



Energy and urban form. The growth of European cities on the basis of night-time brightness



Oriol Nel-lo, Joan López*, Jordi Martín, Joan Checa

Grup d'Estudis sobre Energia, Territori i Societat, Departament de Geografia, Universitat Autònoma de Barcelona, Spain

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ABSTRACT

The European urban system has experienced significant transformations over the last two decades, affecting both the system's articulation and hierarchy, and the morphology of urban areas. The sources of information on land use, although increasingly precise and exhaustive, present some limitations when it comes to identifying and quantifying this development, particularly due to their sporadic nature. In this context, the advances in the availability, precision, territorial coverage and recurrence of night-time satellite images offer new opportunities to assess the transformation of land uses. Under the assumption that there is a direct relationship between light emissions and the level of urbanisation, the present study identifies the development of the European urban system between 1992 and 2012. In this respect, the level of brightness suggests that the extension of urban land uses has been much greater than those calculated by using other sources, such as aerial photography or planning regulations. The contrast with these sources demonstrates that, even though night-time images are subject to significant limitations, their use can have advantages in the explanation of new patterns of land use. Thus, brightness could contribute to a more complex picture of the urbanization process, measuring not only the artificialisation of land but also the spread and intensity of urban uses of space.

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The relationship between urban form and energy consumption has been analysed from many angles over the course of the last few decades. A large variety of territorial and urban elements have clearly had a notable effect on energy consumption, and particular attention has been paid to the impact of the characteristics and placement of buildings on the type and amount of energy used to regulate heat. On the urban scale, other aspects have also been examined, such as the connections between the density of urban fabrics and their public lighting requirements, and between land use and the amount of fuel used by the population for their everyday journeys.

This article, however, seeks to follow a less well-trodden path. It does not analyse the relationship between urban form and energy consumption in terms of the former's effect on the latter but instead looks at them from the other way round. In other words, energy consumption serves as an instrument to evaluate the extension and intensity of an area's land uses: by assessing one of the most obvious external manifestations of energy consumption – the emission of artificial light – we can identify, quantify and compare the evolu-

tion of urban expansion in Western European cities in the last two decades.¹

This approach allows us to establish the relationship between brightness and urbanisation while also analysing the impact of urban morphology on the intensity with which a territory is used. Thus, the article has two objectives. First, to analyse the evolution of European cities from the comparison of nocturnal satellite images taken between 1992 and 2012. Second, to assess the validity of this source of information for the analysis of urban evolution. Two main conclusions emerge from the research. The night images of the Earth suggest that the extension of urban land use in Europe during the period studied might be much greater than those calculated by using other sources. Furthermore, from the methodological point of view, our analysis shows that satellite images of brightness, despite some major limitations, may constitute a very significant

¹ This study forms part of the research project *The light of the city. The delimitation and morphological evolution of the Spanish metropolitan areas from nocturnal images of the Earth (1992–2012)*, undertaken by the Grup d'Estudis sobre Energia, Territori i Societat, Departament de Geografia, Universitat Autònoma de Barcelona (Spain), headed by Dr. Oriol Nel-lo. The research has financial support from the Spanish government programme "Retos de la Sociedad", of the Ministerio de Economía and Competitividad (Ref. CSO2013- 47833-C4-2-R). The authors would like to thank the anonymous reviewers of this article for their insightful comments and suggestions.

* Corresponding author.

E-mail address: juan.lopez@uab.cat (J. López).

tool for ascertaining the development of the urbanisation process at a European and global scale.

The argument is presented in four sections: the first describes, in broad terms, the main characteristics of the morphological evolution of contemporary European cities, with special attention to the last fifty years, when the spreading pattern of urban growth became a common trend in many areas; this is followed by an analysis of the advantages and disadvantages of the use of night-time satellite images to monitor the urbanisation process; thirdly, the evolution of European cities between 1992 and 2012 is analysed according to their brightness, and, finally, the results are compared with those derived from other sources. A few brief conclusions then bring our contribution to a close.

1. The morphology of European cities

By the mid-19th century many European cities had disencumbered themselves from their perimeter walls, or were on the verge of doing so. These walls had not only provided security to the population living inside them but had also come to define a city as something that was urban, known and recognizable in the midst of an immense vastness of countryside and woodland.² It is well known, however, that once their main function – defence – was rendered obsolete by the destructive power of the latest advances in military technology, city walls became a hindrance to social and financial development. The impossibility of enlarging the urban fabric to satisfy the demands of a growing population and attend to functional needs distinct from those of previous centuries led to high densities of population, deplorable sanitary conditions and a host of economic drawbacks. In these circumstances, the need to overcome the physical barrier traditionally imposed by city walls began to hold sway (despite widespread resistance), thereby triggering an unprecedented revolution in urban development.³

Even so, in the decades immediately following the demolition of their walls cities tended to remain compact to a large extent because their high density of population was mostly alleviated by the development of adjacent areas. Thus, in most cases new developments occurred near – or even alongside – existing hubs, as it was vital to keep the populace close to urban activities due to the limited availability of transport.⁴

By the late 19th century, however, the implantation of public railway systems – from the first horse-drawn trams to trains, electric trams and the underground – enabled cities to grow substantially. London was one of the first cities to introduce the new systems of transport and as a result its urbanised perimeter expanded very rapidly. Other European cities were quick to emulate it, giving rise to forms of suburbanisation and to cities' extension beyond their traditional limits, often devoid of any continuity with pre-existing fabrics.

The advantages offered by these new possibilities (as regards space, public health and land prices) were quickly seized on by

both the general public and property developers. Patterns of development were often the result of the apparently infinite territory opened up by the new means of transport, and so cities' high density, overcrowding and congestion were partially relieved by their suburbs. In many cases these were exclusively devoted to residential use, occupying large areas to house a relatively small number of people. In the early twentieth century this trend found its most graphic and proselytising projection in the so-called "garden city", even though in most cases the results were far removed from Ebenezer Howard's model and were more like a "garden suburb" (i.e., sparsely populated suburban spaces with an exclusively residential use). Railway lines (and, later on, roads) frequently determined the tentacular form of these new urban fabrics.

The problems arising from both the concentrated development of urbanisation and its disorderly extension made apparent the need for guidelines designed to control a city's growth. The development of contemporary urbanisation was therefore accompanied by the first planning proposals to opt for alternative models of urban development, taking into account cities' compactness and their relatively high density. These models were intended not only to put a stop to uncontrolled land occupation but also to ensure the efficient functioning of cities that were growing increasingly larger. The new proposals ranged from the development of neighbourhoods close to a pre-existing city to the creation of "new cities" set apart from an urban area in need of decongestion, and they were widely applied throughout Europe, thereby planting the seed for urban planning on a regional scale that extends far beyond the boundaries of a traditional city.⁵

However, the frequent attempts to rein in urban dispersion in the mid-20th century were clearly thwarted. The main reason for this relative failure was the emergence and subsequent ubiquity of the motor car, along with the roads required to ensure its efficient circulation (motorways). The suburbanisation of the great cities, sparked by the railway in the late 19th century, spread further and faster thanks to the car. Use of the car became generalised in European countries after World War Two but the infrastructures it required were not adapted to the pre-existing city; instead, the city – in both its pre-existing areas and its new construction – had to assume the form best suited to this predominant means of transport. Generally speaking, it was not until many years later that the problems of congestion induced by the proliferation of cars forced most European cities to adopt measures encouraging the use of public transport, but by the time these policies were implemented dispersion and low urban density were already a widespread and irreversible reality.

Thus, from the 1960s onwards, in most of the countries of Western Europe the spread of urbanization over the territory became one of the most important characteristics of changes in land use.⁶ The

² For the relationship between the city and its walls, it is inevitable to refer to the classic work Cesare de SETA & Jacques LE GOFF, *La città e le mura*, Rome, Laterza, 1989.

³ It is impossible to mention all the many works that describe the evolution of the development patterns in European cities. Some essential references are Paul BAIROCH, Jean BATOU & Pierre CHÈVRE: *La population des villes Européennes, 800–1850*. Geneva. Librairie Droz, 1988; Leonardo BENEVOLO: *La città nella storia d'Europa*. Bari. Laterza, 1993; Jan DE VRIES: *European urbanisation. 1500–1800*. London, Methuen, 1984; Paul M. HOHENBERG: *The Making of urban Europe, 1000–1994*, Cambridge, Mass, Harvard University Press, 1995. For aspects related to planning, one obligatory reference is Peter HALL: *Cities of Tomorrow: An Intellectual History of Urban Planning and Design in the Twentieth Century*. Oxford and New York. Basil Blackwell, 1988.

⁴ GAMBÌ, Lucio: "Ragionando di confine della città", in PABA, Giancarlo (ed.): *La città e il limite*, Firenze, La Casa Usher, 1990.

⁵ As is well known, examples of these new proposals range from Arturo Soria's "Ciudad Lineal" in Madrid (1894) to the British New Towns from 1946 and the Swedish from 1952, or the "Finger Plan" in Copenhagen from 1948. For an overview see HALL (1988). For the evolution of these proposals in the last decades of the 20th century see Peter NEWMAN and Andy THORNLEY, *Urban Planning in Europe, International Competition, National Systems and Planning Projects*, 1996.

⁶ The phenomenon has been studied from a cross-country perspective by A.G. CHAMPION, *Counterurbanization: the changing pace and nature of population deconcentration*, 1989, and more recently by Antonio FONT, Francesco INDOVINA & Nuno PORTAS, *La explosión de la Ciudad. Transformaciones territoriales en las regiones urbanas de la Europa Meridional*, 2011. The first refers mostly to Northern European countries as compared with other realities such as the USA and Japan. The second focusses on Southern European urban areas. These studies allow us to observe the growing differentiation of the urban tissues between the traditional compact city (dense, complex and without interruption), the tentacular growth (placed along the roads), urban sprawl (low densities in monofunctional specialized areas) and other morphologies. For an overview at the European level see the recent report of the EUROPEAN ENVIRONMENT AGENCY, *Urban Sprawl in Europa* (June 2016).

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