# The urban form of Portuguese cities

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**Abstract.** *This paper addresses two main challenges: how to offer an overview on the urban form of Portuguese cities, and how to analyse the fundamental aspects of the evolution of this physical form over time. The* Morpho *methodology is applied to address these challenges. This methodology focuses on a reduced number of urban form elements and characteristics, all related to the town plan: the spatial accessibility of the street system, the dimension of street blocks, the density of plots, and the coincidence between building and plot frontages.* Morpho *is applied to Portugal's 20 most important cities. In addition to producing specific new knowledge on this sample of Portuguese cities, the paper presents results that are relevant for a wider geographical context, and demonstrates the potential of the methodology in comparing a large set of cities.*

*Keywords: urban form, evolution, Portuguese cities, town plan,* Morpho

National reviews on 'the study of urban form', focused on the discipline (Charalambous *et al*., 2019; Oliveira, 2013a; Oliveira *et al*., 2015), are common in this journal, but national reviews that are centred on 'urban form' as an object of study (Medeiros, 2013) are rare. In the Portuguese case, there have been some attempts to offer a national portrait of the physical form of cities. At a macro-scale level of analysis, Portas *et al*. (2004, 2011) offer a reading of the national territory, including some urban form descriptions, and Domingues (2006) addresses the evolution of 24 medium-sized cities over three decades.

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At meso- and micro-scales of analysis, with an historical perspective and a more selective focus, Teixeira (2008), Teixeira and Valla (1999) and Trindade (2013) debate the main characteristics of the 'Portuguese city', while Fernandes (2005) focuses on six cities in the north of the country from the mid-nineteenth century to the 1920s. 'The morphological atlas of the Portuguese city' is a long-term project, divided into four main parts – streets, squares, street-blocks and buildings – that offers detailed analysis on the main elements of urban form in selected parts of Portuguese cities (see Coelho and Lamas, 2005, 2007 for the two atlases of squares in Azores and the mainland, respectively). Finally, Ferreira (1995) focuses on ten main cities, analysing the evolution of their urban form during the twentieth century and demonstrating a progressive loss of quality in the process of city building. Despite the fundamental importance of these studies, none of these fulfils, cumulatively, three major conditions: i) a balanced geographical distribution over the national territory, including the major cities of Lisbon and Porto; ii) the consideration of different scales of analysis, from the whole city to the plot; and iii) the consideration of 'time'.

The paper addresses all three omissions. It identifies the most permanent and structural aspects of the physical form of a significant number of Portuguese cities by using a reduced set of urban form characteristics. The first part of the paper presents the *Morpho* methodology and the sample of cities. It then offers a description of the urban form of the 20 selected cities. The description is in two parts: in the first, the focus is on each city as whole; in the second, the focus is in four different parts of each city based on the time period of its formation, offering a combined analysis of the 20 samples of each specific time period. The paper's contribution is threefold: i) producing morphological knowledge on the sample of cities; ii) offering potentially generalizable knowledge on cities in Portugal and elsewhere; and iii) demonstrating the potential of the methodology in comparing a large set of cities (as this is its first utilization for that purpose).

## The *Morpho* methodology and the sample of cities

Oliveira (2013b) proposed the *Morpho* methodology for assessing the physical form of cities. That paper argued that higher accessibility of streets, higher density of street blocks and plots and higher continuity of building frontages would contribute to higher social and economic diversity and higher environmental sustainability. While that paper presented the ability of the methodology for morphological description at the street scale, a second paper reported a first application at the city scale, including analysis of extant form and evaluation of planning proposals (Oliveira and Silva, 2013). Later studies, developed by other authors, expanded both the geographical context and the scope of research (Kotov and Goncharov, 2017; Pinho, 2019). Against this background and considering applications of the methodology to Lisbon and Porto (Kropf, 2017; Oliveira and Medeiros, 2016; Oliveira and Silva, 2013), this paper proposes a new application of *Morpho*, highlighting how its focus on the most permanent and structural (but, eventually, less visible) aspects of urban form enables comparison of a large number of Portuguese cities.

In describing something so complex as the physical form of a city, *Morpho* addresses the physical characteristics of the urban landscape that are more permanent in time and that can offer the most relevant information on the city's form (see Oliveira, 2013b, for the selection of these characteristics). *Morpho* emphasises four characteristics, or criteria, that are related to the town plan. While the focus on the town plan as the key element for the description of the urban landscape is shared by some of the main morphological approaches (Conzen, 2018; Hillier, 2016; Whitehand *et al*., 2016), what is specific to *Morpho* is the selection and measurement of this particular set of characteristics, and the innovative nature of the fourth characteristic – the coincidence between building and plot frontages. Being selective and offering a structural reading of urban form, *Morpho* does not aim to deal with all the relevant aspects of that physical form. This first analysis (or the first layer of a morphological reading) can then be complemented by other three-dimensional elements of the building fabric, particularly in areas containing significant heritage structures.

The application of *Morpho* in the analysis of the sample of Portuguese cities is in two stages. In the first it offers a description of extant urban form: in each of the cases it focuses on the city as a whole. In the second stage it offers a description of the evolution of urban form: in each of the cases four different parts of the city, based on the period of formation, are selected; *Morpho* analysis then focuses on the samples of each specific period together, proposing this as a way of analysing the evolution of urban form.

Two aspects deserve attention. The first is the delimitation of each period. The urban history of a city comprises different morphological periods (Conzen, 1988). Each period has its own urban forms, shaped by a particular cultural framework and specific socio-economic needs. While acknowledging the differences between morphological periods, this paper focuses on the most expressive ruptures (Dibble *et al*., 2017) in the process of city building that are still present in the urban form of Portuguese cities. These have been shaped, first, by the industrial revolution and subsequently by the substantial increase of population, the emergence of real estate as a main agent of change, the increasing use of the private car, and the emergence of the theories of the garden city and the modernist city. Against this background, four periods are proposed: pre-1800; 1801–1900; 1901–1950; and after 1950. The second aspect is the delimitation of each sample. For the purpose of comparison between different parts of each city and between different cities, uniformity in the size of the sample was a requirement. The reflection on the limits of the sample draws on the available historical cartography for each of these cities. Particularly in the first and second periods, the size of each sample had to be relatively low, because of the limited size of the smaller cities. A number of street blocks, instead of a metric limit, was favoured as it is a more flexible measure, while still ensuring comparability. Against this background, it was found that a set of 20 street blocks per sample would work for the purposes of comparison. This limit was tested in a pilot study in Porto and subsequently adopted for the other cities studied here. As mentioned, the two readings offered by *Morpho* are based on four criteria (except for the fourth criterion which will only support the reading of the evolution of urban form), as follows. The measurement of the four criteria uses Geographic Information Systems (GIS).

*Morpho* first analyses the spatial accessibility of the street system (including not only streets, but also squares and gardens) (Figure 1). In particular, it uses angular segment analysis (Turner, 2007), focusing on the segment as the basic element between two intersections, and the measures of Normalized Angular Integration / NAIN and Normalized Angular Choice / NACH. NAIN, when analysed at global level (the complete object being studied), measures the distance from each segment of origin to all others in the system, highlighting the most important centralities. NACH, also known as 'betweenness', measures the probability of a segment to be used as the shortest path linking any pair of segments, revealing the hierarchy of the street system. The analysis of NAIN and NACH, particularly of their mean and maximum values, is framed by the concepts of 'foreground' and 'background' networks (Hillier *et al*., 2012). The foreground network represents the main structure of a city in terms of potential centrality or hierarchy and it is expressed by the maximum values of NAIN and NACH respectively. While the foreground network can be related to global scale and micro-economics, the background network can be related to local scale and socio-cultural factors and residence; it is expressed by the mean values of NAIN and NACH. The analysis of each city is framed by morphological continuity and not by administrative boundaries.

*Morpho* then moves to the dimension of street-blocks, as a measure of density of this element of urban form. It considers six classes (based on studies of Lisbon

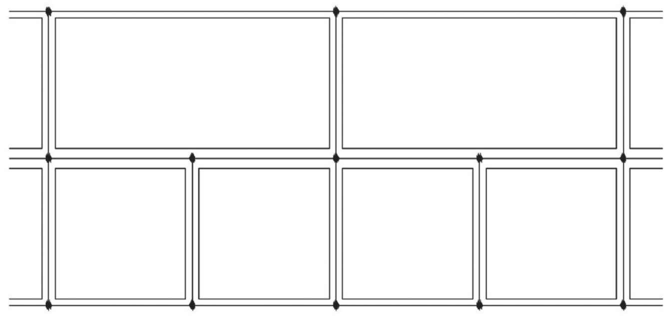
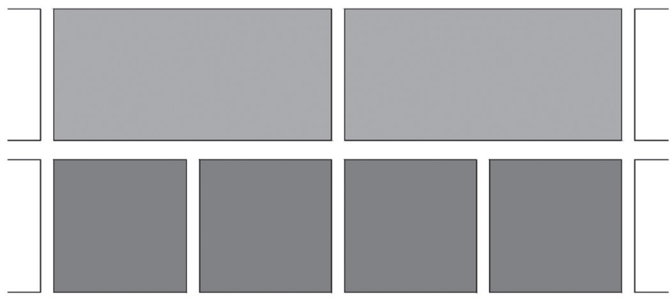
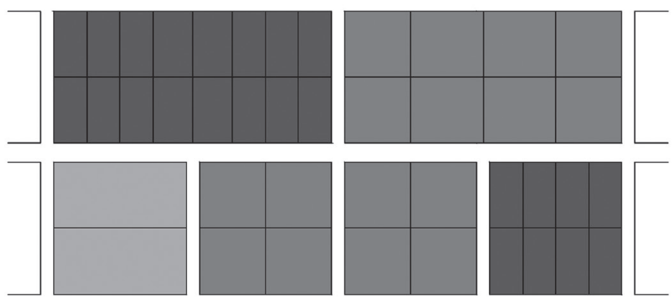
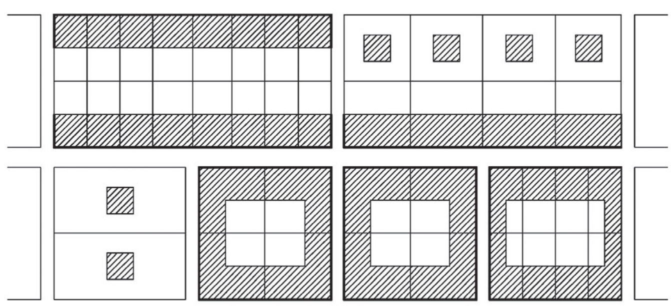
| Criteria | Measurement | Illustration |
|---|---|---|
| 1. Spatial accessibility of streets | It measures the integration and choice potential of each segment of street |  |
| 2. Dimension of street blocks | It measures the area of each street block |  A higher density of blocks (smaller area) is represented by a darker colour. |
| 3. Density of plots | It measures the number of plots and divides it by the area of the respective street block |  A higher density of plots is represented by a darker colour. |
| 4. Coincidence between building and plot frontages | It measures the number of plots where building and plot frontage is coincident |  Coincidence between building and plot frontage is represented by a thicker line. |

**Figure 1. *Morpho*: criteria, measurement and illustration.**

and Porto – Oliveira, 2013b, 2016): under 5000 m², 5000–10,000 m² (these two fall under Siksna's (1997) classification of 'small'), 10,000–20,000 m² ('medium'), 20,000–50,000 m², 50,000–100,000 m², and over 100,000 m² ('large'). It is essential to consider two points. First, in contrast to the measurement of the first criterion, the second and third criteria address not only urban but also non-urban areas, which increases the dimension of street blocks and decreases the density of plots. Secondly, due to the availability of data for the wide territory under analysis, *Morpho* uses not the actual street blocks but the so-called *subsecções estatísticas* defined by Statistics Portugal (Instituto Nacional de Estatística / INE). This involves some simplification in non-urban areas (a comparison, as part of this research, between the real street-blocks and the *subsecções estatísticas* in two different cities, Lisbon and Porto, revealed an error of about 5%).

Then, *Morpho* analyses the density of plots, considering the number of plots per street block and dividing it by the area of the street block (measured in hectares). As in the former criterion, six classes are defined (again based on studies of Lisbon and Porto – Oliveira, 2013b, 2016): fewer than 1, 1–5, 5–10 (low density), 10–20 (medium density), 20–50, and more than 50 (high density) plots per hectare in each street block. Due to the absence of accurate data on plots in Portugal, this criterion considers a proxy, the INE information on the number of buildings per street-block (a comparison, as part of this research, between the number of plots and the number of buildings for a sample of 20 street-blocks in one city, Porto, revealed an error of less than 5%).

Finally, *Morpho* analyses the coincidence between building and plot frontages (front wall of building on front of plot) in each street block. More particularly, in each street block, it measures the number of plots where building and plot frontage is coincident and expresses it as a percentage. Four classes are considered: Coincident / C, Mostly Coincident / MC (coincidence in more than 50% of plots in a street block), mostly non-coincident / MNC (less than 50%) and Non-Coincident / NC. In terms of measurement procedure, one building within one plot is considered aligned if more than 50% of the building frontage coincides with the plot frontage.

This research seeks a sample of Portuguese cities that comprises a balanced geographical distribution over the national territory, a set of cities with a certain complexity of urban form and a comparable administrative status. Due to the differences between the Portuguese *distritos* (sub-regions), the sample also presents a great variety in terms of urban form. The sample includes the 20 main cities of Portugal in administrative terms, comprising the capital cities of all of the 18 *distritos* of the mainland, the capital of the Madeira archipelago and the highest-populated city of the three capitals of the Azores archipelago. Figure 2 presents the location of these 20 cities, and Figure 3 depicts the street system of each city. The diversity of this sample can be demonstrated by some data on their physical, social and economic dimensions: i) the resident population of Lisbon is 22 times higher than that of Portalegre; only one of these 20 municipalities, the Portuguese capital city, has a resident population higher than 500,000, and in more than half this number is lower than 100,000; ii) in half of these municipalities, the ratio between dwellings and buildings is 1:5 or lower; only in Porto and Lisbon is this ratio higher than 3:0; and iii) per capita purchasing power is two times higher in Lisbon than in thirteen of these municipalities; in four of these thirteen municipalities per capita purchasing power is below the national average.

## Application of the methodology to the 20 cities: a description of extant urban form

### *The spatial accessibility of the street system*

The spatial accessibility of the street system of the 20 cities is analysed according to normalised angular integration and choice. The former, NAIN, reveals a wider range of differences than the latter, NACH. Two groups can be distinguished by normalized angular


**Figure 2. A sample of 20 Portuguese cities.**

integration. The highest values of mean NAIN tend to correspond to cities where the different parts are better articulated, balancing irregular with regularly laid-out areas with streets that tend to expand far beyond the integration core; the latter being somehow facilitated by topography or determined by the higher relevance of the city in political, administrative and economic terms. That is the case for Faro, Porto, Lisbon, Setúbal and Beja (Table 1). The lowest performances of NAIN mean values correspond to cities with a predominantly irregular street system, determined by the natural context, where the integration core does not have a balanced distribution within the system, tending to be very focused on one centre or on one line, or a reduced set of lines. That is the case for Vila Real, Santarém, Braga, Coimbra or Funchal.

Figure 4 offers a more detailed view of this description of the accessibility of the street system, by focusing on three cities: Faro and Lisbon, with the highest NAIN values, and Vila Real, with the lowest. The distribution of segments, and particularly the definition of the most integrated segments (in red and orange), in the three maps vary considerably. In Faro, a number of red and orange lines are distributed from the centre to the periphery, assuring a balanced structure of the territory. In Lisbon, the most integrated segments are concentrated at the centre of the urban system (comprising mainly the *Avenidas* and *Alvalade* areas) and do not extend to the periphery. In Vila Real, the red and orange lines are excessively spread in the periphery, creating an external ring of integration.

An analysis of the whole set reveals a uniformity of mean and maximum NACH and a more homogeneous sample (contrary to the NAIN analysis). The gap between the values of mean NACH of different cities is 0.091,

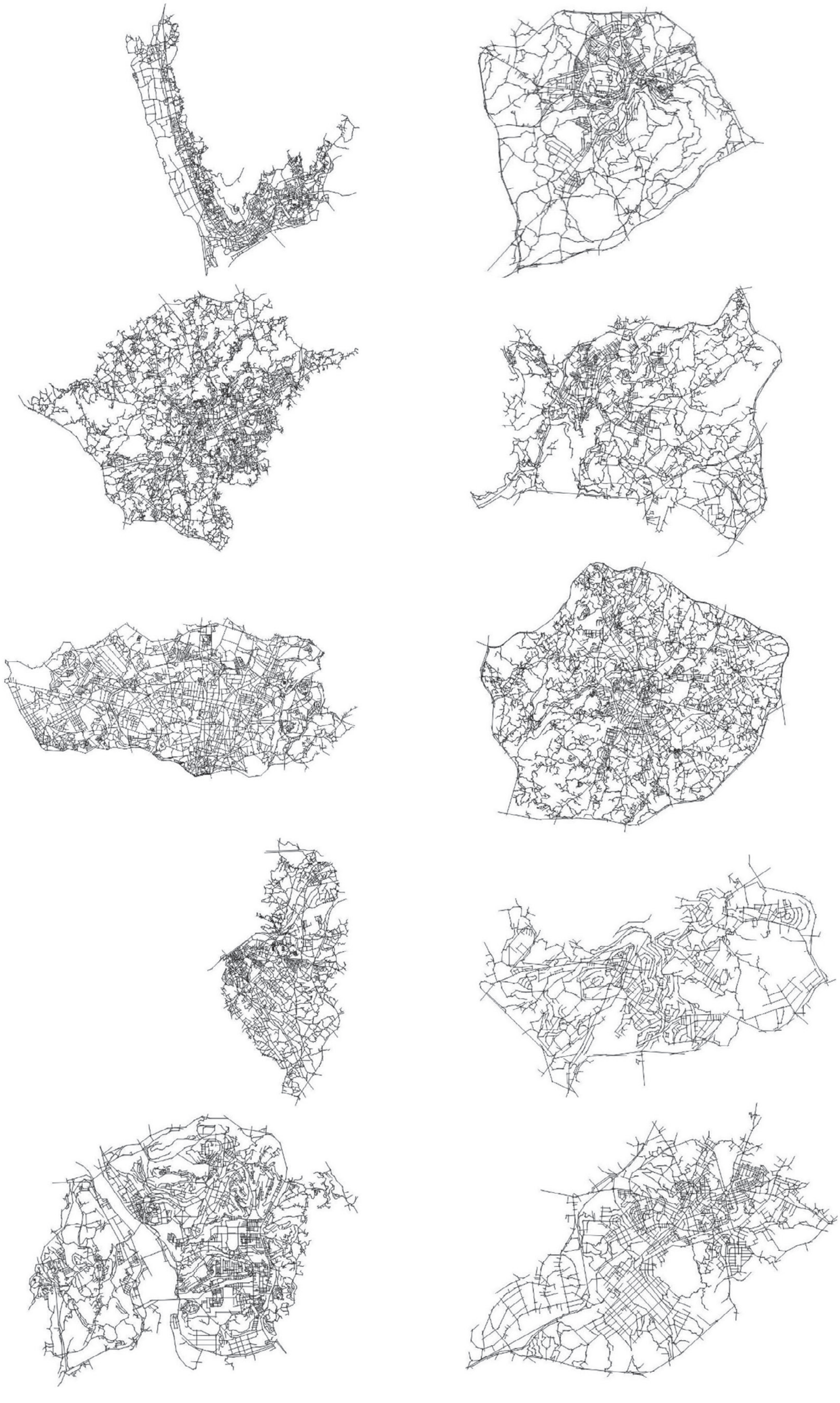


**Figure 3A. The sample of cities (at different scales, following a top/bottom and left/right sequence): Viana do Castelo, Bragança, Braga, Vila Real, Porto, Viseu, Aveiro, Guarda, Coimbra and Castelo Branco.**

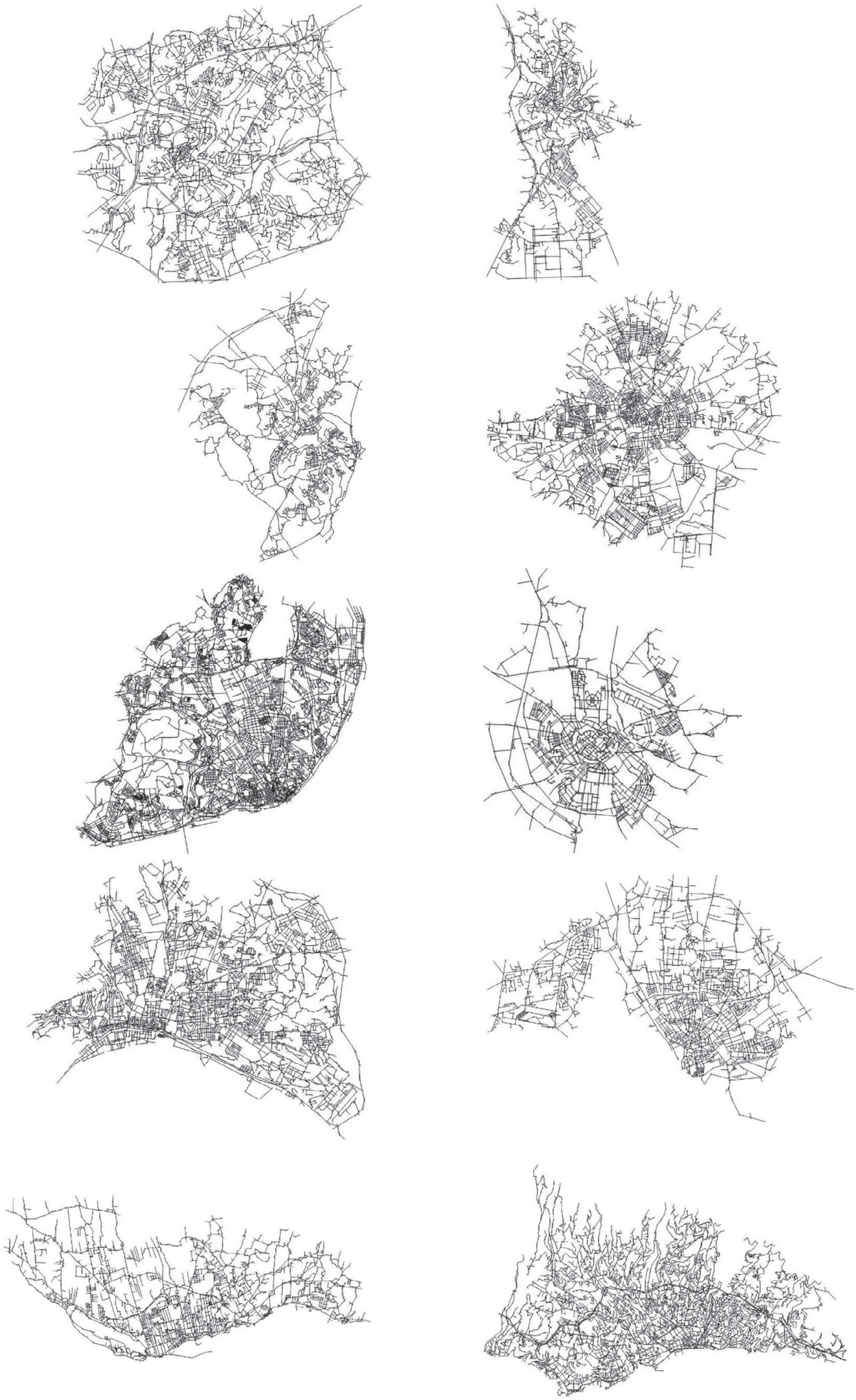


**Figure 3B. The sample of cities (at different scales, following a top/bottom and left/ right sequence): Leiria, Portalegre, Santarém, Évora, Lisbon, Beja, Setúbal, Faro, Ponta Delgada and Funchal.**

**Table 1. NAIN and NACH in the 20 cities**

| City | NACH mean (background) | NACH max (foreground) | NAIN mean (background) | NAIN max (foreground) |
|---|---|---|---|---|
| Aveiro | 0.845 | 1.547 | 0.685 | 1.121 |
| Beja | 0.904 | 1.514 | 0.881 | 1.345 |
| Braga | 0.818 | 1.506 | 0.549 | 0.872 |
| Bragança | 0.874 | 1.467 | 0.701 | 1.065 |
| Castelo Branco | 0.877 | 1.497 | 0.836 | 1.261 |
| Coimbra | 0.813 | 1.482 | 0.592 | 0.916 |
| Évora | 0.843 | 1.513 | 0.772 | 1.207 |
| Faro | 0.845 | 1.547 | 0.981 | 1.478 |
| Funchal | 0.819 | 1.543 | 0.639 | 1.023 |
| Guarda | 0.853 | 1.468 | 0.635 | 0.928 |
| Leiria | 0.830 | 1.538 | 0.789 | 1.242 |
| Lisboa | 0.867 | 1.577 | 0.938 | 1.511 |
| Ponta Delgada | 0.849 | 1.535 | 0.789 | 1.235 |
| Portalegre | 0.844 | 1.451 | 0.644 | 0.908 |
| Porto | 0.889 | 1.551 | 0.974 | 1.503 |
| Santarém | 0.826 | 1.503 | 0.542 | 0.873 |
| Setúbal | 0.852 | 1.573 | 0.926 | 1.511 |
| Viana do Castelo | 0.845 | 1.569 | 0.652 | 1.068 |
| Vila Real | 0.836 | 1.448 | 0.534 | 0.759 |
| Viseu | 0.833 | 1.472 | 0.646 | 1.016 |
| Total | 0.851 | 1.516 | 0.760 | 1.174 |

and between the values of maximum NACH is 0.129.

Considering the relationships between NACH and NAIN (mean and maximum), the highest values of maximum NACH and NAIN can be found in the cities of Lisbon, Setúbal, Porto, Faro and Beja. The cities of Vila Real, Braga, Santarém, Portalegre, Coimbra and Guarda offer the opposite picture – despite the high values of NACH, they exhibit relatively low values of NAIN.

Finally, overall, although there is not a significant trend, coastal and southern cities seem to have a higher accessibility of the street system than those of the interior and north.

*The dimension of street blocks*

Analysis of the 20 cities according to the dimension of street blocks identifies two different groups, having approximately the same number of cities. The first group is made of nine cities, where the presence of small (classes 1 and 2) and medium (3) street blocks is higher than that of large blocks (4 to 6) (Table 2). The second group, slightly larger, includes eleven cities where the presence of large street blocks is higher than that of small and medium blocks. Beja and Lisbon stand out in the first group. In Beja, almost three-quarters of the street blocks are ‘small’, while only one-fifth are ‘large’. In Lisbon, more than half of the street blocks are small, while one-quarter are large. In the second group, where large street blocks are dominant, Viseu and Leiria present the highest values for large blocks (around three-quarters) and the lowest values for small blocks (less than one-fifth).

Figure 5 gathers four maps at the same scale, offering a closer focus on these four cities: the formerly walled area of Beja and the downtown of Lisbon, where small and medium size blocks are dominant; the areas around the polytechnic of Viseu and the *Santo André* hospital in Leiria, where large size blocks are dominant. It is important to highlight that these are illustrations of the research findings

**Figure 4. NAIN: the highest values for the background and foreground networks – Faro (top) and Lisbon (middle), and the lowest values for both networks – Vila Real (bottom). In each map, the colour range is from red (highest values) to orange, yellow, green, blue and dark blue (lowest values).**

**Table 2. The dimension of street blocks in the 20 cities**

| | | Small | | Medium | | Large | |
|---|---|---|---|---|---|---|---|
| City | Number of street blocks | 0–5 000m² (%) | 5 000–10,000m² (%) | 10,000–20,000m² (%) | 20,000–50,000m² (%) | 50,000–100,000m² (%) | > 100,000m² (%) |
| Aveiro | 1 256 | 11.9 | 12.5 | 13.9 | 20.5 | 16.5 | 24.6 |
| Beja | 1 001 | 43.5 | 24.4 | 11.9 | 6.3 | 2.2 | 11.8 |
| Braga | 2 761 | 7.7 | 13.0 | 20.2 | 25.4 | 17.7 | 15.9 |
| Bragança | 1 399 | 12.2 | 15.9 | 18.1 | 27.2 | 11.4 | 15.4 |
| Castelo Branco | 1 596 | 18.5 | 19.6 | 22.1 | 21.8 | 5.4 | 12.6 |
| Coimbra | 2 514 | 12.0 | 11.6 | 15.8 | 24.5 | 15.9 | 20.2 |
| Évora | 1 791 | 32.6 | 21.3 | 13.1 | 11.1 | 4.1 | 17.8 |
| Faro | 1 211 | 20.1 | 15.4 | 12.3 | 11.2 | 10.0 | 30.9 |
| Funchal | 1 340 | 11.9 | 18.4 | 27.8 | 30.0 | 8.5 | 3.4 |
| Guarda | 1 968 | 22.4 | 14.0 | 15.3 | 22.3 | 9.2 | 16.7 |
| Leiria | 3 483 | 7.2 | 8.6 | 11.9 | 21.4 | 18.9 | 32.0 |
| Lisboa | 3 623 | 28.8 | 23.7 | 23.5 | 15.8 | 4.8 | 3.5 |
| Ponta Delgada | 832 | 8.5 | 12.6 | 13.5 | 18.6 | 11.3 | 35.5 |
| Portalegre | 581 | 29.1 | 11.5 | 12.0 | 16.2 | 10.0 | 21.2 |
| Porto | 1 946 | 25.4 | 22.4 | 23.5 | 20.6 | 4.7 | 3.4 |
| Santarém | 1 743 | 14.9 | 9.6 | 9.9 | 11.8 | 12.0 | 41.8 |
| Setúbal | 1 683 | 30.2 | 21.4 | 19.3 | 14.9 | 7.7 | 6.6 |
| Viana do Castelo | 2 917 | 6.8 | 12.2 | 19.0 | 28.7 | 18.5 | 14.8 |
| Vila Real | 1 537 | 10.7 | 11.3 | 11.7 | 19.5 | 16.3 | 30.4 |
| Viseu | 2 276 | 7.3 | 7.1 | 12.7 | 21.6 | 20.1 | 31.3 |
| Total | 37.458 | 18.1 | 15.3 | 16.4 | 19.5 | 11.2 | 19.5 |

expressing the dominant patterns – this means that large blocks can also be found in Beja and Lisbon and small and medium blocks can also be found in Viseu and Leiria.

While the dichotomy between coast and interior cities does not have an influence on these results, cities in the south and larger cities seem to concentrate a higher percentage of small and medium blocks than, respectively, cities in the north and smaller cities.

### *The density of plots*

Analysis of the 20 cities according to the density of plots (measuring the number of plots and dividing it by the area of the respective street block, in hectares) reveals the existence of two groups (Table 3). The first comprises six cities in which a high (classes 1 and 2) and medium (3) density of plots is dominant. The second group includes 14 cities where a low density of plots (4 to 6) is dominant. As in the case of the dimension of street blocks, Beja stands out in the first group: half of its blocks have a high density of plots, and one-fifth have medium density. More than one-third of Porto blocks have a high density of plots, and one-quarter have medium density. Funchal holds the highest level of medium density of plots. Leiria, Viana do Castelo and Viseu (the first and the third are also structured by large blocks, as revealed by the analysis of the last criterion) stand out in the second group: more than four-fifths of their blocks have a low density of plots. In the case of Leiria, only 3.5% of the blocks have a high density of plots (14 times less than Beja).

Figure 6 focuses on very small parts of three of these cities, Beja, Funchal and Leiria – the three maps are at the same scale (due to the uncertainty of the precise plot


**Figure 5. The dominance of 'small' (Beja and Lisbon, top left and right) and of 'large' street blocks (Viseu and Leiria, bottom left and right); at the same scale.**

boundaries in the medieval area of Beja, only the front boundaries are represented). A closer look at the five street blocks in the centre of Beja organized around *Rua da Muralha* and *Rua da Condessa*, reveals a plot density of between 93 and 142 per hectare. The width of these plots is often below 5 m. Figure 6 (bottom left) focuses on part of a street block in Funchal (delimited by *Rua Santa Isabel* and *Rua das Morteiras*) with a plot density of 14, which is 8 times less than the average of the five street blocks in Beja. The average width of the 28 private plots comprising this street block in Funchal is 20 m. Finally, Figure 6 (bottom right) focuses on a street block west of *Santo André* hospital consisting of just one plot.

As in the second criterion, southern and larger cities have a higher density of plots per street block (considering its area) than, respectively, northern and smaller cities. In addition, coastal cities have higher density of plots per street block than interior cities.

*Synthesis: a comparative description of extant urban form*

This synthesis includes reflection on the whole set of cities, on each of these taken individually and on the criteria. Considering the whole set, in the case of the spatial accessibility of streets, it is the normalized angular integration, both maximum and mean, that offers the highest range of variation between cities. Therefore, and bearing in mind the purpose of comparison, the use of NAIN seems to be more useful. In the street-block dimensions, the percentage of 'small' and 'medium' street-blocks has a variation between cities of 52%. Finally, in the density of plots, the percentage of 'high' and 'medium' number of plots per hectare has a variation between cities of 57%. Although there is not a significant trend, southern cities seem to have higher values than northern cities.

Analysing the 20 cases individually, three groups have been identified (Table 4). First,

**Table 3. The density of plots per hectare in the street blocks of the 20 cities**

| City | Number of street blocks | High > 51 Plots/ha (%) | High 21–50 plots/ha (%) | Medium 11–20 plots/ha (%) | Medium 6–10 plots/ha (%) | Low 2–5 plots/ha (%) | Low 1 plot/ha (%) |
|---|---|---|---|---|---|---|---|
| Aveiro | 1 256 | 1.8 | 8.4 | 15.3 | 19.7 | 32.8 | 22.0 |
| Beja | 1 001 | 10.2 | 39.0 | 18.4 | 5.8 | 6.7 | 20.0 |
| Braga | 2 761 | 0.5 | 7.2 | 17.2 | 18.1 | 30.6 | 26.4 |
| Bragança | 1 399 | 1.0 | 9.6 | 13.7 | 18.2 | 34.0 | 23.4 |
| Castelo Branco | 1 596 | 6.4 | 13.5 | 21.1 | 21.7 | 18.5 | 18.7 |
| Coimbra | 2 514 | 2.9 | 9.9 | 14.1 | 16.2 | 31.8 | 25.1 |
| Évora | 1 791 | 11.6 | 23.2 | 17.0 | 7.5 | 8.4 | 32.2 |
| Faro | 1 211 | 4.5 | 16.0 | 13.5 | 10.8 | 14.0 | 41.1 |
| Funchal | 1 340 | 2.2 | 17.4 | 32.2 | 25.2 | 15.2 | 7.7 |
| Guarda | 1 968 | 4.0 | 13.7 | 16.0 | 13.1 | 27.7 | 25.4 |
| Leiria | 3 483 | 0.6 | 2.9 | 7.0 | 15.1 | 35.8 | 38.6 |
| Lisboa | 3 623 | 9.2 | 25.7 | 18.7 | 17.4 | 15.2 | 13.9 |
| Ponta Delgada | 832 | 2.5 | 17.5 | 12.6 | 10.6 | 26.6 | 30.2 |
| Portalegre | 581 | 8.8 | 13.6 | 15.3 | 12.2 | 18.9 | 31.2 |
| Porto | 1 946 | 9.4 | 27.7 | 24.2 | 16.1 | 12.4 | 10.2 |
| Santarém | 1 743 | 2.0 | 9.8 | 12.4 | 9.9 | 17.6 | 48.4 |
| Setúbal | 1 683 | 7.9 | 17.9 | 24.4 | 20.9 | 16.6 | 12.2 |
| Viana do Castelo | 2 917 | 0.8 | 4.4 | 8.4 | 16.0 | 40.4 | 30.0 |
| Vila Real | 1 537 | 1.2 | 8.0 | 12.2 | 13.2 | 29.5 | 35.8 |
| Viseu | 2 276 | 0.8 | 5.6 | 11.1 | 12.4 | 33.4 | 36.6 |
| Total | 37.458 | 4.4 | 14.6 | 16.2 | 15.0 | 23.3 | 26.5 |

there is a set of cities holding the highest values in the three criteria (meaning high accessibility of streets and high density of street blocks and plots), including Lisbon, Beja, Porto and Setúbal. This means that, for instance, Lisbon can be described as a city of high accessibility of the street-system, of high density of street blocks (meaning that small size block is dominant) and high density of plots per street block. This general description can be detailed with numerical data for each of the criteria, with the assessment of different parts within each city, and with a comparison between the capital and the other Portuguese cities. It could also be detailed with other characteristics of urban form that are progressively less relevant in the physical description of cities. While it does not fit into the purpose of the present paper, the agents and processes that have been shaping these forms could also be explored. Another set of cities holds the lowest values for the three criteria, comprising Vila Real, Viseu and Santarém. Finally, a number of cities present significant variations between criteria, including Leiria, Portalegre and Funchal.

Looking at Table 4 from a different perspective, there is a relationship between the three criteria, at least in three-quarters of the sample of cities. This means that, for these, a higher accessibility of streets would mean a higher density of street blocks and a higher density of plots. While there is not a significant variation, the link between density of street blocks and plots seems to be more robust than the links between the two other pairs of criteria.

## Application of the methodology to the 20 cities: a description of the evolution of urban form

In addition to the analysis presented in the previous section, *Morpho* offers a description


**Figure 6. The dominance of high (Beja, top), medium (Funchal, bottom left) and low (Leiria, where one street block corresponds to one plot, bottom right) density of plots; at the same scale.**

**Table 4. Synthesis: accessibility of streets, dimension of blocks and density of plots**

| City | Accessibility of streets NAIN mean | Dimension of blocks % of small and medium | Density of plots % of high and medium |
|---|---|---|---|
| Aveiro | 0.685 | 38.3 | 25.5 |
| Beja | 0.881 | 79.8 | 67.6 |
| Braga | 0.549 | 40.9 | 24.9 |
| Bragança | 0.701 | 46.2 | 24.3 |
| Castelo Branco | 0.836 | 60.2 | 41.0 |
| Coimbra | 0.592 | 39.4 | 26.9 |
| Évora | 0.772 | 67.0 | 51.8 |
| Faro | 0.981 | 47.8 | 34.0 |
| Funchal | 0.639 | 58.1 | 51.8 |
| Guarda | 0.635 | 51.7 | 33.7 |
| Leiria | 0.789 | 27.7 | 10.5 |
| Lisboa | 0.938 | 76.0 | 53.6 |
| Ponta Delgada | 0.789 | 34.6 | 32.6 |
| Portalegre | 0.644 | 52.6 | 37.7 |
| Porto | 0.974 | 71.3 | 61.3 |
| Santarém | 0.542 | 34.4 | 24.2 |
| Setúbal | 0.926 | 70.9 | 50.2 |
| Viana do Castelo | 0.652 | 38.0 | 13.6 |
| Vila Real | 0.534 | 33.7 | 21.4 |
| Viseu | 0.646 | 27.1 | 17.5 |

of the evolution of urban form in these cities. This description is based on the selection of four sample areas per city, taking into account their period of formation (see Figure 7, for an example in Porto). Each of these 80 samples is composed of about 20 street blocks. The process of delimitation of each period and of each sample has already been discussed in this paper. In the case of the spatial accessibility of the street system, the measurement of integration and choice for each of the 80 samples considers their relationship with the rest of the city. Due to the size of the cities, the four areas within each tend to be close to each other. Only in larger cities such as Lisbon and Porto is there a significant distance between the four areas.

While also considering each city individually, the focus in this part of the paper is on the samples of a specific period considered together, proposing this as a way of analysing the attributes of urban form in different periods of time and thus as a way of analysing the evolution of urban form in Portuguese cities. One difficult issue at this stage of the research is the availability of high-quality historical cartography for the selection of the four areas. In the case of Vila Real, its absence meant

**Figure 7. Four areas in Porto, distinguished by their period of formation (top-down, left-right): pre-1800, 1801–1900, 1901–1950, and after 1951 (photographs by the authors).**

that the city could not be analysed for the first period.

*The spatial accessibility of the street system*

Based on the results of the analysis of the 20 cities presented in the previous section, the analysis of the spatial accessibility of the street system of the 80 cases (in the relationship of each to the whole city) focuses on the normalized angular integration, as this measure has revealed a wider range of differences between cities than choice (Table 5). The analysis focuses on the mean and not on the maximum values of NAIN. Taking the 20 cities as a whole and the samples of a specific period together, there is an increase of mean NAIN from the first (pre-1800) to the second period (1801–1900), and a subsequent decrease from this to the third (1901–1950) to a value that is lower than in the first period, and another decrease from the third to the fourth time period (after 1951). While the general trend – where the second period holds the highest value of mean integration – is present in more than half of cities, it is far from homogeneity, and there are variations between cities. Taking the 20 cities individually, there is an average range of variation in each of the four periods of about 0.5. While some parts of Setubal, Porto, Faro and Lisbon have high values of mean NAIN, some parts of Santarém (for the first, second and fourth periods) and Viseu have the lowest values of mean NAIN.

*The dimension of street blocks*

Throughout the four periods, there is a progressive decrease of the percentage of small street blocks and a progressive increase of large street blocks (Table 6). While 'small blocks' represented the total of street blocks in the first period and only half of that in the last period, 'large blocks' were almost non-existent in the first period and were about one-quarter of the total of street blocks in the last period. While in the first period there is a tight range of differences between the 20 cities (for

**Table 5. Mean NAIN in the 20 cities in four time periods**

| City | 1st Period | 2nd Period | 3rd Period | 4th Period |
|---|---|---|---|---|
| Aveiro | 0.766 | 0.686 | 0.799 | 0.660 |
| Beja | 0.777 | 1.020 | 0.981 | 0.883 |
| Braga | 0.741 | 0.771 | 0.756 | 0.729 |
| Bragança | 0.745 | 0.888 | 0.836 | 0.789 |
| Castelo Branco | 0.821 | 0.967 | 0.954 | 0.783 |
| Coimbra | 0.699 | 0.565 | 0.666 | 0.748 |
| Évora | 0.880 | 0.896 | 0.901 | 0.813 |
| Faro | 0.796 | 1.064 | 1.111 | 0.948 |
| Funchal | 0.790 | 0.822 | 0.677 | 0.753 |
| Guarda | 0.731 | 0.740 | 0.715 | – |
| Leiria | 0.916 | 0.951 | 0.871 | 0.764 |
| Lisboa | 0.892 | 1.125 | 0.880 | 1.046 |
| Ponta Delgada | 1.003 | 1.003 | 0.851 | 0.987 |
| Portalegre | 0.797 | 0.770 | 0.692 | 0.653 |
| Porto | 0.923 | 1.138 | 0.963 | 0.816 |
| Santarém | 0.583 | 0.517 | 0.518 | 0.606 |
| Setúbal | 1.021 | 1.058 | 1.081 | 0.937 |
| Viana do Castelo | 0.752 | 0.789 | 0.825 | 0.667 |
| Vila Real | – | 0.645 | 0.588 | 0.624 |
| Viseu | 0.812 | 0.903 | 0.882 | 0.801 |
| Total | 0.830 | 0.846 | 0.821 | 0.790 |

**Table 6. The dimensions of street blocks in the 20 cities in four time periods**

| | 1st Period (%) | | | 2nd Period (%) | | | 3rd Period (%) | | | 4th Period (%) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **City** | **S** | **M** | **L** | **S** | **M** | **L** | **S** | **M** | **L** | **S** | **M** | **L** |
| Aveiro | 100.0 | 0.0 | 0.0 | 100.0 | 0.0 | 0.0 | 45.0 | 45.0 | 10.0 | 85.0 | 15.0 | 0.0 |
| Beja | 95.0 | 5.0 | 0.0 | 95.0 | 5.0 | 0.0 | 70.0 | 20.0 | 10.0 | 35.0 | 25.0 | 40.0 |
| Braga | 85.0 | 15.0 | 0.0 | 25.0 | 45.0 | 30.0 | 25.0 | 40.0 | 35.0 | 60.0 | 20.0 | 20.0 |
| Bragança | 85.0 | 10.0 | 5.0 | 73.7 | 21.0 | 5.3 | 70.0 | 20.0 | 10.0 | 35.0 | 25.0 | 40.0 |
| C. Branco | 100.0 | 0.0 | 0.0 | 90.0 | 10.0 | 0.0 | 70.0 | 25.0 | 5.0 | 80.0 | 10.0 | 10.0 |
| Coimbra | 100.0 | 0.0 | 0.0 | 95.0 | 5.0 | 0.0 | 35.0 | 30.0 | 35.0 | 85.0 | 5.0 | 10.0 |
| Évora | 90.0 | 5.0 | 5.0 | 100.0 | 0.0 | 0.0 | 45.0 | 40.0 | 15.0 | 60.0 | 40.0 | 0.0 |
| Faro | 88.9 | 11.1 | 0.0 | 95.0 | 5.0 | 0.0 | 90.0 | 5.0 | 5.0 | 45.0 | 35.0 | 20.0 |
| Funchal | 100.0 | 0.0 | 0.0 | 40.0 | 50.0 | 10.0 | 25.0 | 60.0 | 15.0 | 40.0 | 15.0 | 45.0 |
| Guarda | 100.0 | 0.0 | 0.0 | 84.2 | 15.8 | 0.0 | 85.0 | 15.0 | 0.0 | 55.0 | 35.0 | 10.0 |
| Leiria | 100.0 | 0.0 | 0.0 | 100.0 | 0.0 | 0.0 | 52.6 | 31.6 | 15.8 | 35.0 | 40.0 | 25.0 |
| Lisboa | 78.9 | 21.1 | 0.0 | 60.0 | 5.0 | 35.0 | 45.0 | 45.0 | 10.0 | 15.0 | 55.0 | 30.0 |
| P. Delgada | 95.0 | 5.0 | 0.0 | 33.3 | 33.3 | 33.3 | 40.0 | 5.0 | 55.0 | 9.1 | 36.4 | 54.5 |
| Portalegre | 94.7 | 5.3 | 0.0 | 100.0 | 0.0 | 0.0 | 50.0 | 22.2 | 27.8 | 85.0 | 10.0 | 5.0 |
| Porto | 90.0 | 10.0 | 0.0 | 35.0 | 20.0 | 45.0 | 65.0 | 20.0 | 15.0 | 35.0 | 30.0 | 35.0 |
| Santarém | 100.0 | 0.0 | 0.0 | 85.0 | 15.0 | 0.0 | 60.0 | 15.0 | 25.0 | 65.0 | 25.0 | 10.0 |
| Setúbal | 100.0 | 0.0 | 0.0 | 100.0 | 0.0 | 0.0 | 90.0 | 5.0 | 5.0 | 45.0 | 30.0 | 25.0 |
| V. Castelo | 100.0 | 0.0 | 0.0 | 60.0 | 33.3 | 6.7 | 66.7 | 13.3 | 20.0 | 53.3 | 26.7 | 20.0 |
| Vila Real | – | – | – | 80.0 | 15.0 | 5.0 | 65.0 | 25.0 | 10.0 | 35.0 | 35.0 | 30.0 |
| Viseu | 84.6 | 15.4 | 0.0 | 57.1 | 42.9 | 0.0 | 15.8 | 31.6 | 52.6 | 40.0 | 35.0 | 25.0 |
| Total | 94.1 | 5.4 | 0.5 | 75.4 | 16.1 | 8.5 | 55.5 | 25.7 | 18.8 | 49.9 | 27.4 | 22.7 |

Note: S – Small; M – Medium; L – Large.

instance, the existence of large street blocks varies between 0 and 5%), this range progressively increases over the four periods.

Taking the cities individually, in the third period, the presence of large street blocks is higher in the selected areas in Ponta Delgada, Viseu, Braga and Coimbra. In the first three cities the result is highlighted by the small distance between these areas and the historic core. In the fourth period, the number of large street-blocks is higher in the areas in Ponta Delgada, Funchal, Braga and Beja. Except for Funchal, the areas in the three cities are located very near the historic core.

### *The density of plots*

The density of plots per hectare in each street block of the 20 cities, taken as a whole, has been progressively decreasing over the four periods under analysis (Table 7). Indeed, the density was high in the first and second periods (around three-fifths of street blocks have a high density of plots), medium to high in the third period (two-fifths have high and nearly two-fifths have medium density) and low in the fourth period (three-fifths of street blocks have low density). The progressive decrease of density over the four periods is most evident in thirteen cities, while the other seven have some deviation from this average pattern. The decrease is particularly evident in the cities of Viseu, Santarém, Castelo Branco and Beja.

### *The coincidence between building and plot frontages*

On average, building frontages and plot frontages have been progressively separated (as expressed by the sum of 'Non-Coincident' / NC and 'Mostly Non-Coincident' / MNC)

**Table 7. The density of plots per hectare in the street blocks of the 20 cities in four time periods**

| | 1st Period (%) | | | 2nd Period (%) | | | 3rd Period (%) | | | 4th Period (%) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **City** | **H** | **M** | **L** | **H** | **M** | **L** | **H** | **M** | **L** | **H** | **M** | **L** |
| Aveiro | 53.3 | 26.7 | 20.0 | 85.0 | 10.0 | 5.0 | 15.0 | 50.0 | 35.0 | 15.0 | 60.0 | 25.0 |
| Beja | 79.0 | 10.5 | 10.5 | 65.0 | 15.0 | 20.0 | 55.0 | 25.0 | 20.0 | 25.0 | 20.0 | 55.0 |
| Braga | 40.0 | 30.0 | 30.0 | 30.0 | 35.0 | 35.0 | 10.0 | 25.0 | 65.0 | 0.0 | 45.0 | 55.0 |
| Bragança | 75.0 | 15.0 | 10.0 | 68.4 | 10.5 | 21.1 | 65.0 | 20.0 | 15.0 | 0.0 | 5.0 | 95.0 |
| C. Branco | 95.0 | 0.0 | 5.0 | 55.0 | 25.0 | 20.0 | 40.0 | 55.0 | 5.0 | 10.0 | 20.0 | 70.0 |
| Coimbra | 80.0 | 10.0 | 10.0 | 85.0 | 5.0 | 10.0 | 10.0 | 55.0 | 35.0 | 5.0 | 15.0 | 80.0 |
| Évora | 45.0 | 35.0 | 20.0 | 90.0 | 10.0 | 0.0 | 50.0 | 30.0 | 20.0 | 15.0 | 70.0 | 15.0 |
| Faro | 44.4 | 11.2 | 44.4 | 45.0 | 10.0 | 45.0 | 60.0 | 35.0 | 5.0 | 15.0 | 20.0 | 65.0 |
| Funchal | 15.0 | 10.0 | 75.0 | 30.0 | 15.0 | 55.0 | 60.0 | 30.0 | 10.0 | 5.0 | 40.0 | 55.0 |
| Guarda | 90.0 | 5.0 | 5.0 | 0.0 | 36.8 | 63.2 | 60.0 | 35.0 | 5.0 | 30.0 | 45.0 | 25.0 |
| Leiria | 85.0 | 5.0 | 10.0 | 33.3 | 22.2 | 44.5 | 10.5 | 36.9 | 52.6 | 0.0 | 40.0 | 60.0 |
| Lisboa | 84.2 | 15.8 | 0.0 | 25.0 | 10.0 | 65.0 | 35.0 | 40.0 | 25.0 | 0.0 | 10.0 | 90.0 |
| P. Delgada | 25.0 | 35.0 | 40.0 | 40.0 | 26.7 | 33.3 | 60.0 | 20.0 | 20.0 | 9.1 | 0.0 | 90.9 |
| Portalegre | 84.2 | 10.5 | 5.3 | 95.0 | 5.0 | 0.0 | 27.8 | 44.4 | 27.8 | 65.0 | 15.0 | 20.0 |
| Porto | 60.0 | 35.0 | 5.0 | 65.0 | 20.0 | 15.0 | 10.0 | 65.0 | 25.0 | 10.0 | 15.0 | 75.0 |
| Santarém | 93.8 | 6.2 | 0.0 | 75.0 | 20.0 | 5.0 | 65.0 | 15.0 | 20.0 | 0.0 | 40.0 | 60.0 |
| Setúbal | 90.0 | 5.0 | 5.0 | 100.0 | 0.0 | 0.0 | 85.0 | 5.0 | 10.0 | 0.0 | 40.0 | 60.0 |
| V. Castelo | 75.0 | 10.0 | 15.0 | 26.7 | 53.3 | 20.0 | 60.0 | 20.0 | 20.0 | 6.7 | 33.3 | 60.0 |
| Vila Real | – | – | – | 50.0 | 25.0 | 25.0 | 30.0 | 20.0 | 50.0 | 10.0 | 25.0 | 65.0 |
| Viseu | 69.2 | 15.4 | 15.4 | 28.6 | 57.1 | 14.3 | 0.0 | 47.4 | 52.6 | 0.0 | 0.0 | 100.0 |
| Total | 67.5 | 15.3 | 17.2 | 54.6 | 20.6 | 24.8 | 40.4 | 33.7 | 25.9 | 11.0 | 27.9 | 61.1 |

over the four periods (Table 8). All cities but Lisbon have followed this trend. The turning point in the relationship between the two elements of urban form is the passage from the second to the third periods in the mid-twentieth century. It is then that the sum of NC and MNC becomes higher than the sum of 'Coincident' / C and 'Mostly-Coincident' / MC. Individually, most cities (four-fifths) follow this trend. The exceptions are Aveiro, Faro and Santarem (Castelo Branco has a balanced distribution). Finally, looking at average values in the beginning and at the end of the timeframe, and focusing on the extremes of Coincident and Non-Coincident, it is possible to see how the former has decreased from three-quarters to almost zero, while the latter has increased from zero to two-fifths. In addition to a radical change in the relationship between building and plot frontages, a higher homogeneity at the beginning of the timeframe and a higher heterogeneity at the end of that frame is evident.

Figure 8 illustrates the evolution of the coincidence of building and plot frontages over the four periods by focusing on samples from Braga and Aveiro (total coincidence) and Guarda and Coimbra (a coincidence of about 10%). The figure illustrates the turning point of this relationship in the beginning of the twentieth century.

*Synthesis: a comparative description of the evolution of urban form*

The previous sub-sections demonstrated two crucial findings. The first is that each time period can be described according to a singular combined appraisal of the four criteria, and vice versa (Table 9). The first period is characterized by medium to high accessibility of the street system, small street-blocks, high density of plots and high coincidence between building and plot frontages. The second period shares the same characteristics of

**Table 8. The coincidence of building and plot frontages (percentage per street-block in different time periods)**

| | 1st Period (%) | | | | 2nd Period (%) | | | | 3rd Period (%) | | | | 4th Period (%) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | C | MC | MNC | NC | C | MC | MNC | NC | C | MC | MNC | NC | C | MC | MNC | NC |
| Aveiro | 87 | 13 | 0 | 0 | 100 | 0 | 0 | 0 | 35 | 45 | 15 | 5 | 0 | 30 | 40 | 30 |
| Beja | 75 | 25 | 0 | 0 | 75 | 20 | 0 | 5 | 20 | 15 | 55 | 10 | 5 | 20 | 70 | 5 |
| Braga | 100 | 0 | 0 | 0 | 30 | 70 | 0 | 0 | 5 | 20 | 30 | 45 | 0 | 10 | 85 | 5 |
| Bragança | 44 | 56 | 0 | 0 | 47 | 47 | 6 | 0 | 15 | 30 | 45 | 10 | 25 | 15 | 45 | 15 |
| C. Branco | 30 | 70 | 0 | 0 | 45 | 35 | 10 | 10 | 22 | 28 | 33 | 17 | 0 | 35 | 45 | 20 |
| Coimbra | 95 | 5 | 0 | 0 | 70 | 25 | 5 | 0 | 0 | 10 | 32 | 58 | 0 | 0 | 10 | 90 |
| Évora | 70 | 30 | 0 | 0 | 100 | 0 | 0 | 0 | 5 | 5 | 20 | 70 | 0 | 10 | 5 | 85 |
| Faro | 56 | 44 | 0 | 0 | 90 | 10 | 0 | 0 | 14 | 79 | 7 | 0 | 5 | 15 | 40 | 40 |
| Funchal | 95 | 5 | 0 | 0 | 30 | 60 | 0 | 10 | 15 | 10 | 50 | 25 | 0 | 0 | 50 | 50 |
| Guarda | 40 | 60 | 0 | 0 | 11 | 53 | 21 | 15 | 0 | 5 | 5 | 90 | 0 | 0 | 35 | 65 |
| Leiria | 80 | 20 | 0 | 0 | 50 | 40 | 5 | 5 | 5 | 32 | 58 | 5 | 20 | 15 | 40 | 25 |
| Lisboa | 70 | 30 | 0 | 0 | 45 | 55 | 0 | 0 | 5 | 0 | 35 | 60 | 10 | 30 | 45 | 15 |
| P. Delgada | 95 | 5 | 0 | 0 | 0 | 80 | 13 | 7 | 10 | 30 | 40 | 20 | 0 | 18 | 64 | 18 |
| Portalegre | 84 | 16 | 0 | 0 | 50 | 50 | 0 | 0 | 6 | 17 | 33 | 44 | 0 | 10 | 20 | 70 |
| Porto | 75 | 25 | 0 | 0 | 53 | 47 | 0 | 0 | 5 | 0 | 10 | 85 | 0 | 0 | 15 | 85 |
| Santarém | 88 | 12 | 0 | 0 | 15 | 70 | 15 | 0 | 0 | 75 | 20 | 5 | 0 | 30 | 60 | 10 |
| Setúbal | 100 | 0 | 0 | 0 | 55 | 45 | 0 | 0 | 0 | 45 | 25 | 30 | 0 | 10 | 55 | 35 |
| V. Castelo | 85 | 0 | 0 | 0 | 13 | 67 | 20 | 0 | 0 | 13 | 67 | 20 | 0 | 13 | 40 | 47 |
| Vila Real | – | – | – | – | 25 | 55 | 15 | 5 | 0 | 5 | 30 | 65 | 0 | 0 | 40 | 60 |
| Viseu | 38 | 62 | 0 | 0 | 13 | 87 | 0 | 0 | 5 | 40 | 45 | 10 | 0 | 15 | 70 | 15 |
| Total | 75 | 25 | 0 | 0 | 46 | 46 | 5 | 3 | 8 | 25 | 33 | 34 | 3 | 14 | 44 | 39 |

Note: C – Coincident; MC – Mostly Coincident; MNC – Mostly Non-Coincident; NC – Non-Coincident.

the first – with the exception of a higher spatial accessibility of streets. There is a significant difference between the first and second periods, on the one hand, and the third and fourth periods, on the other hand. The third period is characterized by medium accessibility of the street system, small street blocks, medium to high density of plots and low coincidence between building and plot frontages. Finally, the combination of low accessibility of the street system, small to medium street blocks, low density of plots and low coincidence between building and plot frontages characterizes the fourth period. It is important to mention that, in terms of their urban form, the first and second periods are more homogeneous than the third and fourth periods.

The second key finding is about the relevance of each criterion for the historical description of the four time periods. Indeed, the third (density of plots) and fourth criteria (the coincidence between building and plot frontages, which was the more 'innovative' criterion of the four) proved to be more relevant for differentiating the four time periods than the other two criteria. Despite that fact, the spatial accessibility of the street system and the dimension of street blocks are not negligible – the former criterion differentiates the first and the second period; the latter criterion helps to highlight the differences between the third and fourth periods.

## Conclusions

Cities have complex physical forms. Many elements can be explored in describing and analysing this complexity. *Morpho* focuses on the most permanent elements of urban form: streets and squares, street blocks, plots and the block plans of buildings. Being selective

**Figure 8. The evolution of the coincidence of building and plot frontages over the four periods – samples from Braga (first period), Aveiro (second), Guarda (third) and Coimbra (fourth). (Photographs from Google Earth.)**

**Table 9. Synthesis: a comparative description of the evolution of urban form**

| | Accessibility of streets | Dimension of street-blocks | Density of plots | Coincidence between building and plot frontages |
|---|---|---|---|---|
| 1st Period | Medium to high | Small | High | High |
| 2nd Period | High | Small | High | High |
| 3rd Period | Medium | Small | Medium to high | Low |
| 4th Period | Low | Small to medium | Low | Low |

and offering a structural reading of urban form, the methodology does not aim to deal with all relevant aspects of that physical form. This paper applies *Morpho* to the analysis of 20 Portuguese cities. The first part of the analysis, addressing each city as a whole, has revealed three different groups each comprising a similar number of cities: a first group, with high values for all characteristics of urban form; a second group, with low numbers for all characteristics; and a third group with no clear pattern.

More importantly, the second part of the analysis focused on the samples of a specific time period together, proposing this as a way of analysing the evolution of urban form. The analysis has revealed two important results. The first is that each time period can be described according to a singular combined appraisal of the four criteria, and vice versa. This means that, for instance, the second period (the nineteenth century) is characterized by a high accessibility of the street system, small street-blocks, high density of plots and high coincidence between building and plot frontages. It also means that this particular combination of characteristics can only be found in this time period, and not in the other three. It is argued that this result is relevant for a wider geographical context and hence it should continue to be explored in future research.

The second result is that some criteria (the density of plots and the coincidence between building and plot frontages) are more relevant than others in this description; but the latter are nevertheless fundamental to stress the differences between some periods. While the first result is more related to the 'object' of analysis, this second result is more relevant to the 'method'. As is usual in scientific research, *Morpho* has been developing step by step: first, in the analysis of streets, secondly in the description of whole cities, thirdly in the study of particular time periods in the 'life' of different cities; and now this paper offers a comparison between a large number of cities, addressing not only their present form but also their evolution. Future research should involve the development of the methodology in its understanding of the city in a permanent learning process.

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## References

Charalambous, N., Cömert, N. Z. and Geddes, I. (2019) 'The study of urban form in Cyprus', *Urban Morphology* 23, 35–43.

Coelho, C. D. and Lamas, J. (eds) (2005) *Squares in Portugal, a public space inventory – Azores* (Direção-Geral do Ordenamento do Território e Desenvolvimento Urbano, Lisbon).

Coelho, C. D. and Lamas, J. (eds) (2007) *Squares in Portugal, a public space inventory – mainland* (Direção-Geral do Ordenamento do Território e Desenvolvimento Urbano, Lisbon).

Conzen, M. P. (2018) 'Core concepts in town-plan analysis', in Oliveira, V. (ed.) *Teaching urban morphology* (Springer, Cham) 123–43.

Conzen, M. R. G. (1988) 'Morphogenesis, morphological regions and secular human agency in the historic townscape', in Denecke, D. and Shaw, G. (eds) *Urban historical geography* (Cambridge University Press, Cambridge) 253–72.

Dibble, J., Prelorendjos, A., Romice, O., Zanella, M., Strano, E., Pagel, M. and Porta, S. (2017) 'On the origins of spaces: morphometrics foundations of urban form evolution', *Environment and Planning B: Urban Analytics and City Science* 46, pp. 707–30.

Domingues, A. (ed.) (2006) *Cidade e democracia – 30 anos de transformação urbana em Portugal* (Argumentum, Lisbon).

Fernandes, M. G. (2005) *Urbanismo e morfologia urbana no norte de Portugal: Viana do Castelo, Póvoa de Varzim, Guimarães, Vila Real, Chaves e Bragança* (Faculdade de Arquitetura da Universidade do Porto Publicações, Porto).

Ferreira, A. M. (1995) *Aspetos da organização do espaço Português* (FAUP, Porto).

Hillier, B. (2016) 'What are cities for? And how does it relate to their spatial form?', *Journal of Space Syntax* 6, 199–212.

Hillier, B., Yang, T. and Turner, A. (2012) 'Normalising least angle choice in Depthmap and how it opens up new perspectives on the global and local analysis of city space', *Journal of Space Syntax* 3, 155–93.

Kotov, E. A. and Goncharov, R. V. (2017) 'Connecting Morpho to urban vitality: the case of Moscow', unpublished paper presented to the Twenty-Fourth International Seminar on Urban Form, Krasnoyarsk, Russia.

Kropf, K. (2017) *The handbook of urban morphology* (Wiley, Chichester).

Medeiros, V. (2013) *Urbis Brasiliae, o labirinto das cidades Brasileiras* (Universidade de Brasília, Brasília).

Oliveira, V. (2013a) 'The study of urban form: reflections on national reviews', *Urban Morphology* 17, 85–92.

Oliveira, V. (2013b) '*Morpho*: a methodology for assessing urban form', *Urban Morphology* 17, 21–33.

Oliveira, V. (2016) 'Forma e paisagem urbana de Lisboa', *Paisagem e Ambiente* 38, 13–32. DOI: https://doi.org/10.11606/issn.2359–5361.v0i38p13-32

Oliveira, V., Marat-Mendes, T. and Pinho, P. (eds) (2015) *O estudo da forma urbana em Portugal* (Edições Universidade do Porto, Porto).

Oliveira, V. and Medeiros, V. (2016) 'Morpho: analysing and designing streets, plots and buildings', *Environment and Planning B: Planning and Design* 43, 805–25. DOI: 10.1177/0265813515596529

Oliveira, V. and Silva, M. (2013) 'Morpho: investigação morfológica e prática de planeamento', *Revista de Morfologia Urbana* 1, 31–44.

Pinho, G. (2019) 'Morfologia de aglomerados rurais', unpublished PhD thesis, Universidade Estadual de Campinas, Brazil.

Portas, N., Domingues, A. and Cabral, J. (2004) *Políticas urbanas I – tendências, estratégias e oportunidades* (Fundação Calouste Gulbenkian, Lisbon).

Portas, N., Domingues, A. and Cabral, J. (2011) *Políticas urbanas II – transformações, regulação e projetos* (Fundação Calouste Gulbenkian, Lisbon).

Siksna, A. (1997) 'The effects of block size and form in North American and Australian city centres', *Urban Morphology* 1, 19–33.

Teixeira, M. C. (2008) *A forma da cidade de origem Portuguesa* (Universidade Estadual Paulista, São Paulo).

Teixeira, M. C. and Valla, M. (1999) *O urbanismo português, séculos XIII-XVIII Portugal-Brasil* (Livros Horizonte, Lisbon).

Trindade, L. (2013) *Urbanismo na composição de Portugal* (Imprensa da Universidade de Coimbra, Coimbra).

Turner, A. (2007) 'From axial to road-centre lines: a new representation for space syntax and a new model of route choice for transport network analysis', *Environment and Planning B: Planning and Design* 34, 539–55. DOI: https://doi.org/10.1068/b32067

Whitehand, J. W. R., Conzen, M. P. and Gu, K. (2016) 'Plan analysis of historical cities: a Sino-European comparison', *Urban Morphology* 20, 139–58.