Green structure and planning evolution in Porto

Helena Madureira, Teresa Andresen, Ana Monteiro

A R T I C L E   I N F O

Keywords:
Green space
Multifunctionality
Spatial configuration
Urban planning

A B S T R A C T

The 20th century produced completely distinct contexts for the implementation of green structures at the Municipality of Porto. This paper examines the transformations that occurred to the green structure of the city of Porto during the 20th century, based on spatial analysis and comparison of four planning instruments produced between 1954 and 2006. This period was marked both by intense urban growth, which diminished the city's green areas. Successive master plans for the city were an opportunity for the definition of Porto's green structure. However, the opportunity was not taken hence fragmentation and discontinuity of green structures occurred. Overall, the planning process through the century can be seen as a lost opportunity in maintaining a continuous and multifunctional green structure. This situation calls for green infrastructure as a large-scale planning framework adapted to the reality of today’s metropolitan territories.

I n t r o d u c t i o n

The contribution of urban green areas to sustainable development has been highlighted by various international publications and organisations (e.g., European Environment Agency, 2003, 2010; World Health Organization-Regional Office for Europe, 2003; UN-Habitat, 2007, 2009). With the emergence and consolidation of environmental concerns during the 20th century's last decades, which was enhanced by the success of the sustainable development concept, connectivity and multi-functionality have been established as the central components of plans aimed at the definition and management of green areas in metropolitan regions. Therefore, the focus of these plans has moved from individual green areas (public and private open spaces in urban areas, primarily covered by vegetation) to urban green structures (the spatial structure defined by a collection of urban green areas).

The concept of green infrastructure has emerged in the last decades with the intent of improving urban green space systems to coherent planning entities (Tzoulas et al., 2007). Based on the different definitions found in contemporary literature (e.g., Walmsley, 1995, 2006; Hough, 2004; Sandström, 2002; Sandström et al., 2006; Benedict and McMahon, 2006; Turner, 2006; Ahern, 2007; Tzoulas et al., 2007; EU WG, 2009; Forest Research, 2010), we define green infrastructure as an integrated and coherent system of multifunctional green areas that links the city with the countryside through biophysical and social infrastructure. According to this definition, two key conditions need to be met: spatial continuity, or connectivity, and multi-functionality.

The benefits associated with the spatial continuity of green areas have often been mistaken with the evolution of ideas and concepts about the relationship between the green structures and the city. In fact, at the end of the 19th century, when Frederick Law Olmsted and Ebenezer Howard delineated two of the most important concepts in the history of green structures in urban areas – green belts and parkways – the idea of continuity was already included.

The potential of a continuous configuration of green structures is an idea that was explored during the 20th century, both as a structuring element of urban development and to promote the leisure experience of users. However, ideas related to the need for continuous configurations matured during the last decades of the 20th century through the adoption of the "connectivity" concept. In fact, one of the main problems related to biodiversity losses in strongly dynamic urban areas, in addition to the reduction in the number and area of the natural habitats, is the fragmentation introduced by infrastructure. In this context, the importance of connectivity for the maintenance and promotion of biodiversity has been a constant in the landscape ecology literature (e.g., Forman, 1995; Bennett, 1999; Hess and e Fischer, 2001; Turner et al., 2001; Ahern, 2003, 2007; Opdam, 2006; Ahern, 2007).

The increasing importance of the ecological dimension reflects an increasing valorisation of the multi-functionality of urban green structures (James et al., 2009). The importance given to multi-functionality derives from the benefits attributed to the presence of green areas in the city: environmental benefits, as well as climatic regularisation (Rosenfeld et al., 1998; Gill et al., 2007; Grignaffini
and Vallati, 2007; Rizwan et al., 2008; Hamada and Ohta, 2010), atmospheric purification (Givoni, 1991; McPherson et al., 1997; Beckett et al., 1998; Bolund and Hunhammar, 1999; Brack, 2002; Nowak et al., 2006), energy savings (Ca et al., 1998; Papadakis et al., 2001; Simpson, 2002; Brack, 2002; Akbari and Konopacki, 2005); social benefits, such as health promotion through atmospheric pollution reduction, the facilitation of physical exercise (Humpel et al., 2002; Takano et al., 2002; Pikora et al., 2003; Owen et al., 2004; Cohen et al., 2007; Kaczynski and Henderson, 2007) and the promotion of mental wellness (Chiesura, 2004; Maller et al., 2006; Tzoulas et al., 2007); economic benefits, specifically the increase in property values (Geoghegan, 2002; Morancho, 2003; Holden et al., 2004) and the economic value of the environmental and social functions promoted by urban green areas (Bolund and Hunhammar, 1999; Chen and Jim, 2008). Several studies have demonstrated that urban populations are able to perceive the benefits of green areas. Urban environments containing green spaces are considered more attractive than urban areas without vegetation, contributing towards a higher perception of well-being for local residents (Chiesura, 2004; Tyrväinen et al., 2007; Tzoulas et al., 2007; Priego et al., 2008).

Therefore, the multi-functionality and connectivity of urban green structures depend on the historical development process of each city. In fact, the urban dynamics, planned or unplanned, went changing the structure, the shape and the functions of built and non-built areas.

This article examines the transformations that occurred in the green structure of the city of Porto, Portugal during the 20th century through two main procedures. We compared the spatial configuration of the green structure at two moments in time: the end of the 19th century, when Porto’s urban structure reflected the first modifications due to the Industrial Revolution and at the turn of the 20th century, when the city had already exceeded its administrative limits and evolved to a metropolitan area. Additionally, we examined the impact of master plans on the evolution of the spatial configuration of the green structure. The analysis of these plans allows the identification of continuities and divergences of conceptions related to the city’s development and its green structure.

While urban planning concerns arose in the second half of the 19th century, the city only produced a first overall urban planning instrument in the middle of the 20th century. Troubled processes delayed the production of a master plan (Garrett, 1974; Oliveira and Pinho, 2008), and until the submission of the Plano Regulador da Cidade do Porto by Almeida Garrett (1954), the city continued to grow without any global strategy for its development.

The Constitution of 1976 opened the door for new legislation concerning physical and environmental planning. Portugal joined the EEC in 1986 and then began the process of replacing of many of its directives, particularly environmental directives. From the early 1990s on, a new set of land use regulations was put forth, and plans were developed and approved. This created an entirely new framework for a more comprehensive planning process, including taking into account concerns related to environmental protection and management. As a result of this process, only the two most recent plans for Porto (1991 and 2006) were effectively approved and implemented.

Study area and methods

The study area

Porto is located in the northwest of Portugal. The Douro River runs through the south of the city, and to the west is the Atlantic Ocean (Fig. 1). With an estimated population of 216,080 and an area of 4100 ha, the city is the heart of the country’s second biggest metropolitan area (GAMP), which has 1,682,447 inhabitants (INE, 2009).

<table>
<thead>
<tr>
<th>Categories</th>
<th>1892</th>
<th>2000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agricultural</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tree-covered</td>
<td></td>
<td></td>
</tr>
<tr>
<td>areas</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Residual</td>
<td></td>
<td></td>
</tr>
<tr>
<td>yards</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Public gardens</td>
<td></td>
<td></td>
</tr>
<tr>
<td>and parks</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Semi-public</td>
<td></td>
<td></td>
</tr>
<tr>
<td>gardens</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Street trees</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Methods

For the purpose of understanding and evaluating the role and evolution of green structures in Porto city planning, two methodological steps were taken. First, we identified reliable databases to understand and compare the potential spatial configuration of green structures. Second, we relied upon four master plans and evaluated the outcome in terms of green structure planning.

The spatial configuration of green structures at the end of the 19th and 20th centuries

To evaluate the spatial configuration of green structures in the late 19th century, we used a topographic map of Porto, the Carta Topográfica da Cidade do Porto (1:5.000 scale) from 1892, which was the first map of Porto presenting an accurate representation of its administrative boundaries, drafted under the responsibility of Telles Ferreira. Five categories of green areas were defined and vectorised on the original map: agricultural areas, tree-covered areas, residential yards, public gardens and parks and tree planted streets (Madureira, 2001).

To evaluate the spatial configuration of green areas in the late 20th century, we used digital orthophotomaps with a spatial resolution of 0.5 m produced by the Instituto Nacional de Intervenção e Garantia Agrícola (INGA) in 2000.

The definition of a typology suitable to compare the evolution of green structures almost one hundred years apart was conditioned by the differences between the two cartographic frameworks used in the study and by the variation of the characteristics of the green areas during the 20th century (Table 1).

<table>
<thead>
<tr>
<th>Categories</th>
<th>1892</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agricultural covered areas</td>
<td>Tree or shrub-covered areas</td>
</tr>
<tr>
<td>Tree-covered areas</td>
<td>Tree or shrub-covered areas along transport corridors</td>
</tr>
<tr>
<td>Residential yards</td>
<td>Green areas for private use inside city blocks</td>
</tr>
<tr>
<td>Semi-public gardens</td>
<td>Not present in 1892</td>
</tr>
<tr>
<td>Street trees</td>
<td>Street trees</td>
</tr>
</tbody>
</table>

The impact of master plans on the evolution of the spatial configuration of the green structure. The analysis of these plans allows the identification of continuities and divergences of conceptions related to the city’s development and its green structure.
Evaluation of green structure planning in Porto

Four master plans were analysed: the Plano Regulador da Cidade do Porto (1947–1954) by Almeida Garrett, the Plano Director da Cidade do Porto (1960–1962) by Robert Auzelle, the Plano Geral de Urbanização/Plano Director Municipal (1978–1991) and the Plano Director Municipal (2006). To interpret the municipal strategy for the green structure, the master plan maps were digitalised and vectorised.

Results

Green structure transformations during the 20th century

At the end of the 19th century, despite reflecting the urban development enabled by industrialisation, Porto was still a very green city. It was green in the enormous rural belt that surrounded its still small urban centre, green in the interior of the blocks developed in the urban expansion of the 18th and 19th centuries and green with respect to the significant number of public gardens that served the city (Fig. 2).

In 2000, the context was significantly different, with an obvious dramatic decrease in green area in the city (Figs. 2 and 3). While one century ago green areas occupied more than 75% of the city (3044 ha), in 2000 they occupied less than 30% (1164 ha), representing a decrease of approximately 60% (Table 2 and Fig. 3).

In addition to this drastic decrease, there was a significant fragmentation of the green structure. The results of the selected landscape metrics applied to the overall green structure (Fig. 4) at the two time points investigated allowed us to quantify the tendency for fragmentation that was qualitatively illustrated by the comparative analysis of the categorical maps. Despite the considerable decrease in the total green area, the number of patches increased substantially (from 1995 to 4316 patches), resulting in a decrease in mean patch size (from 150 to 26 m²). The mean nearest-neighbour distance values also increased from approximately 126 to 247 m. This change indicates that the green structure patches...
in 2000 were more isolated than the 1892 patches and, thus, that interpatch connectivity decreased.

In fact, the rural belt that dominated a great part of the municipality a century ago had also become fragmented, consisting of a number of small green spaces that rarely maintained rural function. With the disappearance of the rural belt, a "territorial homogenisation" of green area categories had occurred due to the propagation throughout municipality of "more urban" green area categories: residential yards, public gardens and parks.

The variation of the surface occupied by each of the green area categories between 1892 and 2001 demonstrates this process of "territorial homogenisation" (Table 2 and Fig. 5). While in 1892 almost half of the surface area of the municipality of Porto was occupied by agricultural areas, in 2000 these areas were almost nonexistent, occupying only 3% (130 ha) of the surface, which reflects a decrease of approximately 93%. Examination of tree-covered areas revealed a less sharp decline of approximately 48%, which is a sign of a clear differentiation in the socio-cultural valorisation of both categories. This category currently represents 9% of the municipality’s surface.

The area of residential yards also decreased, although more moderately (by 17%), occupying 10% of the municipality’s surface in 2000. In fact, despite the fact that residential yards had extended throughout the whole municipality, they were much

| Table 2 | Surface area (ha and %) of the different green area categories in 1892 and 2000. |
|---------|---------------------------------|-----------------|-----------------|----------------|----------------|
|         | 1892 (ha) | % of city area | 2000 (ha) | % of city area |         |          |
| Agricultural areas | 1801 | 44.8 | 143 | 3.6 |         |          |
| Tree-covered areas | 693 | 17.2 | 334 | 8.3 |         |          |
| Residential yards | 503 | 12.5 | 417 | 10.4 |         |          |
| Public gardens and parks | 28 | 0.7 | 171 | 4.3 |         |          |
| Semi-public gardens | – | – | 71 | 1.8 |         |          |
| Cemeteries | 19 | 0.5 | 28 | 0.7 |         |          |
| Total | 3044 | 75.8 | 1164 | 29.0 |         |          |
Auzelle (1913–1983), who was deeply involved in and inspired by Plano Director da Cidade do Porto (1960–1962) by Robert Auzelle and to the consequent elaboration of a new master plan. The transition between the objectives of the two plans led to the revision of previously defined as “green and rural zones”. The existing conflict引发了住宅发展在土地上，the city council created a new planning office and invited Duarte Castel Branco, an urbanist professor at Lisbon Tech-

Public gardens and parks, which occupied 4% of the municipality’s surface, were the only class of green area that witnessed an increase during the last century – an increase which was quite considerable (510%). This extraordinary growth of formal green areas is a direct consequence of the intensification of the urbanisation process during the 20th century. By gradually moving populations away from direct contact with nature through the banishing of old rural structures or promoting construction, the urban development of Porto has induced the need for the creation of green leisure areas. Public gardens and parks have, in fact represented the privileged instrument of green structure planning in the 20th century, as will be discussed below.

Planning


Antão de Almeida Garrett (1896–1961), the initiator of urban studies at the School of Engineering at Porto University, coordinated the city’s master plan. He was confronted with a city still confined to its traditional nucleus and yet largely supported by rural areas. The plan – Plano Regulador da Cidade do Porto – incorporated these rural areas into the city’s future urban development according to a model that simultaneously included influences from the Modern Movement and the Garden-Cities Movement.

The plan organised the green structure through three belts of gardens and parks (Fig. 6) that would allow intensive urban growth associated with the presence of large green areas in the city if the plan was to be implemented. Two years after the submission of the plan, some of its aims were found to be in conflict with the objectives of a housing investment program, the Plano de Melhoramentos (1956), which promoted residential development on terrains previously defined as “green and rural zones”. The existing conflict between the objectives of the two plans led to the revision of Plano Regulador and to the consequent elaboration of a new master plan.

Plano Director da Cidade do Porto (1960–1962) by Robert Auzelle

Plano Director was coordinated by the French urbanist Robert Auzelle (1913–1983), who was deeply involved in and inspired by the Modern Movement. Modernist concepts were widely applied in this plan, specifically related to the implementation of single-use zoning of urban areas, compared to the mixed uses that had characterised the city until that time, and to the building model proposed for the new residential expansions: autonomous blocks independently implemented based on the structure of roads that would be surrounded by green areas.

The most striking characteristic of the master plan concerning green structure planning is discontinuity (Fig. 7). The plan allows for a balanced distribution of gardens and public parks throughout the city. However, it does not introduce a continuum strategy for the city’s green structure.

The contrast between this plan and Plano Regulador is dramatic. Following the proposed preservation strategy of the continuous green belt surrounding, the disaggregation of this belt through the punctual insertion of public gardens and parks was proposed. We find three main justifications for this differentiation. First, the elaboration of the master plan was, since its inception, dependent on the decisions previously made based on Plano de Melhoramentos (1956), specifically, the occupation of the previous rural beltway by residential developments. Second, the two plans have distinct perspectives about the territorial evolution of the city. Plano Regulador proposed more compact urban development, leaving open space for the development of a wide green structure around the city. In contrast, Plano Director advocated a more dispersed urban development, to promote the spread of urbanisation along the green belt. Third, despite being included in Plano Regulador, some of concepts of the Modern Movement, such as the use of zoning, were only rigorously applied in Plano Director. The development of modernist buildings rising from pilotis above a free-flowing landscape resulted in a reduction of the formal green areas planned and a progressive fragmentation of the green structure. These changes cannot be dissociated from city’s management, which progressively acted in a passive way and has been lead by the solicitations of private operators. It was in this context that a new master plan emerged.

Plano Geral de Urbanização/Plano Director Municipal (1978–1991) by Castel Branco

In 1978, the city council created a new planning office and invited Duarte Castel Branco, an urbanist professor at Lisbon Tech-
technical University, to coordinate a new master plan for Porto, first titled Plano Geral de Urbanização. The elaboration process of the new plan experienced significant delays: the first step was the publication of the plan’s strategic guidelines in 1984 (Opções do Plano, 1984). The plan was completed in 1986 and approved in 1988. However, with the publication of Decree No. 69/90, which revised the legal planning framework, Plano Geral de Urbanização evolved into Plano Director Municipal, which was finally ratified in 1991.

From the preparatory studies and the presentation of the strategic guidelines to the concrete formulation of a formal planning instrument culminating in the Plano Director Municipal (1991), this process exhibited an impoverishment of the green structure conception. In Opções do Plano, the need of an interconnected green areas network that combines the various functions attributed to green areas in urban environments is mentioned. However, in the final proposal (Fig. 8), the Plano Director Municipal limits its actions to the creation of public gardens and parks, specifically two large urban parks at the east and west sides of the city, disregarding the master plan as an instrument for the promotion of green structure connectivity and multi-functionality.

Plano Director Municipal (2000–2006) by the Porto Municipal Planning Department

At the beginning of the decade, the city council initiated the revision of the master plan, this time under the direction of Manuel Fernandes de Sá, a professor of urbanism at the School of Architecture at the University of Porto. This plan, which is currently in force, defines as one of its five goals the rehabilitation of public spaces and built environments to adopt a systemic view of ecological and landscape resources. It represents a clear departure from the preceding plans: first, it discards the previous zoning methodology; secondly, more recent regulations called for the delimitation of a municipal ecological network in the master plan.
The approach taken by this plan towards the urban green structure is, therefore, different from the preceding plans, establishing its multi-functionality. However, the potential ecological network considered in the plan had already undergone significant occupation due to building and infra-structure construction when the plan was conceived (Fig. 9). In addition to public green areas (public parks or parks for public use), other categories were defined: mixed green areas (agricultural or forested structures that can integrate recreation and leisure activities without harming their productive function); private green areas to be preserved (gardens, parks or farms not related to collective usage that are relevant for the city’s image due to their location and quality) and green areas along transport corridors (with the purpose of physical, visual and auditory protection of sectors of the city that flank transportation corridors).

This multi-functional and systemic perspective is more integrated and goes further than the previous plan’s perspectives on parks and gardens. Nevertheless, the current proposal introduces fragmentation and lacks connectivity. Connectivity is only artificially assured along transport corridors, specifically, straight green corridors related to the high-speed roads that cross the city.

Discussion and conclusion

The diminishing of green areas during the 20th century was an inevitable process. A century ago, the municipality of Porto was still largely concentrated around its medieval city. During the 20th century, Portugal experienced some of the most rapid increases in urban development in the European Union, which were focused around the two metropolitan areas of Lisbon and Porto (European Environment Agency, 2006). Porto has been following the trend of rapid urbanisation that has been taking place throughout the world (United Nations, 2010) and the general European trend of urban sprawl, associated with green area decreases (European Environment Agency, 2002, 2006; Kasanko et al., 2006).

Therefore, we do not consider the inevitable diminishing of green areas as a process associated with a desirable urban development process. However, associated with the decrease of the city’s green areas, a major transformation occurred in its spatial structure, specifically, the high levels of fragmentation and discontinuity that characterise the actual green structure. The fact that these profound modifications of the green structure have occurred simultaneously with the development of the city’s planning gives rise to two main conclusions.

A first conclusion is related to the influence of urban planning on the city’s development. The delayed initiation of planning, the successive amendments to the proposed plans and the long time periods taken for the elaboration and approval of these documents resulted in the nonexistence of global, long-term urban development strategies during a great part of the 20th century. Thus, the evolution of green structures also reflected the lack of an overall, long-term strategy.

A second conclusion is related to the influence of each of the plans on the configuration of the green structure. According to the results of our analysis, we can distinguish two groups of plans. The first group includes the plans that do not favour the multi-functionality and connectivity of the green structure and of a larger temporal influence on the city’s development:

- The Plano Director da Cidade do Porto (1962–1964), which applies the fundamental concepts of the Modern Movement by regulating few green areas, believing in an urban development model that would build large green areas by itself and which allowed the progressive fragmentation of the green structure.
- The Plano Geral de Urbanização/Plano Director Municipal (1978–1991), which almost limited its function to the creation of a network of public gardens and parks, restricting the concept of green structure to recreational functions, while potentiating discontinuity between regulated areas.

The second group aggregates the plans with a more comprehensive vision in terms of green structure connectivity and multi-functionality, with a smaller time period of influence on the city’s development:

- The Plano Regulador da Cidade do Porto (1947–1954), which defines a model of compacted urban development in association with “green and rural belts” and regulates a connected and multi-functional system of green areas.
- The Plano Director Municipal (2004–2008), which is currently in force and favours multi-functionality and connectivity of green areas, representing clear progress in terms of a holistic concept of the city’s green structure. However, this proposal for the green...
structure reveals clear difficulties in the spatial implementation of these aims.

In summary, the urban planning system, in association with an urban green strategy based primarily on leisure uses, has resulted in the fragmentation of the city’s green structure. Without any consistent planning strategy, the green structure continued its transformation according to the evolution of the urbanised area.

Most European cities have developed regional green spaces plans in order to deal with the uncontrolled growth of cities. In some cases, the need for containment of urbanization became the starting point for the protection of natural areas around the cities. The best known of these open space planning models are the green belt, the green fingers and the green heart. In other cases, multi-purpose linear systems of open spaces – like greenways or ecological networks – were planned within the urban areas (Maruani and Amit-Cohen, 2007).

However, Porto did not follow the growing concern for the preservation of its urban green structure as an integrated and coherent system. We are aware that strategies related to the green structure have been and continue to be difficult to implement due to the failure of the planning process itself, which opened the door for the fragmentation of the city’s green structure. Thus, the challenge now is to take away from this process a lesson about the lost opportunity in terms of the configuration of a continuous and multi-functional green structure, foreseeing the necessity to intervene at the metropolitan scale.

Green infrastructure is an emerging planning and design concept (Ahern, 2007) that was introduced to improve urban green space systems as part of a coherent planning entity (Tzoulas et al., 2006). However, this concept may be able to meet the challenges and opportunities related to green area conditions at the metropolitan scale. If green infrastructure is considered as a planned and designed infrastructure system, it can take into account both the challenges associated with connectivity/continuity and the opportunity of multifunctionality at the metropolitan scale.


References


