Improving the planning of public facilities

Considering the spatio-temporal distribution of population

Sérgio FREIRE[1]; Christoph AUBRECHT[2]; António RODRIGUES[1]; Teresa SANTOS[1]; José António TENEDÓRIO[1]

[1]e-GEO, FCSH, Universidade Nova de Lisboa
Avenida de Berna 26-C, 1069-061 Lisbon, Portugal
sfreire@fcsh.unl.pt (correspondent author)
[2]AIT Austrian Institute of Technology GmbH
Donau-City-Str. 1, A-1220 Vienna, Austria
+43-50550-4522, christoph.aubrecht@ait.ac.at

Keywords: urban planning, public facilities, site suitability analysis, population distribution

Introduction

Updated and detailed mapping of population distribution is important for decision support in a variety of fields, such as emergency management, transportation planning, land planning, GeoMarketing, and environmental studies. Such data sets can be useful for virtually any application involving the spatial distribution of people if they are produced at appropriate, application-specific, spatial and temporal scales [1]. Having this information in a GIS-usable raster format significantly increases its value and facilitates integration with other spatial datasets for analysis or modeling. Although efforts to rasterize population distributions predate the development of most commercial GIS packages [2], increased availability of digital spatial data combined with the improved analysis capabilities in GIS have allowed for the development of several global population distribution databases. However, their spatial detail is still insufficient to adequately support analysis at the local level and to distinguish between daytime and nighttime population distributions.

Population distributions are not static in time, varying over daily, seasonal and long term time scales [1]. Due to a number of human activities, such as work and leisure, population counts and their distribution vary widely from nighttime to daytime, especially in metropolitan areas, and may be misrepresented by census data. Data mining combined with dasymetric mapping allows re-distributing population to specific areas where it is present in more detailed temporal periods, by using ancillary data and zonal interpolation.

In Portugal, existing population distribution maps and analyses of population covered by a given service are based on census data. Census figures register where people reside and usually sleep, but for certain activities, considering also where people work or study can improve decision-making. The planning of public facilities is one of those activities. *Public facilities* are infrastructures (public or private) that provide services of public interest which are essential for the quality of life of citizens [3]. The decision to build public facilities is a fundamental aspect of urban planning and land management, and is based on official criteria that guide their size

and location. Although these criteria vary with the specific type of facility being considered (e.g., high school, central hospital, urban park), they usually include a population threshold or interval and a service area, measured in minutes or kilometers. This should turn the decision-making into an inherent geographic problem, able to be objectively solved using spatial modeling and analysis. However, the base population used to assess thresholds is usually the residential population from the census, while most public facilities only operate during the daytime period, and hence also serve a daytime population present in their service area. This daytime population can be much higher than the nighttime and reach the necessary population thresholds to influence or justify the location of public facilities. Therefore, explicitly considering both the nighttime and daytime population distributions in the analysis would likely benefit the planning of public facilities, resulting in better service coverage and decision-making.

This study employs a dasymetric mapping approach for modeling and mapping of the spatio-temporal distribution of population at high resolution in the Lisbon Metropolitan Area, Portugal, and concerns its use for territorial planning. The objective is to introduce nighttime and daytime population densities and to demonstrate the usefulness and importance of considering the dynamics of population change in the daily cycle in the process of planning public facilities.

Study area and data

The study area for modeling and assessing population exposure encompasses the eighteen municipalities that compose the Lisbon Metropolitan Area (LMA), the main metropolitan area in Portugal (Figure 1).

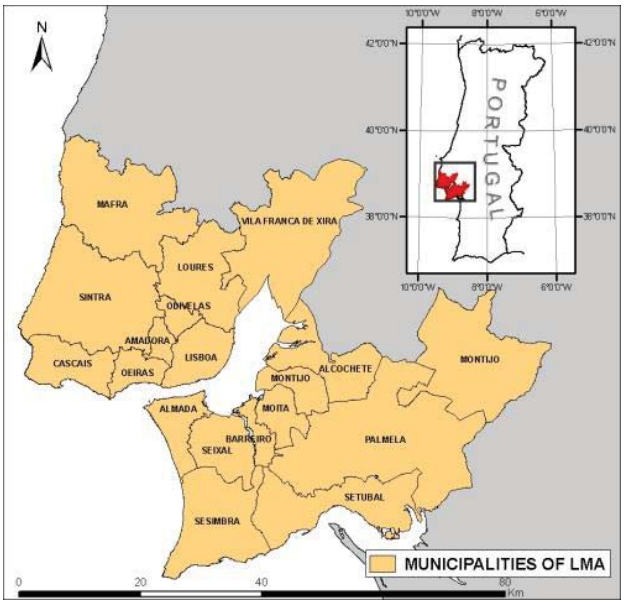

Figure 1. Study area – Lisbon Metropolitan Area (LMA)

The LMA occupies a total land area of 2,963 km^2 and is home to 2,661,850 residents, 26% of the country's total population [4]. The average population density is 898 inhabitants per square kilometer, but these densities vary widely in space and

time. Due to daily commuting for work and study, the daytime population of municipalities in the metro area of Lisbon can differ by more than 50% of the residential figures from the census [5]. Input variables used for modeling population distribution include both physiographic and statistical data. The first group comprises street centerlines and land use and land cover (LULC) maps, while the second includes census counts [4], data on workforce, and commuting statistics [5] for the study area.

Methods

The methodology includes development of spatio-temporal population surfaces, and their integration into spatial analysis for planning of public facilities in the LMA.
New high-resolution daytime and nighttime population distribution grids are developed using 'intelligent dasymetric mapping' [6] to combine best-available population statistics with physiographic data. Data mining is used to improve and further detail an existing land use and land cover by identifying new functional areas. The most recent census enumeration figures and mobility statistics (from 2001) are combined with improved land use data to allocate nighttime population to residential areas, and mobility statistics are considered for mapping daytime distribution. Empirical parameters used for interpolation are obtained from a previous modeling effort of part of the study area. Main results represent expected maximum daytime population and maximum nighttime residential population for each 50-meter grid cell in the study area.
Since the same spatial reference base is used to re-allocate population, day and night distributions are directly comparable, and can be temporally averaged to create a surface of 'ambient' population. These refined distributions are used to re-assess the varying population contained in the service areas and the location of existing public facilities such as sports and health centers.

Results and outlook

This research is an initial approach towards including the spatio-temporal population distribution in the planning of public facilities in metropolitan areas. Previously unavailable and detailed spatial resolution datasets of nighttime and daytime population were used to assess population thresholds and define service areas for some types of public facilities. Even the nighttime distribution from the model is more spatially refined than the census data, and can benefit analysis at the local level.
Results show that the spatio-temporal variation of population distribution in the LMA is very significant in the daily cycle. This variation, if considered, has an impact in the location and service area of public facilities, and therefore should be considered in urban planning and management.

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