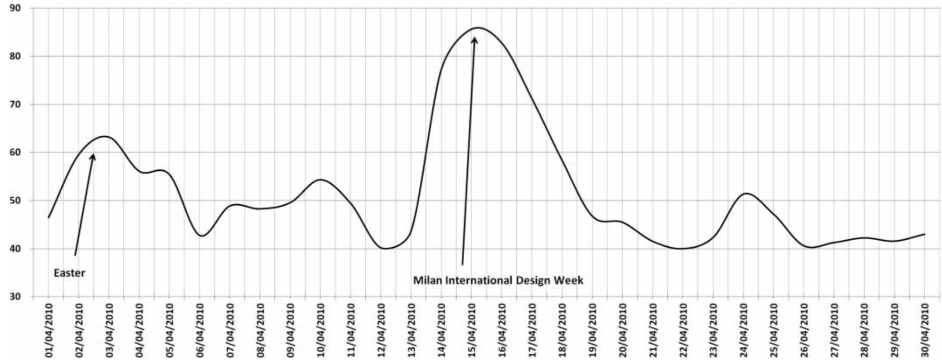

Figure 17: Average hourly number of foreign active clients—April 2010.

During this period, the Milan International Design week, a leading event that takes place in the Milano area (therefore not in the Brianza region), was held. This trend may be related to the existence of the Brianza district of wood furniture, one of the most important in Italy, showing very important quantitative and qualitative performances in terms of the 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 professional visitors to the Milan International Design Week went to the enterprises specialized in the production of wood furniture for contacts and for defining commercial contracts.

Conclusions

Mobile phone providers have a lot of indirect information on population behaviors that could be successfully used for analyzing and monitoring trends of people's use of urban spaces. This is information that can not be gained through traditional data.

In fact, data commonly used in urban analysis appear to be increasingly inadequate to describe city dynamics and time-dependent variations in the intensity of the use of urban spaces. This "world" of data and information has not yet been fully explored, but it could represent a key factor in defining a new approach in urban research. Urban practices take place daily, in a given set of places that are "meaningful" for an individual (Pucci, 2008). Vice versa, all these places are affected by transformations of daily and working life, caused by technological and social innovations (e.g., increasing role of transportation, information and communication technology). Recognizing and mapping these places, in their spatial and temporal dimensions, could be a major achievement in the understanding of contemporary city dynamics for urban studies and for urban planning (Kwan, 2007).

Analyzing the spatial and temporal uses of cities in their contemporary daily-life practices requires an integration of 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 geo-located digital traces, aimed at identifying the complexity and multiplicity of individual behaviors (Gonzalez et al., 2008). In other words, it is possible to point out that through new data, we can define who we are by the places we go, overcoming some limitations due to characteristics of traditional sources of data in describing contemporary city dynamics. Traditional data, in fact, is scarcely updated and does not take into account the temporal use of urban space by residents and citizens.

Moreover, 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 methods, because urban and regional data are normally available at the level of statistical subdivisions which correspond to municipal and administrative boundaries and not to the geographic dimension of processes and urban transformations.

The intensity of the use of a city and the rhythms of a city change in time and in space. City usage is the result of different daily practices carried out by temporary urban populations that are difficult, if not impossible, to grab through traditional analytical tools usually available to geographers and urban planners. In this context, the real challenge for urban studies is to integrate available databases together with an innovative use of traditional sources, aimed at capturing the variety of changes in urban practices.

Despite the proposed methodology still being experimental and integrative to traditional sources, the telephone traffic data are, also at this stage, useful for monitoring the variability of the use of spaces and for providing new knowledge and interpretation closely related to population density in urban areas. Indeed, as it is clear from other studies, the intensity of activity in a cell is proportional to the presence of mobile phone users (Ahas and Mark, 2005; Ratti et al., 2006; Reades et al., 2007; Sevtsuk and Ratti, 2010). In particular, the anomalies emerging from the analysis of mobile phone data can be interpreted as clues of interesting dynamics that can be recognized, selected, and further investigated with in-depth examinations.

Knowledge in real time of land-use practices, in their time and space distribution, represents an important tool not only for interpreting the densities of practices, but also to support diversified management policies and mobility services, increasing the efficiency of the supply of public services.

The different types of cell-phone data used in this research, integrated with each other and inserted into an urban information system, can help provide knowledge about new urban dynamics, useful for public administrations, beyond their consistency with traditional data sources.

Note

1. The chain of daily movements is more articulated than in the past: the individual daily travels in the Province of Monza and Brianza are 3.61 per day (2.65 per day in Lombardy Region), with an average of two moves in sequence; the mobility for personal reasons, for shopping and leisure, increases; the daily rush hours are dilated (22 percent of the travels are between the 7am and 9am), the mean time of displacement increases (1 hour and 12 minutes on the average) partly because of traffic congestion that grows with an annual trend of +2.5 percent on the provincial roads (Pucci, 2009).

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