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Procedia Computer Science 207 (2022) 877–886

Procedia Computer Science

www.elsevier.com/locate/procedia

26th International Conference on Knowledge-Based and Intelligent Information & Engineering Systems (KES 2022)

Social dynamics in cities: analysis through LBSN data

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Abstract

Location-Based Social Networks data —LBSN data— reveal, in essence, user preferences and patterns of use of urban space. This information plays a key role in research on social dynamics in cities. Today, social network applications are widely available and this digital data represents a complementary and inescapable source of data for the analysis of urban dynamics. Ten years ago, a handful of pioneering researchers paved the way to tackle city issues employing different types of LBSN data. The present work describes a series of case-studies that have contributed to a research methodology which, in turn, helps to unveil the traces of the city pulse lying hidden behind digital footprints. These cases exemplify how these sources help to gain a better understanding of social dynamics and can be used in urban interventions. The presented case studies were mainly data-sourced by Foursquare, Twitter, and Google Places, while other social networks such as Airbnb, Wikiloc, and Strava were used for the specific cases of tourism or sport-related topics. The case studies address urban issues based on multiscale approaches, using different LBSN datasets simultaneously in order to obtain a complex and accurate analysis, such as: a) the social dynamism at the neighborhood scale, searching for urban regeneration opportunities; b) tourism-related urban dynamics, both at the local and city scale, with a high granularity; c) user presence and preferences when assessing the city green infrastructure system; and, d) tracking informal sport activity in the urban periphery, connecting urban tissues and natural assets on the city borders.

Keywords: LBSN data; Social dynamics; Urban analysis; City Planning;

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10.1016/j.procs.2022.09.143

1. Introduction

Digital data generation has improved our knowledge of a broad range of topics linked to the urban environment. The Urban Digital Skin has notably been acknowledged as the layer of virtual information generated from: (i) the use of digital services, such as transport or bank cards; (ii) the capture of data through sensors; or (iii), the use of mobile phones [1–3]. In addition to these sources, digital information generated by social network applications stands out for its immediacy and availability, as well as for providing individual information on people's behavior, interests, and habits which are key to a better understanding of social dynamics in cities [1,4].

The use of GPS technology to locate a person, company, organization, event, etc., at a specific point in the territory, is of special interest when analyzing urban phenomena and social dynamics in cities because this is how information is linked to space. Different Location-Based Social Networks data —henceforth, LBSNs data— are regarded as a valuable source that provides information on the actions, events and activities that are happening, linked to a physical environment and registered in the virtual space [5].

LBSN data reveal, in essence, preferences and patterns of use of urban space that can explain a city's phenomena and dynamics. Ten years ago, a handful of researchers decided to trust LBSN data as a source to tackle a range of city analyses— [6–11], to name but a few pioneering works. However, their work makes it possible today to expand the knowledge and information available on present urban realities and, therefore, contributes to designing cities and better informing urban planning decision-making [12].

The aim of this article is to review a collection of research case-studies in which different types of LBSN data were used to analyze social dynamics. These cases exemplify how a better understanding of social dynamics was applied to urban interventions. Based on the analysis of the selected case studies, social dynamics in different cities helped to identify: [i] places of opportunity; [ii] tourist activity areas; [iii] relevant green areas in the city used daily; and [iv], informal outdoor sports and leisure venues. The presented case studies were mainly data-sourced from Foursquare, Twitter, and Google Places, while other social networks such as Airbnb, Strava or Wikiloc were used for the specific cases of tourism or sport related topics.

2. Valuable features of Location-based Social Media data for social dynamics analysis

The data generated by social networking applications includes information on both users and their activities. The former can be used to analyze gender or age trends in relation to social behavior. The latter, i.e., data on user activities, interests and opinions, among others, were employed for studies on social dynamics in cities. This content is often accessible either through APIs —Application Programming Interfaces— or through web-scraping services that provide raw data which require verification, validation and mining procedures prior to analysis and monitoring [3].

The information generated by users on a voluntary basis is useful to study a city when two conditions are met. First, the information is linked to the city's physical realities —with unambiguous geographical coordinates. Second, the content —text, photographs, rating, etc.— refers to an interaction with the urban realities, namely: presence at a location, interest in activities, perception of the environment, opinions, etc. Specifically, data from Foursquare, Twitter, Google Maps Platform, Airbnb or Strava meet these conditions of geolocation and description of reality and are useful for the analysis of urban phenomena and social dynamics.

The databases obtained from these social networks are structured according to different variables —metadata— and, depending on the nature of that information, the data will be useful to study different topics. For example, location and temporal metadata can unveil spatiotemporal patterns of presence in different city areas, and metadata with information on the rating and type of activity/place can reveal user preferences —or levels of interest— regarding specific places or activities. In turn, voids of activity, i.e., a lack of this type of data, can indicate an opportunity or the need for urban regeneration and dynamization policies. To sum up, the most relevant types of metadata for the analysis of social dynamics in these LBSNs are: location variables, that is, latitude and longitude geographical coordinates; fields relating to the time when the register is shared, i.e., temporal variables; variables expressing perception, such as text, photographs or ratings, among others—which indicate interests, preferences or engagement with an activity or place; and records that allow to classify information, such as the type of activity or place —category, subcategory, type of property, etc. [12,19].

Examining the types of variables that contain the information on the LBSNs used in the selected case studies, some common features can be identified. Firstly, these LBSN data are linked to the geographical coordinates where the data is either generated or referred to —e.g., for Twitter, the coordinates refer to the place where the tweets have been posted and for Airbnb, the location variables refer to the property address. Secondly, each LBSN incorporates a diversity of specific information on realities that is valuable for the analysis of urban environments. In a nutshell, Foursquare reveals interest in places and activities; Twitter, spatiotemporal patterns of presence as well as perceptions over places and urban areas; Google Maps data, types of places and economic activities; Airbnb, types of rented short-term accommodation; and, Strava & Wikiloc, a selection of routes used for informal sport and leisure tracks. Finally, since the information is generated by users themselves, it is necessary to thoroughly revise and examine the LBSN data so as to avoid duplicates or the misrepresentation of information.

3. Social dynamics analysis through LBSN data: case studies

This section presents different LBSN data experiences that showcase a number of approaches to social dynamics. Each of the four selected studies provide complementary approaches as they apply a similar methodology that only varies according to the singular issues tackled in each case. First, the case of Las Cigarreras presents the combination of LBSN data to unveil social dynamics that can reveal urban opportunity places for commerce and socialization. Second, the identification of Tourist Activity Centers —TAC— provides an insight into tourism-related urban dynamics with a high granularity. Third, the analysis of social preferences and people's presence in urban parks and gardens is useful to align urban planning with user habits. And fourth, tracking informal sport and leisure activities in urban peripheries allows to depict itineraries that are used the most spontaneously and connect urban tissues and natural assets on the city borders. The analysis of social dynamics via LBSN in these four case-studies broadens our knowledge of the city, providing ample information to support decision making on urban planning and city policies design. These four case-studies help to understand the contribution of LBSN to city planning from four different perspectives: opportunity areas and trails, specialized activity centers, design of urban infrastructures, and tourism and leisure planning.

3.1. Identifying places of opportunity through the understanding of social dynamics: the case of Las Cigarreras in Alicante (Spain)

The characteristics of public spaces and the way communities use them are key factors to foster neighborhood social ties. Social dynamism has positive repercussions on urban living standards when achieved at a neighborhood scale —which is widely acknowledged as the unit of city planning organization [13,14]. This study represents a step forward in LBSN data interpretation for urban regeneration, introducing an innovative method that approaches inner-city neighborhood spatial and functional dynamics from a dual perspective: people-based and place-based. For the first time, up to four different LBSN databases —Google Places, Foursquare, Twitter and Airbnb— were combined in order to explore the city's social dynamics [15].

The place-based perspective allows to interpret the neighborhood scale as an urban functional entity, considering unique local urban dynamics. This fills a recognized research gap in urban regeneration studies regarding the social and physical inequalities among inner-city neighborhoods [16]. The method proposes to identify places of opportunity, on a case-by-case basis, considering the relationships between adjacent districts as well as core centrality.

The people-based perspective is entirely sourced from LBSN data where people generate information about their interests, activities, and presence in their day-to-day lives. While Google Places reflects existing economic activity, Foursquare showcases interest in those venues as well as information about formal public spaces, informal activity hotspots, and private indoor spaces. Moreover, Twitter geolocated tweets allow tracking users' spatiotemporal presence while Airbnb listings provide information on the location and availability of non-regulated temporary accommodation.

This method was implemented in the Las Cigarreras urban area in the city of Alicante (Spain). The area comprises seven neighborhoods under the framework of an urban regeneration program financed by European funds aiming to develop sustainable and integrated urban development strategies. Alicante is a medium-size capital province with

330,500 inhabitants, i.e., a similar size to 84% of European cities. Therefore, experiences in this domain are regarded as a benchmark for two main reasons: the area is located in the city center, with declining retail activity and a poorly designed public space, while also being in the vicinity of some of the most valued urban areas. In addition, the promotion of intra-neighborhood regeneration and inter-neighborhood dynamics emerge as strategic goals to balance the city center dynamics from a social and spatial perspectives.

The proposed data analysis approach follows a two-step method: first, each dataset is analyzed separately, then, all four datasets are represented on a map to overlap the information and analyze the study area in search of opportunity places for urban regeneration. The four LBSNs provide complementary layers of information which, when combined, reveal specific user trends, facilitating a richer analysis.

Las Cigarreras case study allowed verifying whether the proposed method was valid to conduct a multiscale approach within different neighborhoods, facilitating high granularity at the local level, while providing an overall view. This study yielded interesting findings on the proposed method: a) LBSNs combined analysis facilitates a cross-cutting vision that incorporates people-based and place-based dynamics; b) inactive nodes emerged in contrast to highly active areas, highlighting the need for intervention in specific areas that would balance both dynamics, those developed intra-neighborhood and those produced inter-neighborhoods; c) LBSNs overlapping allows to complement and complete the penetration of each social network, i.e., when records are scarce in one dataset, they can be supplemented by records from other datasets.

The social dynamics analysis yielded results on the identification of places of opportunity that could be linked through specific routes. A proposal for the urban regeneration of this area would involve actions to promote new itineraries that could link disconnected urban nodes that were already socially acknowledged —corresponding to the pink discontinued lines on Fig.1. Moreover, actions to add value to existing itineraries would enhance intra-neighborhood social life and contribute to forge closer inter-neighborhood links.

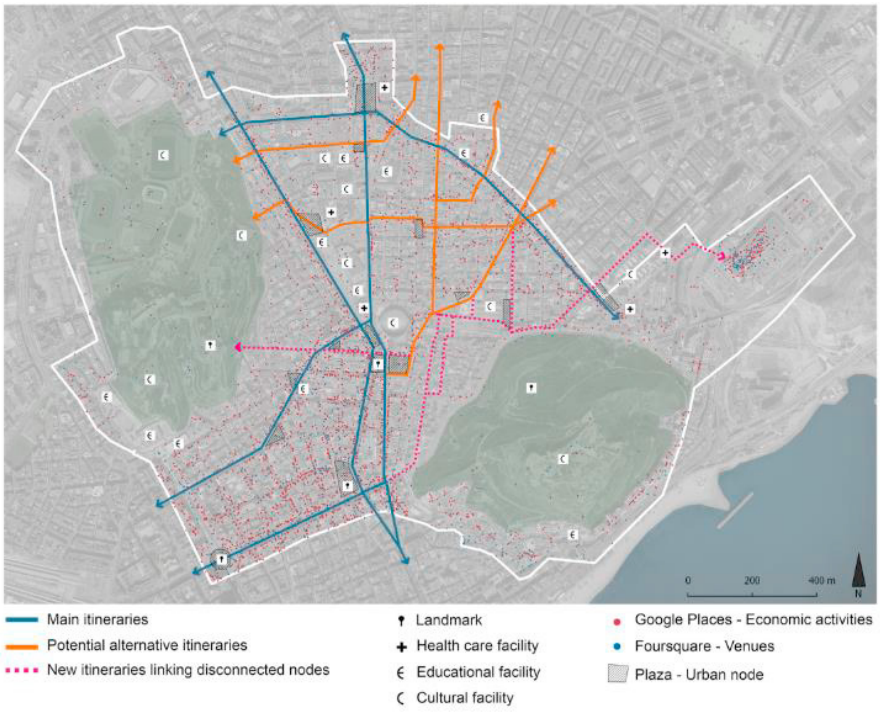

Fig. 1. Proposed urban regeneration routes in the area considering the existing social dynamics —people-based approach— as well as place-based dynamics [15].

3.2. Characterization of the urban tourist activity pulse: identifying Tourist Activity Centers in Valencia and Alicante (Spain)

Cities are dynamic environments and human activity concentration is a key factor in the analysis of socioeconomic changes [17]. Specifically, urban tourism has been a major economic driver of cities until the COVID-19 world pandemic in winter 2020.The true impact of the pandemic on socioeconomic city dynamics is still unknown, but whilst tourism rates are expected to fully recover in a foreseeable future, data analysis aims to shed light on tourism dynamics from a multidisciplinary approach. In particular, the use of big data generated by tourists on social media and web services has mainly been for addressing spatiotemporal analyses, using both a single source or combined datasets. Additionally, cross-referencing data from several datasets is being increasingly implemented as a methodological tool to conduct more accurate analyses, which, in turn, allows to crosscheck the information obtained, minimizing errors or misinterpretations.

LBSN user-generated content introduces a novelty with respect to other types of sources: user preferences —regarding itineraries, places, formal and informal hotspots— lie hidden behind digital footprints that help to better understand urban dynamics.

A methodology to uncover tourist social dynamics through digital footprints was proposed to facilitate a granular analysis of tourism-related places of interest by making headway in bridging the gap between user preferences and traditional approaches [18]. In this case, the study intertwines the Instasights heatmap activity-related areas —sightseeing, shopping, eating and nightlife— with user-generated content in LBSNs —namely, Foursquare, Google Places, Twitter, and Airbnb— aiming to determine the places in the city related to social dynamism and the concentration of tourism-related activities. These places were characterized under the name 'Tourist Activity Centers'—TAC—i.e., areas with a large concentration of people and tourist-oriented activities. The research develops a two-fold strategy: First, Instasights heatmaps is used as a baseline for identifying TAC areas; and second, LBSN data is overlapped to obtain an up-to-date characterization of urban activities.

Specifically, Foursquare data facilitated the identification of key urban hotspots and their social significance in the city, whereas Twitter, Google Places, and Airbnb data provided complementary information for characterizing dynamic tourist places and specific urban axes —itineraries and landmark nodes— in relation to the tourist land uses and user presences. To collect LBSN data, a self-developed web-based application was used —the Social Media Urban Analyzer, or SMUA— that retrieved data from Foursquare, Twitter and Google Places via the social network APIs [19]. A case-study approach was applied to the cities of Valencia and Alicante, which are representative touristic cities on the Spanish Mediterranean coast. They are located in the Valencian Community Region, which is Spain's leading leisure destination and a major international destination for European tourists.

The results revealed the potential of this method as a complementary tool to support urban planning decision-making. Several TAC areas were identified: four in Valencia and two in Alicante, all of them linked to historical or traditional urban districts. Additionally, specific activity centroids were represented, so the most relevant hotspots were included in the areas. Unexpectedly, not all the TAC areas included activity centroids and not all the centroids were situated within a TAC area. This analysis allowed to reflect the functional diversity of TAC areas or the presence of specialized urban pockets, that are sometimes disconnected from the most dynamic places. By overlapping TAC areas and LBSN data, it was found that several nodes were connected by specific itineraries or 'city hotspot connectors', proving the complex social nature of tourism and unveiling urban spatial patterns with a highly granular characterization of urban tourism-related dynamics —Fig.2—.

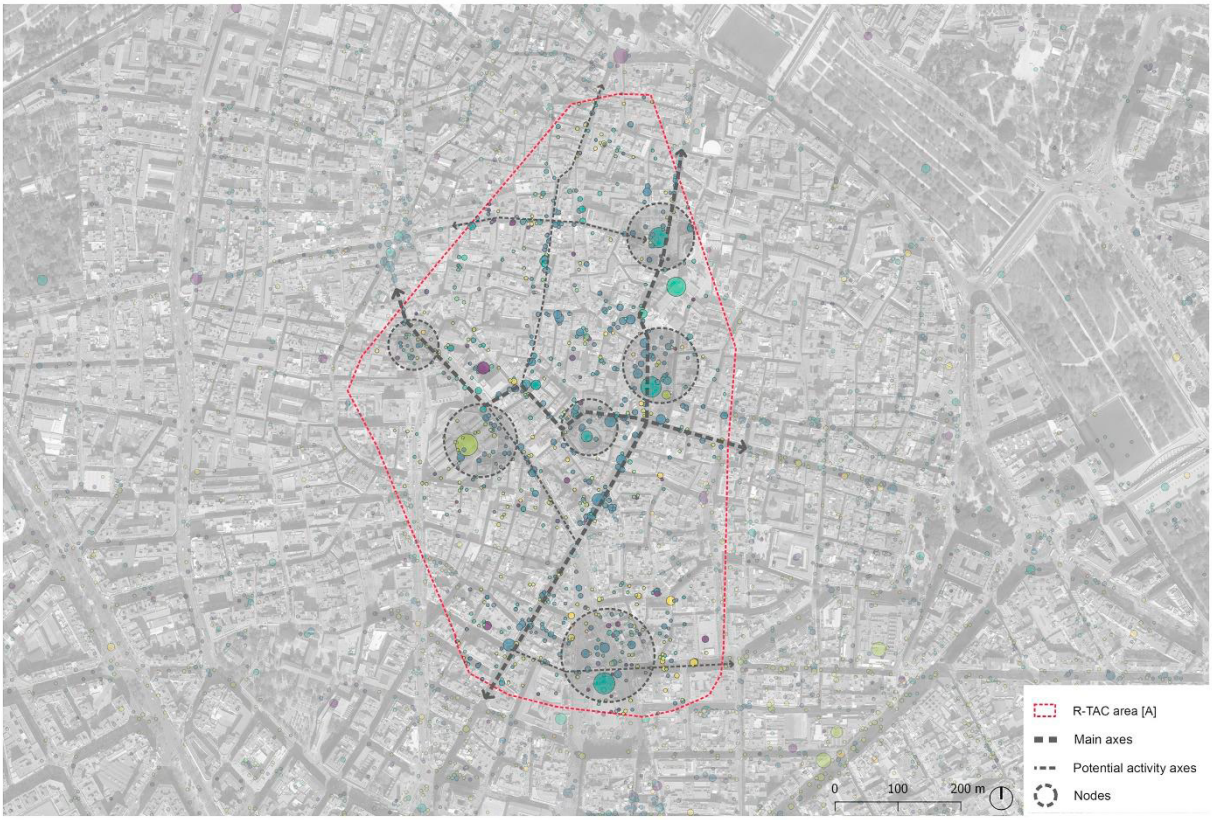

Fig. 2. Concentration of land-use mixed activities following potential axes of tourist activity in the city of Valencia (Spain) [17].

3.3. Social preferences over green urban areas: green infrastructure design considering user interests in places in Valencia (Spain)

In the case of Valencia (Spain), the social dynamics and people's preferences regarding public and green spaces were identified via Foursquare data [20]. Foursquare can provide valuable insights into user perceptions of relevant places that can potentially be part of the city's green infrastructure. This social network has proven to be effective to identify socially relevant urban plazas [21] as the meta-data retrieved include the cumulative number of unique users, visitors, and check-ins per each registered venue. These values are not only an indication of how many Foursquare users have passed by or stayed in a place, but also reveal people's interest in the places that are commonly used: indeed, the venues are registered by users rather than automatically recorded as in the case of other social networks [12].

The city of Valencia implemented a first version of the city's Green Infrastructure —henceforth, GI— proposal in the city's urban plan [22]. The proposal includes the configuration of an integrated GI network that interlinks important natural, cultural and heritage elements at the territorial scale with local urban spaces anchored in the city's social framework. One of the benefits attained from GI planning in a city is the creation of linkages between green and open spaces and local communities' wellbeing, who can enjoy integrated activities in common spaces. Thus, social dynamics analysis can help in the identification of key city spaces that are already recognized as identity places and,

therefore, must be incorporated into newly designed infrastructures. This work explored the identification of socially relevant places that should be included in the design of the GI network considered by the city plan.

In this analysis, the work with Foursquare data allowed to identify three types of elements that are key to the configuration of urban green infrastructure. The first type corresponds to the venues that are properly considered as GI elements, that is, natural spaces —such as parks, gardens, or beaches. The second type is the attractor facilities and activities, i.e., spaces where permanent or temporal activities promote social dynamism for citizens in their surrounding area— such as children playgrounds, multipurpose sports grounds, dog runs, etc. Lastly, the third type of elements are the connectors or corridors: the links that inter-connect green spaces at multi-scale levels —plazas, streets, avenues, bridges, among others—. These three types of venues combine natural spaces, attractive activities, and linking corridors.

Once the venues were classified according to these three types of elements, they were ranked by the total number of registered users, thus revealing their degree of social significance within the city structure —Fig. 3—. The findings uncovered that many of these places were considered as part of the city's GI in the Plan, especially the primary natural spaces in the city; however, many pocket gardens or social spaces intensely used and appreciated at a neighborhood scale were overlooked in the design of the GI plan.

Therefore, user generated content from LBSNs, such as Foursquare, proved to be useful complementary information to understand the city's social dynamics. These data contribute to the design of urban networks, helping to identify social spaces, thereby facilitating more effective urban planning, and contributing to the social sustainability of the city.

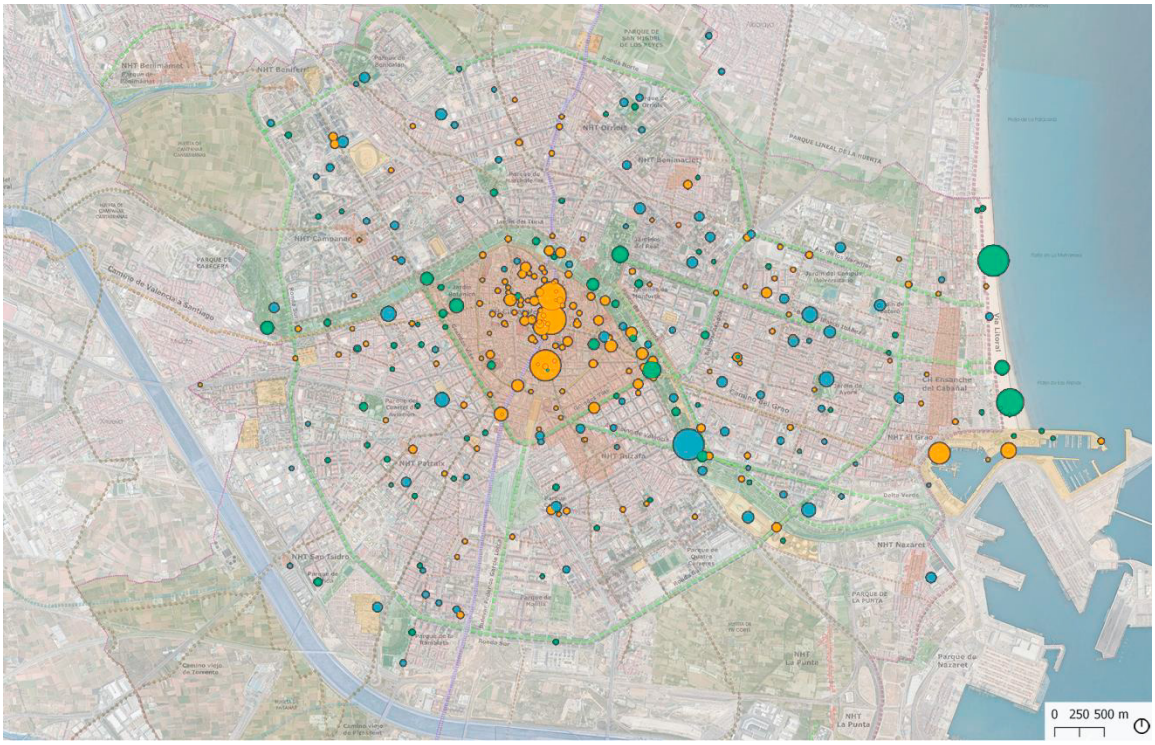

Fig. 3. Analysis of three types of GI elements obtained from Foursquare data in Valencia (Spain) according to its social relevance. Green circles – Type A: Natural elements; Blue circles – Type B: Hotspot facilities; Orange circles – Type C: Connectors [20]

3.4. Identification of informal outdoor sports and leisure venues: the case of peri-urban greenways in Olot-Girona (Spain) and Alcoi-Alicante (Spain)

Reading social dynamics in peri-urban spaces is a complex task, yet it plays a key role in the design of regeneration strategies in these border areas. Peri-urban spaces frequently lack planning regulations and their social use results from spontaneous and informal interpretation of its use. This is the main reason why LBSN data can provide relevant information to broaden knowledge on the informal use of peri-urban contexts. As an example, Strava data was analyzed to unveil the most widely used hiking, running and leisure paths in close proximity of two peri-urban areas: El Carrilet in Olot (Girona, Spain) and the Alcoi greenway in Alicante (Spain) [23]. A common characteristic to both case studies was the presence of obsolete railroad track paths which have been retrofitted and refurbished to be used as leisure spaces to enjoy nature or to develop outdoor activities.

The transformation of obsolete railroad itineraries into green corridors has become a successful strategy to regenerate outdated transport infrastructures as well as to create places of opportunity that promote sport practice and outdoor leisure in close contact with nature. These spaces have made it possible to provide access to a diversity of landscapes of high ecological and environmental value in connection with the built environment. They also have a leverage effect as they act as social, landscape, and environmental connectors. Moreover, they play a significant strategic role in linking the regional scale and the urban green infrastructure as they represent a valuable resource to enhance recreation activities in rural areas. Their most valuable features are the combination of their use as a space for health, leisure and outdoor sports, with other services and facilities located in peri-urban areas to contribute to the development of active tourism and sustainable tourism activity. The purpose of this study was to identify the paths used to approach the greenways through the analysis of social dynamics in both cities.

The analysis of data generated though Strava, Wikiloc and Google Maps allowed to identify areas of greater usage presenting social dynamics in relation to sports, leisure, or cultural activities. These sources provide evidence of use intensity and user preferences based on user-generated information.

People's interest in activities and a great intensity of use were identified in the surroundings and in continuity of the greenway's layout. Most of the facilities and services —retrieved from Google Maps— are located on intensively-used streets, according to Strava Heatmap data —Fig. 4—. This proves that these peri-urban areas are socially significant spaces in the city. Firstly, in the case of El Carrilet greenway, Wikiloc registers show a total of 2102 routes for the whole city. Some 16% of the total sample —169 routes— are labelled "greenway Carrilet Olot". Considering only the paths in the city's peri-urban area —335 routes in total— this greenway appears on half of those registers. Secondly, in the case of the Alcoi greenway, 361 routes start in the urban area, representing 6.13% of a total of 5,891 registered routes; however, a total of 2,496 routes, representing 42.37%, have been inventoried in the peri-urban area. These figures show significant activity concentration differences with respect to El Carrilet. A possible reason may be the fact that Alcoi presents a larger concentration of uses and activities, as well as a better interconnection of nodes of structural urban facilities —Fig. 4—.

These results showcase the social interest shown in the greenways as cityscapes for wellbeing, leisure and outdoor sports and activities. Moreover, the diversity of land uses close to the greenways confirms the attractiveness of the area, not only for the citizens but also for visitors and tourists due to the existence of specific cultural and tourist usages along the trails. Landscape and environmental qualities, together with the services and facilities built in urban and peri-urban areas have contributed to the development of active tourism and sustainable tourism activity.

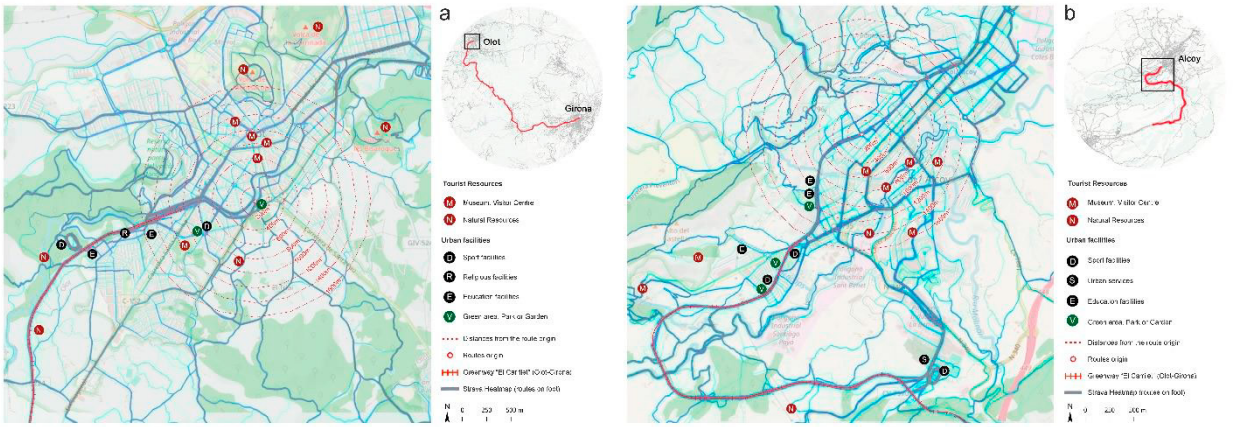

Fig. 4. Map representation of Strava intensity of use and Google Maps activities for (a) the El Carrilet Olot-Girona data analysis; and, (b), the Alcoi-Alicante data analysis [23].

4. Conclusions

LBSN user-generated information is a valuable source of data allowing to understand a number of social dynamics in urban and peri-urban contexts. As presented in this selection of case-studies, different LBSNs contribute to the understanding of general or specific —i.e., related to specific activities— social dynamics, depending on the nature of the area, the scale, and the purpose. The selection of the social network and the combination of meta-data from different LBSNs play a major role in the analysis of any topic and particularly for the reading of social dynamics.

Some years ago, questions were raised around the lack of representativeness of the whole population in the data. However, the growing amount of social network users together with an increasing number of studies have demonstrated that LBSNs are a valid data source presenting a vast amount of possible applications to city planning and city policy decision-making.

It has been shown that LBSN data improves our knowledge of current urban realities because it makes information on social dynamics available. The information used to develop the presented case-studies was easily accessible over the past years —through an API, third parties, or web-scrapping techniques— [19]. A major limitation, however, in the use of this type of information is the vulnerability of access to social media data because of the conditions and privacy policies of management companies. A few years ago, social media data access was mostly open and free, but management companies have recently been reducing the amount of data openly accessible in order to monetize the information. This restriction hinders the development of further research on applications of this type of data, even when such an implementation would be for the public good.

Despite the limitations, the analysis of geolocated social network data in urban studies offers interesting results regarding the interpretation of city social dynamics. Today, it is not only possible but also advisable to resort to LBSNs as a resource to obtain a comprehensive view of what is happening in a city's physical environment. The presented case-studies cover a multiscale approach, ranging from the neighborhood scale to the city and the peri-urban scope of action. Social activity is difficult to perceive and quantify, and the uniqueness of the data provided by each of the social networks makes it possible to adopt specific approaches that can complete the vision obtained from traditional sources and methods. In a nutshell, this new approach to urban research brings additional value to the study of complex issues, such as social dynamics, offering a better understanding of current urban realities.

Acknowledgements

The authors wish to thank Mappingame City Lab, at the University of Alicante, the research laboratory where the methodologies presented were developed and implemented.

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