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Green infrastructure in strategic spatial plans: Evidence from European urban regions☆

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1. Introduction

Green infrastructure (GI) is an umbrella term for a strategically planned and managed network of green areas, conservation sites, working lands and water bodies capable of delivering a wide range of benefits for humans and ecosystems (Benedict and McMahon, 2006; Rouse and Bunster-Ossa, 2013). The emergence of the GI concept has been described as form of ecological modernization with potential for reconciling nature protection with economic development goals (Thomas and Littlewood, 2010).

There is no clear time and place of origin of the idea of a network of multi-functional green and open spaces (Lennon et al., 2017). Benedict and McMahon (2006) place the roots of this idea in the planning and nature conservation efforts that started in the early 19th century. Nevertheless, the term green infrastructure is rather recent. Wright (2011) described it as emerging from a long period of apparent convergence in theories and practices in different contexts, including nature conservation, US greenways, Garden Cities, New Towns, ecological city and sustainable urbanism. In the United States, the term GI was first used in the 1990s (Benedict and McMahon, 2006). In Europe, GI has been extensively advocated by the European Union through a series of strategies and reports (European Commission, 2010, 2013; Mazza et al., 2011). Countries with long tradition of green space planning, such as the UK, have been particularly keen on adopting the term GI (Mell et al., 2017). Literature from the Global South (Schäffler and Swilling, 2013) and Asia (Byrne et al., 2015) reveal a worldwide growing interest in the topic. Considering that GI has been extensively promoted by both science and policy, and is being supported by a multitude of actors, it is time to look at how much GI planning has been consolidated.

Scholars have proposed various principles to incorporate both the ecological and social perspectives into green area planning in order to support the design of a functional GI. Although there is no agreed-upon set of principles (Hansen and Pauleit, 2014), six of them stand out as recognized in most of the studies: *coordination*, *multi-functionality*, *connectivity*, *multi-scale planning*, *diversity* and *identity*. Coordination of GI expansion and management with other domains of spatial planning has been encouraged to better integrate the various planning goals. Coordination with policies on climate change adaptation (Gill et al., 2007), flood prevention and water management (Liao et al., 2017), increasing health and quality of life (Tzoulas et al., 2007), and recreation provision and tourism (EEA, 2014; Kambites and Owen, 2006) are especially relevant for urban settings. Moreover, coordination between the development of green elements and built-up areas has been encouraged for better control and guidance of urban expansion (Kambites and Owen, 2006). Multi-functionality is reflected in the combination of functions fulfilled by the GI which cover social, economic, ecological (Hansen and Pauleit, 2014, Iojă et al., 2014) and cultural aspects (Lafortezza et al., 2013; Lewicka, 2013). Such an intertwining of functions is particularly relevant in urban areas, allowing the limited space to be used more effectively (Ahern, 2007). Supporting the connectivity of the green elements enables the creation of a network that works as a whole and not as separate unrelated parts (Benedict and McMahon, 2006). Connectivity allows ecological processes to be maintained by permitting flows and movement of species (Hansen and Pauleit, 2014). Green infrastructure planning is recommended for addressing issues at multiple scales, from the parcel to urban region to national level, and for considering a high diversity of green elements, including street trees, gardens and parks (Ahern, 2007). Recently, authors have emphasized the need to plan GIs so that they can contribute to creating a sense of place and enhancing the feeling of identity (Hunziker et al., 2007; Roe and Mell, 2013; Rouse and Bunster-Ossa, 2013).

Although there are many studies which address GI planning, most of them seek to promote its benefits rather than critically reflect on bridging theoretical consideration with implications for planning practice (Lennon et al., 2017). Thus, it remains unclear how current spatial plans address the green infrastructure. A solid understanding of how the principles are applied in practice would pave the way for theoretically based advances in GI development and support the science – practice knowledge transfer. Furthermore, building this knowledge can be seen as a necessary step towards future comprehensive evaluations and quality assessments of GI planning.

In our quest to build a better understanding of the current European

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approaches to GI planning, we focus on the urban region level (i.e. often refed to as metropolitan area, greater area, city region). While acknowledging that there are multiple levels at which GI planning can take place, ranging from local to European-wide, we consider strategic spatial planning practised in urban regions as most appropriate for our aim. An increasing number of urban regions are consolidating strategic planning as a tool to tackle contemporary environmental challenges, including climate change and flood management, for which GI acts as a means of adaptation (Gill et al., 2007). Strategic plans adopted at urban region level often regulate, orient and coordinate the objectives and proposals of municipal plans (Elinbaum and Galland, 2016; Soria and Valenzuela, 2013), and thus serve as reference for decisions taken at local level, including the implementation of GI projects (Forman, 2008; Oliveira and Hersperger, 2018). We focused on the urban region level also because we believe the geographic coverage of strategic plans is best suited for assuring coherence between the functionality of green areas located in urban centres (e.g. urban parks) and those in the surrounding hinterland (e.g. nature protection areas, cultural sites), while the goals set by the plans, for up to 40 years in the future, help build long-term visions. The focus on the urban region is also a complementing recent work on green infrastructure planning within the Green Surge Project (www.greensurge.eu) that focused primarily on the city (i.e. local) level.

The few studies (Austin, 2014; Caspersen et al., 2006; Cassatella, 2013; Mell et al., 2017; Thomas and Littlewood 2010) which have pursued an analysis of how GI has been integrated into strategic spatial plans have focused on countries with a long tradition of landscape and green area management or have investigated the contextuality and specificities of particular urban regions. To our knowledge, the only explicit attempt to evaluate how planning principles have been accounted for in policy and practice have been pursued by Davies et al. (2017), as part of the Green Surge project, and by Mell et al. (2017). Davies et al. (2017) addressed the principles from the perspective of the planning approach (i.e. “connectivity”, “multi-functionality”, “grey-green integration”, “multi-scale”), the planning process (i.e. “strategic”, ”inter- and transdisciplinary”, “social inclusive”), and policy themes (i.e. “biodiversity”, “ecosystem services”, “climate change adaptation”, “green economy”, “human health”, “social cohesion”) and showed the existence of gaps regarding the scope and level of consideration. Mell et al. (2017) explored the way the principles “connectivity”, “multi-functionality” and “access and sustainable landscape/water management” have been followed in landscape planning in Germany and the United Kingdom. The findings revealed a role of regional planning bodies in experimenting with GI planning approaches in Germany and a heterogeneous interpretation of the term GI in the United Kingdom as a result of reforms within the planning system. The emergence of the term GI in strategic plans in England has been documented by Thomas and Littlewood (2010) to be the result of coalitions of actors feeding the term into the plans. In Ireland, Lennon et al. (2017) observed that the term GI was rapidly adopted because it was considered a better concept than “ecological networks”, which was not able to capture the interest of urban planners. Furthermore, by using the terms “green” and “infrastructure”, several professional disciplines (e.g. landscape architecture, transport planning, park management) have been able to raise the profile of their planning objectives. Specificities of strategic GI planning have been discussed for several urban regions. For instance, Caspersen et al. (2006) addressed the need to strengthen the coordination between municipalities and urban regional authorities in Greater Copenhagen in order to efficiently implement the vision of green wedges. Similarly, Cassatella (2013) described the conditions behind the successful implementation of the Corona Verde project in Turin, and Austin (2014) described the integrated nature and human systems approach followed in the strategic plan of the Stockholm urban region. Nevertheless, an overview of European practices at the urban region level is still lacking.

Existing comparative studies of GI which provide overviews at the European level have so far focused on cities and investigated quantitative aspects, such green space availability (Kabisch and Haase, 2013), determined the level of compliance between greenspace planning and the principles of planning approaches, processes and policy themes (Davies et al., 2017), or identified conditions for successful planning and management (Baycan-Levent et al., 2002). As a great emphasis is being placed by the European Commission (2013) on the strategic planning of GI and the need to mainstream GI into spatial planning and territorial development, we consider an assessment of current practices of GI integration into strategic planning of urban regions to be timely. Thus, we address the following research questions:

1) which principles of GI planning are followed in strategic plans of urban regions?
2) can we identify different approaches to GI integration into strategic planning?

2. Methodology

2.1. Case study selection

To answer the research questions, we focused on the strategic planning of European urban regions. The first criteria for case selection was the existence of a strategic spatial planning document which addresses GI planning at the urban region level. Additionally, case studies were selected to cover: (a) the diversity of European legal planning traditions described by Newman and Thornley (1996), (i.e., Napoleonic, Germanic, British and Scandinavian) and planning systems identified by The EU Compendium of Spatial Planning Systems (EC, 1997) (i.e., comprehensive integrated, land use management, regional economic and urbanism); (b) a variety of terms to refer to the GI and its components (e.g. green network, wedges, ecological network), (d) urban regions with a long experience in strategic planning as well as urban regions where strategic plans are a rather new planning instrument, and (e) different urban regions in terms of geographical extent, population size and climatic conditions. The final sample consisted of 14 case studies spanning 11 countries (Fig. 1). The geographical extent of the urban regions varied from 160 km^2 in Brussels to 6500 km^2 in Stockholm, the population size spanned from approximatively 600.000 inhab. in Helsinki to 8.7 mil. inhabitants in Greater London, while the climatic conditions reached from warm Mediterranean to temperate continental and temperate oceanic climates. These 14 cases are considered enough to derive some generalized findings on European urban regions.

We retrieved the strategic plans from the websites of the planning authorities. Depending on the characteristics of the planning system, the strategic plans took the form of regional development guidelines, strategic development plans, metropolitan plans, mission statements or strategic visions. Size and complexity of the plans varied from urban region to urban region, ranging from plans approximately 50 pages long with mainly textual explanations and rather poor consideration of green aspects (e.g. Barcelona) to plans up to 400 pages long with distinct subchapters on GI, where textual descriptions are accompanied by cartographic representations (e.g. London). Not all plans were in force at the time when the analysis was conducted. Some plans were in the public debate phase (i.e. Brussels, Hannover), while approval of one plan was delayed for several years due to disagreements regarding implementation of several strategic transportation infrastructure projects (i.e. Lisbon).

In cases where they existed, supporting planning documents, such as technical notes, supplementary planning guidance, implementation guidelines were used to support a better understanding of the terminology used in each plan, while the official website of the planning authorities were consulted to obtain information on the planning context. When necessary, local authorities were contacted to ask for clarifications. The list of the reviewed planning documents can be found in Appendix A.

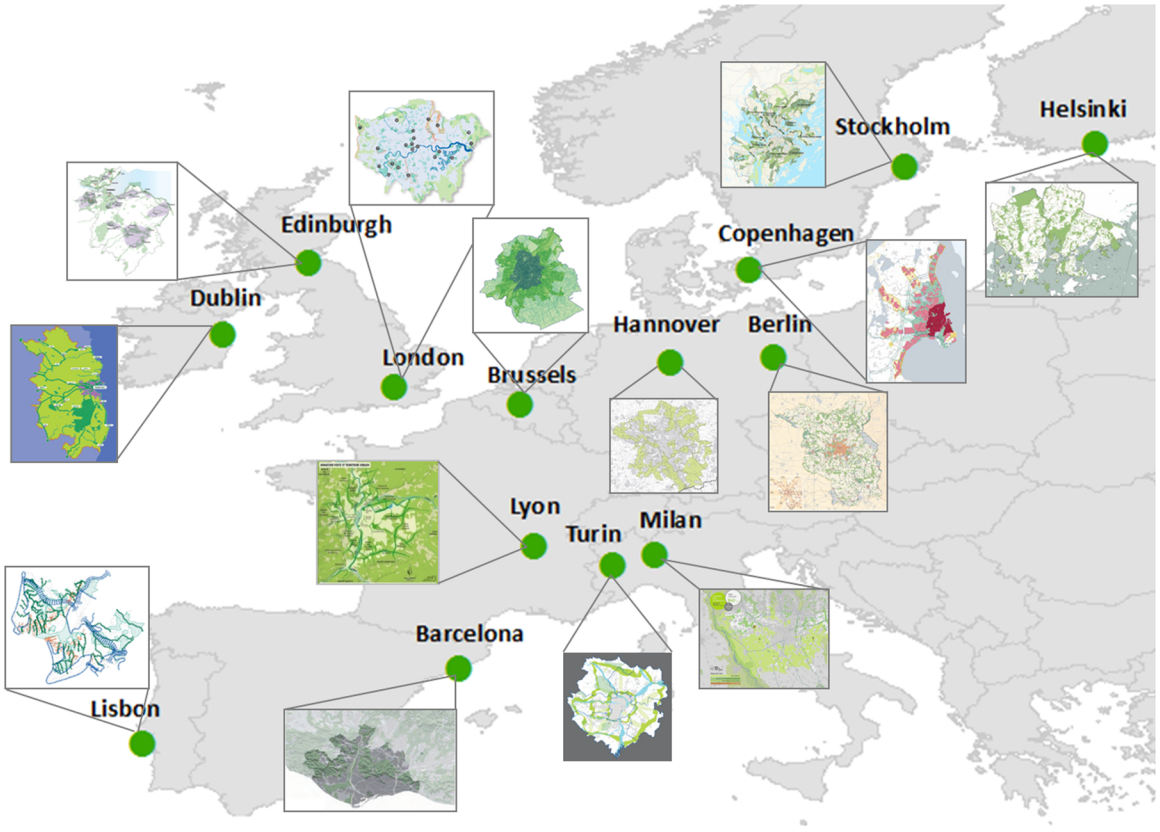

Fig. 1. Selected case studies.

2.2. Content analysis of strategic planning documents

A protocol was developed to perform the content analysis of the strategic plans (Hsieh and Shannon, 2005) and gather the data. The protocol contained 35 predefined items (i.e. questions) grouped into three categories addressing: (1) aspects regarding the plan and the planning context, such as the name of the plan, its legal status, year of approval and planning authority in charge of implementation (items 1–5); (2) general aspects on how GI is discussed in the plan, referring to clarity of GI definition, inclusion of GI aspects in individual chapters, and sections of the plan in which GI is discussed (items 6–11); and (3) the followed GI planning principles as visible in the text and cartographic representations of the plan (items 12–36). The detailed list of protocol items can be found in Appendix B. The data collected by applying the protocol offered an overview of GIs in strategic spatial plans. However, it did not touch on the performance and implementation of the plans.

The planning documents were read in order to address the protocol items. This method was preferred to a keyword-search analysis because of the diversity of terms used to refer to GI (e.g. green network, green wedges, ecological network) and its components, such as corridors (e.g. green chain, green route) and patches (e.g. greenbelt, fingers). Hence, we analysed the plans, irrespective of if they contained the term "green infrastructure" or not. Moreover, reading the documents was particularly useful to verify the coordination between GI and other strategic planning domains, as they are regularly described in separate chapters. Language assistance from native speakers working or studying in the field of planning was provided for analysis of plans not available in English, specifically the plans of Copenhagen, Berlin-Brandenburg, Hannover, Milan, Torino, Lyon, Lisbon and Brussels.

To determine which principles of GI planning were followed in the strategic plan, we made use of the principles discussed in the introduction: *coordination*, *multi-functionality*, *connectivity*, *multi-scale planning*, *diversity* and *identity*. *Coordination* was investigated regarding seven strategic planning domains: built-up development (Hansen and Pauleit, 2014), water management (EEA, 2011), climate change mitigation (Niemelä, 2014), food provision (Rolf et al., 2017; Seto and Ramankutty, 2016), quality of life (Tzoulas et al., 2007) and improvement of air quality and cultural assets conservation (EEA, 2011). The protocol also included an open question (i.e. item 19) to identify any other planning domains that were coordinated with GI, as evident in the plans. *Multi-functionality* was addressed regarding social, ecological, economic and cultural functions provided by GI. We investigated if *connectivity* was addressed by the plan, and if the plan focused only on structural aspects or addressed functionality for both nature and humans. Plans were analysed in order to identify if GI is described as part of a *multi-scale* network, from the national to neighbourhood level, or if the plan provides only site-specific information (Benedict and McMahon, 2006), for example on particular projects. To account for the *diversity* of green elements, we differentiated between two management types (i.e. natural and semi-natural; managed), each of which includes two categories of size (i.e. large; medium and small). For example, large managed green elements were considered to be agricultural lands that are part of the green network, whereas medium and small managed elements referred to small parks and green roofs. Finally, we investigated if the plan makes any reference to GI as a means to strengthen the sense of place and local *identity* by discussing community involvement in GI management. Detailed data on planning principles followed in each urban region are provided in Appendix C.

The answer to the protocol items in each of the first two categories (items 1–11) was documented as text, while the answer for the third category, namely items addressing the planning principles (items 12–36), was coded according to Table 1.

Each sub-category was coded according to two to four classes which measure the level at which a planning principle is considered in the planning documents. In the case of principle *coordination*, we coded as

Table 1
Green Infrastructure planning principles: rules for coding.

GI planning principles	Sub-categories	Each sub-category was coded according to these classes
1. Coordination of GI planning with other strategic domains	a) Built-up development b) Water management c) Climate change adaptation d) Food provision e) Quality of life f) Air quality g) Cultural assets conservation h) Other	1. Domain not considered in the plan 2. No coordination 3. Weak coordination 4. Strong coordination
2. Multi-functionality	a) Social functions b) Ecological functions c) Economic functions d) Cultural functions	1. Not considered 2. Poor consideration 3. Detailed consideration
3. Connectivity of GI elements	a) Structural connectivity b) Functional connectivity for animal and plant species c) Functional connectivity for humans	1. Not considered 2. Poor consideration 3. Detailed consideration
4. Multi-scale planning of GI	a) GI part of a national network b) GI part of a regional network c) GI planning at local (municipal) level d) GI planning at neighbourhood level e) Site specific GI planning	1. Not considered 2. Poor consideration 3. Detailed consideration
5. Diversity of GI elements	a) Large natural and semi-natural areas b) Large managed areas c) Medium and small natural and semi-natural areas d) Medium and small managed areas	1. Not considered 2. Poor consideration 3. Detailed consideration
6. Identity building	Identity building	1. Identity building considered 2. Identity building not considered

"Strong coordination" cases where references to a strategic planning domain (e.g. climate change adaptation) are provided in detail (i.e. as measures, actions, projects) in both sections of the plan dedicated to GI and that specific planning domain, while we coded as "Weak coordination" cases where such references were few or general. The "No coordination" category was included to refer to situations where a planning domain is discussed in the plan but there is no reference to GI. The "Not considered" category was additionally included in order to cover plans which do not address a particular strategic domain. In the case of the other planning principles, the sub-categories were coded as "Not considered" when no information was found in the planning documents about it, as "Poor consideration" when the sub-category was mentioned in the plan but with no details about its operationalization (e.g. no details about related measures, actions, projects) and as "Detailed consideration" when such details were provided. Similar methods for plan evaluations were adopted by Rudolf and Grădinaru (2017) to assess the quality of local plans in Switzerland.

2.3. Data analysis and classification of GI planning strategies

Results regarding the plan and the planning context, as well as aspects referring to clarity of GI definition, individual chapters on GI and sections of the plan in which GI is discussed (items 1–11) are reported in a qualitative synthetized manner. Results on items 12–36 are reported in detail to show the level of consideration for each sub-category of each principle. Furthermore, we classified the case studies according to single principles and overall. The overall assessment allowed us to identify different approaches to GI integration into the strategic planning of European urban regions. The assessment on single principles provided information on which urban regions are similar based on the level of consideration of a certain principle and its components in the plan (i.e. sub-categories).

The classifications were performed through hierarchical cluster analysis (HCA) based on average linkage between groups (Rokach and Maimon, 2005). The Dice similarity index was used to determine linkages because this measure uses a double weighting of matches and provides a better identification of the clusters than other indices. The resulting dendrograms, representing the nested grouping of urban regions and the similarity levels at which groupings change, were used to interpret the findings. The smaller the distance at which clusters unite on the dendrogram, the more similar the approaches of GI integration into the plans are. In contrast, a greater distance at which clusters unite indicates larger differences in planning approaches. Five separate HCAs were performed for the principles *coordination*, *multi-functionality*, *connectivity*, *multi-scale planning* and *diversity*. We did not perform a HCA for the *identity* principle because it was poorly considered in the reviewed plans and doing so would have led to a HCA output containing only two clusters. However, we did include this principle in the overall assessment.

3. Results

The first subsection of the results describes the qualitative findings regarding the terminology used within strategic plans to refer to the GI and its components, the clarity of the definitions and the plan section where GI is discussed. The second and the third subsections include quantitative findings regarding each GI planning principle and the identified approaches to GI integration into strategic spatial plans.

3.1. General aspects regarding GI in strategic spatial plans

To refer to the overall network of green spaces, the term "green infrastructure" was used in only a few plans (i.e. London, Dublin, Barcelona), while the majority adopted other terms including "green network" (i.e. Edinburg, Helsinki), "green wedges" (i.e. Stockholm, Copenhagen) or "ecological network" (i.e. Hannover, Milan, Lisbon, Turin). Depending on the language, other terms, such as "Corona Verde" in Turin, "l" armature verte" in Lyon and "maillage vert" in Brussels, were used to communicate the overall concept of an interconnected and multi-functional network of green spaces. To ensure consistency, for the reminder of the paper we refer to GI in a general manner, irrespective of the term used in the plans.

Plan sections in which GI was discussed strongly depended on the overall structure of the document. Only four plans mentioned the GI in the fact-base section of the plan (i.e. introductory part referring to the context and future trends and the basis for development of the plan's objectives), while in ten plans GI was part of the vision and goals, strategic issues or key domains. All reviewed plans contained measures,

specific tasks or actions, or at least policy recommendations for GI preservation and management.

Eight plans contained clear definitions explaining the purpose, components and functions fulfilled by the GI, while in six plans the term was used vaguely to describe the green and open spaces, or there was no definition at all. Good examples were the definitions provided in the plans of London, Dublin, Copenhagen and Turin, which explicitly referred to the fulfilled functions, provided benefits, spatial distribution, size and management types of GI elements. In the plans of the two analysed German urban regions, green spaces were described as falling under the umbrella of cultural landscapes and open space preservation.

3.2. Principles of GI planning as followed in strategic spatial plans

Few plans explicitly mentioned the principles they follow to guide the development of GI. For example, some strategic plans mentioned *connectivity* (Brussels, p 67, Lyon DOG, p 87) and *multi-functionality* (Lyon, DOG p. 83), while others, such as Stockholm, describe how "the planning principles that are the primary guides in the development of the green structure are a dense, vibrant urban environment with parks and green spaces and a coherent green structure and cross-connections in the transport system". For situations in which plans did not contain any explicit information, the textual information and cartographic representations were analysed to check for indirect references. For instance, the Milan plan did not mention the *diversity* principle as being followed, but the plan provided information regarding the diversity of green elements considered (e.g. agricultural parks, natural reserves).

3.2.1. Coordination with other strategic domains

The strongest coordination in strategic plans was identified to be between Green infrastructure and objectives on increasing quality of life, specifically in 11 out of the 14 plans (Fig. 2). Green infrastructure was considered to encourage sport activities and healthy lifestyles and to increase the aesthetic value of the urban environment, thus creating more attractive places to live, work and visit. In 10 out of the 14 reviewed plans, GI was strongly coordinated with objectives on built-up development. Green infrastructure was regarded as an urban containment tool (e.g. the green belt in London and Dublin) or a necessary element of urban design (e.g. Helsinki), or the green elements and built spaces were considered two integral components of the territorial development model of urban regions (e.g. Copenhagen, Lisbon). A weak coordination between GI and built-up development was observed in the Barcelona strategic spatial plan, where the need to develop multifunctional public spaces, including green spaces, is generally discussed in respect to the territorial development of the city, but without providing information on actions to pursue such developments. Green infrastructure was considered strongly coordinated with cultural assets conservation in 7 out of the 14 plans, for instance by including Royal Parks into the GI in London. Regarding water management, in half of the plans recognized the importance of GI in assisting flood management and mitigation (e.g. Hannover), protecting coastal zones and estuaries (e.g. Dublin) or protecting underground water reserves (e.g. Lisbon). In some cases, GI was addressed in parallel with the Blue Infrastructure (e.g. London, Brussels). Although more than half of the reviewed strategic plans addressed climate change, a distinction was made between climate change mitigation (i.e. reducing the human impact on the environment) and adaptation (e.g. developing measures to cope with and reduce the effect of climate change on the urban environment). Green infrastructure was coordinated with adaptation measures in only 5 out of the 14 plans. Mitigation measures addressed energy efficiency, reduction of carbon emissions and smart transport systems, such as in Barcelona, Stockholm and Lisbon. Even less attention was paid to the potential of GI to improve air quality. Other planning domains that have been coordinated with GI planning are urban region branding, economic attractiveness, regeneration of contaminated soils and transportation.

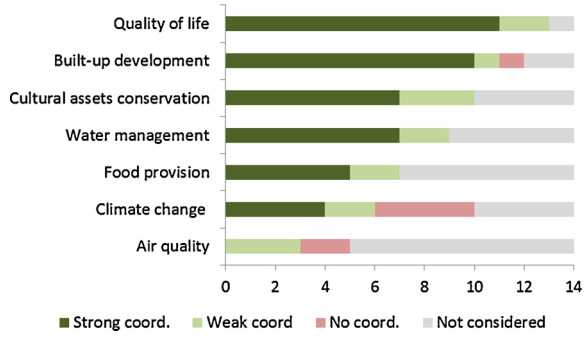

Fig. 2. Coordination between GI and other spatial planning domains.

The HCA dendrograms (Fig. 3a) identify three clusters of urban regions regarding the coordination between GI and other planning domains. All urban regions included in the first cluster (red) strongly coordinate GI planning with five to seven strategic planning domains. They all are urban regions with a long experience in strategic planning. They have in common coordination of GI with built-up development, food provision and quality of life, and at least four of the regions additionally coordinate GI with climate change adaptation, water management and air quality. The second cluster (green) includes seven urban regions which share a strong coordination between GI and cultural assets conservation, and to a lesser extent a strong or weak coordination with built-up development and quality of life.

3.2.2. Multi-functionality

The multi-functionality principle was partially followed in the strategic plans. Great emphasis was placed on social and ecological functions, but less attention was paid to economic and cultural aspects, which were poorly or not at all considered in half of the plans (Fig. 4). The results of the HCA revealed five clusters representing different combinations of functions (Fig. 3b). The first cluster (red) was composed of six urban regions that promoted multi-functional planning by considering all the four assessed functions, predominantly in detail (referring to the coding category "Detailed consideration" in Table 1). The second cluster (green) included urban regions that considered in their plans the social and the ecological functions in detail but considered economic functions poorly and varied in the consideration of cultural functions. The other clusters (blue, orange and yellow) included urban regions that focused in detail mainly on only two out of the four functions.

3.2.3. Connectivity of GI elements

Structural connectivity (i.e. spatial configuration of green elements) is considered in all reviewed plans, while functional connectivity for plant and animal species (i.e. movement of species among green elements) and for humans (i.e. flow of people among green elements) is considered in detail in 10 out of 14 plans (Fig. 4). The HCA revealed a large cluster (red) including 10 urban regions which considered all types of connectivity, mainly in detail (Fig. 3c). A smaller cluster (green) is composed of urban regions which address structural connectivity and connectivity for humans in detail, while functional connectivity for animal and plant species is poorly or not at all considered by the strategic plans. The Dublin region stands out because its plan gives detailed consideration of connectivity for humans and poor consideration of the other types of connectivity.

3.2.4. Multi-scale planning of GI

All analysed plans discussed GI as being part of a regional network, and the majority of plans considered GI planning with respect to other scales, from the national to neighbourhood level, including site-specific information. The findings from the HCA (Fig. 4d) revealed a large cluster (red) composed of eight urban regions with plans that address all planning scales from the national to site level. A second cluster (i.e.

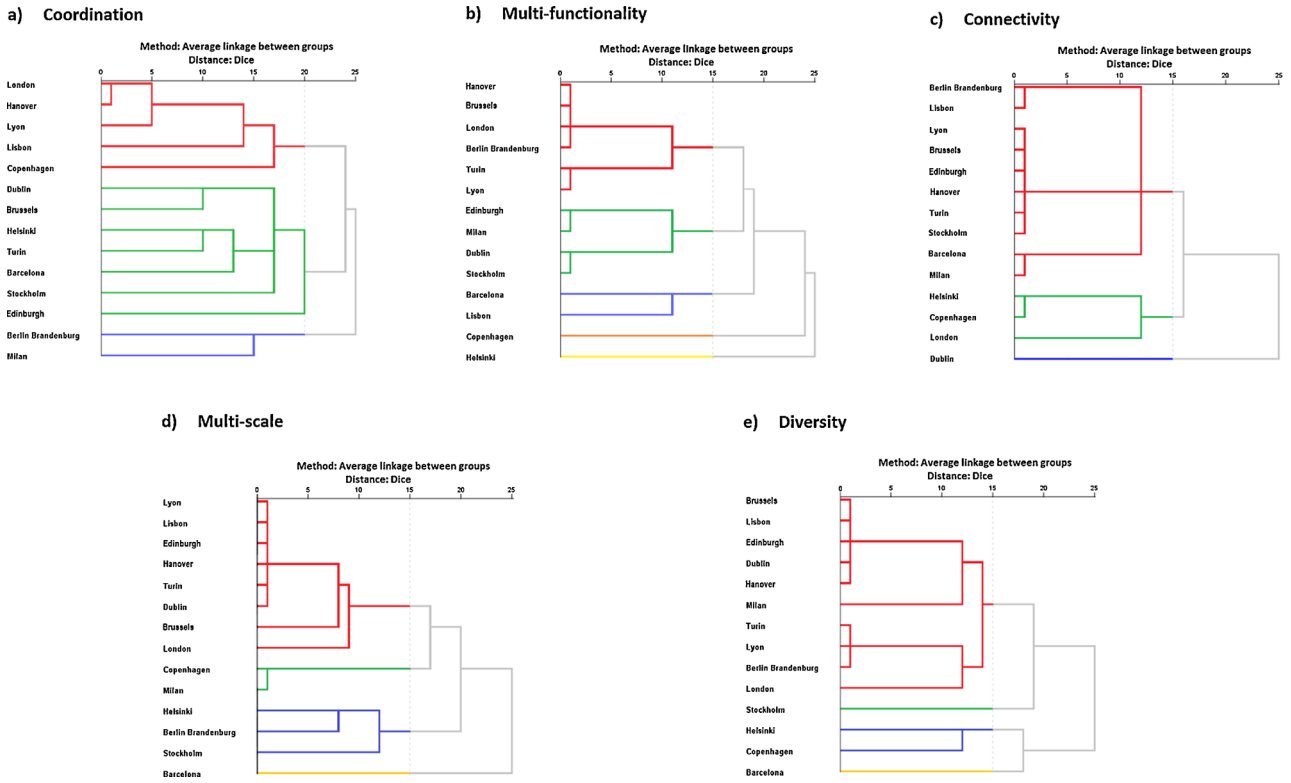

Fig. 3. Dendrograms resulting from the HCA of urban regions for each GI planning principle investigated.

green) is composed of two urban regions that consider the regional and local scales, as well as providing information on site-specific GI planning. The third cluster (blue) consists of urban regions for which strategic plans address in detail GI planning at the national and regional levels, while mainly disregarding the other scales. Barcelona stands out as a separate cluster (yellow) because its strategic plan addresses only the regional and local scales, both in a poor manner.

3.2.5. *Diversity of GI elements*

Regarding the diversity of considered green elements (Fig. 3), we observed that plans mainly refer to managed areas of large (e.g. agricultural land, large urban parks) and medium and small size (e.g. allotments, green roofs) (Fig. 4). Natural and semi-natural areas of medium and small size, such as nature reserves or bogs, were mentioned as being part of the GI in only half of the reviewed strategic plans. The results of the HCA show that ten urban regions (red cluster)

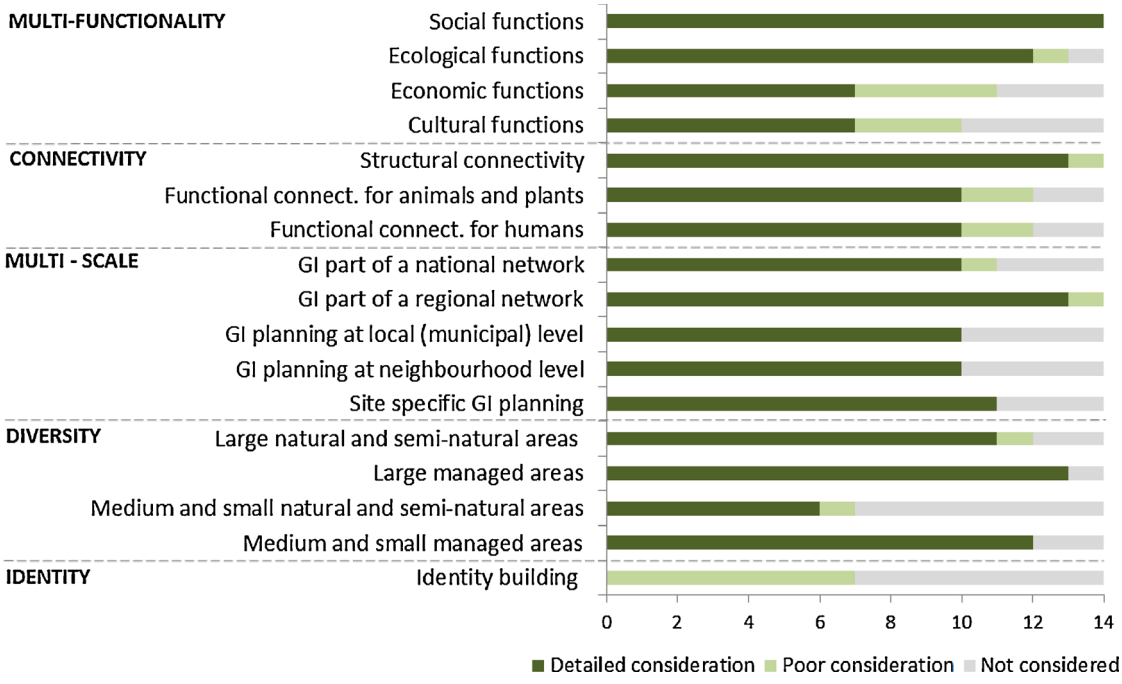

Fig. 4. Green Infrastructure planning principles followed in strategic plans.

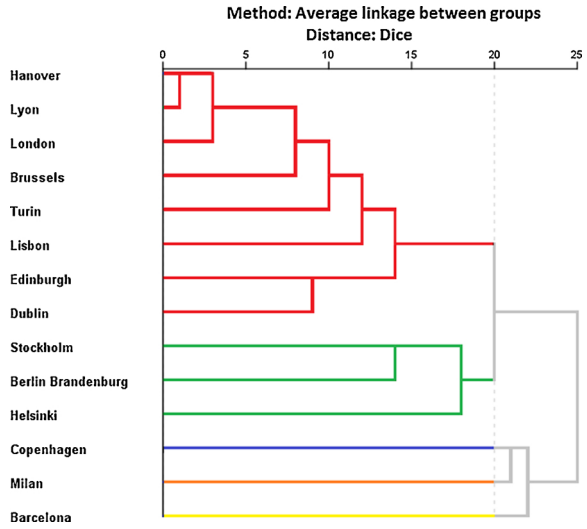

Fig. 5. Approaches to GI integration into strategic spatial planning as revealed by the HCA dendrogram including all planning principles.

have in common the consideration of large sized green areas of both management types, while some variation exists among them regarding consideration of medium and small sized green areas. The Stockholm (green cluster) region stands out because its strategic plan addresses only large-sized green areas called green wedges. The other two clusters (blue and yellow) include urban regions that mainly focus GI on managed green elements of medium and small size.

3.2.6. Identity building

GI planning as a means to strengthen or build place identity was mentioned in half of the reviewed strategic plans, specifically in Dublin, Barcelona, Lisbon, Milan, Stockholm, Helsinki and Copenhagen. However, the identity principle was poorly considered in all these plans.

3.3. Approaches to GI integration into strategic spatial planning

By including all planning principles in one HCA (Fig. 5), we were able to identify two different approaches to GI integration into strategic spatial planning practised in the large majority of European urban regions. We call them the *integrated approach* and the *socio-cultural approach*. Three other approaches were identified as practised in individual urban regions.

The integrated approach to GI planning for both humans and nature is followed by urban regions in the first cluster (red). The cluster includes urban regions for which GI is well-coordinated with several planning domains and multiple GI functions are considered at various planning scales. The strategic plans in this cluster consider a high diversity of green elements and the structural and functional connectivity among them. Moreover, in these urban regions GI planning is intended to strengthen the sense of place and identity.

The socio-cultural approach to GI planning is followed by the three urban regions included in the second cluster (green). In these regions, GI is strongly coordinated with built-up development and cultural assets conservation. Furthermore, the strategic plans address planning of large natural and managed green areas of national and regional importance. The social and cultural functions fulfilled by GI are of main importance.

The other three clusters (blue, orange, yellow) each consist of a single urban region. They have in common planning of GI for increasing quality of life by focusing on social functions, although none of the plans mention the GI as strengthening the sense of place and identity. However, as clusters merge at a greater distance, the similarities among the planning approaches in these three urban regions are less evident compared to those among the clusters mentioned above. Copenhagen considers the coordination with several strategic planning domains (e.g. built-up development, climate change adaptation) and focuses on social and economic functions of the managed GI elements. In Milan, the level of coordination between GI and other strategic domains is weak, but the plan addresses all connectivity types, several functions of GI and a rather high diversity of green elements. In Barcelona, GI is coordinated only with increasing the quality of life, whereas aspects of multi-scale planning are poorly considered and little information is provided regarding the diversity of green elements.

4. Discussion

All planning principles, that is *coordination*, *multi-functionality*, *connectivity*, *multi-scale planning*, *diversity* and *identity*, are followed by at least half of the analysed plans. However, some principles are followed more often than others. Furthermore, certain variation exists regarding the interpretation of each planning principle. All urban regions engage in a certain level of *coordination* between GI and other strategic domains, but most often coordination is performed with objectives on improving quality of life and steering built-up development. Plans mainly focus on the provision of social and ecological *functions*, whereas cultural and economic functions are mentioned less frequently. For the majority of urban regions, *connectivity* is at the core of the planning strategies and is sometimes even addressed in a differentiated manner to cover connectivity for humans and biological connectivity. The *multi-scale* principle is clearly taken into account, as more than half of the urban regions address the GI design at all scales from the national to site level. Regarding the *diversity* of green elements, most plans focus on managed areas of varying sizes. The *identity* principle, although discussed only briefly, was identified as followed in half of the reviewed plans.

The level of *coordination* of GI with strategic planning domains varies greatly between domains but is strong in terms of quality of life, built-up development, cultural assets conservation and water management. Our findings thus largely reflect the recommendations of the European Commission (2013), which emphasize the supporting role of GI for nature conservation, water management and prevention of land conversion to impervious surfaces. A notable exception is the rather poor coordination between GI and climate change adaptation objectives in many plans. This might be explained by the fact that several plans have been adopted in times when climate change issues did not yet receive much attention. Furthermore, differences in plan's focus on adaptation or mitigation objectives might be related to specific events in the past (e.g. heat waves) and predicted climate change effects. For instance, London was one of the urban regions which proposed adaptation measures in response to the 2003 heat wave but also in response to climate change predictions of a temperature increase of up to 2.7 °C by 2050 (Greater London Authority, 2015, p 36). In contrast, Stockholm is more concerned with a possible increased risk of flooding in low-lying areas of the region and greater energy costs (Johnson, 2012); thus, the Stockholm strategic plan addresses only mitigation measures such as reducing greenhouse gas emissions.

The comparison of clustering for the single principles (Fig. 3) shows that the urban regions cluster together in unique ways for each principle. This is quite remarkable and indicates that none of the 14 plans analysed follows the same pattern as another plan in terms of the degree to which the planning principles are considered. We don't see a school of thought or a common strategy. This leads to the observed great variation in addressing green infrastructure in plans. Most likely the observed variation is due to the strong context-specific development of green infrastructure in the strategic spatial plans. Furthermore, in methodological terms, the variation indicates that the five principles represent independent aspects of green infrastructure.

We were able to identify two main approaches to the integration of GI into strategic spatial planning. An integrated human and nature approach to GI planning is characteristic of eight urban regions. This approach is comprehensive and addresses the interplay between social and ecological

systems, thus having the potential to be effective and able to handle the complex issues which characterize urban environments (European Commission, 2013; Hansen and Pauleit, 2014). The socio-cultural approach is followed by three urban regions for which green areas play an important role in urban aesthetics, cultural landscape preservation and conservation of historical heritage. Such regions might have other instruments to address planning of natural components, such as landscape plans in Germany or the regional land use plan in the Helsinki region.

In addition to these two main approaches to GI planning, different approaches were observed in three urban regions with a rather long tradition of strategic spatial planning. In Copenhagen, green areas have been at the core of the territorial development model promoted since 1947 through a series of Finger Plans (Caspersen et al., 2006), and which is based on the division of the urban region into built-up areas (i.e. fingers) and green and open spaces (i.e. green wedges). Besides the role GI plays in urban containment, its primary purpose is to facilitate general outdoor activities. However, several other functions are recognized as important, such as the provision of land for extensive agriculture. In contrast, in Barcelona, strategic planning has consolidated since the first strategic plan was adopted in 1990. In the years since then, the main focus of strategic planning has been on economic development, social aspects and city branding, and only recently the development of a metropolitan GI has been integrated into the strategic plan as one of the objectives. In Milan, the aim and structure of the current strategic plan has changed since the previous strategic planning initiative in 2005, which promoted the concept of liveability through a number of innovative socially and culturally oriented projects (Balducci et al., 2011). Recently, the urban region went through an administrative reform which aimed to increase the level of coordination between the urban region (i.e. Città Metropolitana di Milano) and the higher planning level (i.e. Regione Lombardia) in, among other activities, planning of the "ecological network".

The description of the current state of green infrastructure in strategic spatial plans can serve as starting point for future research on, for example, the reasons for the observed differences and the strategies pursued by various actors during the plan-making process. Since many interests are commonly negotiated during the plan-making process the way GI planning principles are addressed in the plans is likely a combination of factors, such as preferences by political leaders, the influence exerted by the professionals involved in plan-making, as documented by Fedeli (2017) for Italian strategic plans, a way of communications as suggested by Klein et al. (2016) for Helsinki in terms of how environmental protection departments communicate climate change adaptation information is to planners, and national GI policy influence as Mell et al., 2017 documented for Germany and the UK. The observations could also be used to determine if the three stages of GI evolution defined by Mell (2015) fit the strategic plans of European urban regions, i.e. exploration (i.e. a small number of ideas are discussed), expansion (i.e. a broader discussion on principles, utility and values of GI) and consolidation (i.e. a more refined approach to evidence-based policy making). Indeed, in our research, we identified urban regions that introduced GI in their plans for the first time (e.g. Barcelona) as well as plans in which the GI has consolidated over a succession of plans (e.g. London).

Findings show that a certain level of ambiguity surrounds the definition of the GI concept provided in the plans. Ambiguity has been described by Wright (2011) as not necessarily being a negative attribute, since it allows "the concept to adapt to the varied requirements of different spatial and temporal situations", while a clear definition "would be restricting freedom in its interpretations and applications". In parallel, research on the development, adoption and use of spatial concepts in planning shows contradictory views. Some authors argue that concepts which are stretched and vague tend to loose meaning and the ability to influence actions (Davoudi, 2003; Rauhut, 2017). Other authors emphasize that the more meanings a concept accumulates, the more support it attracts, as mutually compatible and reinforcing meanings increase the mobilization capacity (van Duinen, 2013). However, in the context of individual strategic plans, lack of a clear definition could hamper the development of a functional network, considering that GI has a strong spatial dimension. For instance, as strategic plans are often implemented through projects completed at the local level (Oliveira and Hersperger, 2018), lack of clear information on what the GI components could lead to various disconnected interpretations.

Urban regions often select tailored spatial concepts (i.e. terms) in order to answer the local planning context and reveal information on the purpose of each GI component. For example, the term "Corona Verde" in Turin denotes the incorporation of both natural and cultural aspects, as green areas and cultural heritage linked to the Royal House of Savoy are part of the GI. In other cases, the integration of existing ecological networks (i.e. the Natura 2000 Network) into the strategic spatial planning process led to the dominant use of ecology-oriented terminology. However, it is not uncommon in Europe for the term "green infrastructure" to be lacking from urban plans (Davies et al., 2017). In addition to our findings, previous studies point out that the selection of terminology and the lack of common terms can also be dictated by the preferences of the professionals involved in the planning process (Lennon et al., 2017), the newness of the term (Davies et al., 2017), the lack of knowledge or understanding of the term "green infrastructure" or the use of terms already existing in national legislation (Niță et al., 2018).

No clear-cut pattern was observed regarding the way in which urban regions approach GI planning with respect to planning traditions. We put forward two hypotheses to explain these findings. The first is linked to the very nature of strategic spatial planning. This implies that strategic plans are forged to answer local challenges and to adapt to specific planning contexts (Albrechts, 2004), meaning that large variations could exist even within the same planning system (Fedeli, 2017). Furthermore, as Elinbaum and Galland (2016) note, despite the fact that strategic plans in Europe tend to converge in relation to the general themes they address (e.g. GI), certain variation also exists as a result of the unique institutional contexts in which plans are adopted. The second hypothesis is that the number of case studies used in this investigation might not have been sufficient to reveal clear patterns. In contrast to our findings, the study by Davies et al. (2017) on 20 European cities, including those from Eastern Europe, revealed that planning traditions might exert more influence on other aspects such as the quality of the GI and social inclusiveness.

5. Conclusions and recommendations

Based on the analysis of the 14 urban regions, we can provide some general recommendations to better address GI in strategic spatial plans. Actors involved in drafting strategic plans may need to be aware of how they approach and define GI in order to establish a realistic connection to existing implementation mechanisms. Clear definitions of GI and its components could help form a common understanding of the actions that need to be performed in order to create a functional GI and have visible effects on the ground. A stronger coordination between GI and other strategic domains is recommended, as it would open discussions about the utility of GI for the overall development of an urban region. Plans could benefit from dealing with relational aspects of GI (flows, dynamics) and incorporating more information regarding functional connectivity for people and plant and animal species. In particular, cartographic representations of the GI could be used more effectively to communicate the connectivity principle to the wider audience. Regarding multi-scale planning, although a strong emphasis is placed on the regional scale, plans could strengthen connections to the lower (e.g. municipal) and upper (e.g. national) planning levels. This point is especially relevant for urban regions where strategic plans play an important role in the vertical coordination of planning decisions. Strategic plans, and particularly those that follow a socio-cultural approach to GI planning, could benefit from a stronger emphasis on the role of GI in building a sense of place and identity. Irrespective of the

planning approach individual urban regions prefer to follow, GI could be used as an umbrella concept to strategically plan a network capable of providing benefits to humans and ecological systems.

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Appendix A. Strategic spatial plans and supporting planning documents reviewed in this research.

Urban region	Planning tradition[a]	Strategic spatial plan	Year of issuing or approval	Revisions and updates
Edinburgh	British/Land use management	SES PLAN – Strategic Development Plan	2013	Ongoing; expected to end in 2018
		Green Network Technical Note	2011	
		Green Belt Technical Note	2011	
London	British/Land use management	The London Plan − Consolidated with alterations since 2011	2015	Latest revisions from March 2016
		Green Infrastructure and open Environments: the All London Green Grid	2015	
Dublin	British/	Regional development plan of the Greater Dublin area 2010–2022 Volume 1 and Volume 2	2010	Ongoing; expected to end in 2018
Barcelona	Napoleonic/Urbanism	2nd Strategic Metropolitan Plan – Barcelona Vision 2020 (2010)	2010	Ongoing as part of adoption of a new general land use plan
		REM – Metropolitan strategic reflection	2015	
Stockholm	Scandinavian/ Comprehensive integrated	RUFS 2010 – Regional development plan for the Stockholm region	2010	Ongoing; expected to end in 2018
Helsinki	Scandinavian/ Comprehensive integrated	Helsinki – From city to city region	2009	–
Copenhagen	Scandinavian/ Comprehensive integrated	The Finger Plan A Strategy for the Development of the Greater Part 1 – Key messages, Part 2 – Planning Decision, Part 3 – Background Copenhagen Area 2013 – English summary	2013	Ongoing; expected to end in 2018
Berlin Brandenburg	Germanic/ Comprehensive integrated (+regional economic)	Model Capital Region Berlin – Brandenburg	2006	–
		LEPro 2007 – Development Programme for the Berlin-Brandenburg Region	2007	–
		LEP B-B 2009 – State Development Plan Berlin-Brandenburg	2009	Ongoing; expected to end in 2019
Hannover	Germanic/ Comprehensive integrated (+regional economic)	RROP – Regionales Raumordnungsprogramm Region Hannover 2015 (draft) and 2016	2015/2016	–
Milan	Napoleonic/Urbanism	Piano strategico della Citta metropolitana di Milano 2016	2016	2019
Torino	Napoleonic/Urbanism	Turin Metropolis 2025 – The third Strategic Plan of the metropolitan area of Turin	2015	Ongoing
Lyon	Napoleonic/Regional economic	SCOT – Project d'amenagement et de Developpement Durable (PADD); Document d'orientation generale (DOG)	2010	
Lisbon	Napoleonic/Regional economic (+urbanism)	Regional Spatial Plan of the Lisabona Metropolitan Area	Proposed 2010; approval postponed	Ongoing debate
Brussels	Napoleonic/Land use management	Plan Régional de Développement Durable PRDD	Proposed 2017; under public debate	–

[a]Planning traditions according to Newman and Thornely (1996) and The European Union Compendium of Spatial Planning Systems and Policies (1997); – The date of the revisions is not specified or undecided.

Appendix B. The protocol and the 36 items for the content analysis of the plans.

I. General aspects

Regarding the planning context

1. Name of the plan
2. Year of approval
3. Timeframe of the plan
4. Type of institution in charge of the strategic planning? (leading/coordination role)
5. Legal status of the strategic spatial plan

Regarding how GI is addressed in the plan

6. Is the GI concept mentioned in the plan?
7. In which section(s) of the plan is GI addressed?
8. If the plan's strategic objectives do not address GI directly, to which objective(s) is GI linked to?
9. Is GI discussed as individual chapter or subchapter?
10. If no, in which chapter/subchapter is GI discussed?
11. Does the plan provide a definition of GI?

II.Planning principles

Coordination with other strategic planning domains

12. .Is GI planning coordinated with built-up development planning?
13. .Is GI planning coordinated with water management planning in terms of physical and functional relations?
14. .Is GI planning coordinated with climate change mitigation?
15. Is GI planning coordinated with food provision?
16. Is GI planning coordinated with objectives on increasing the quality of life?
17. Is GI planning coordinated with objectives on increasing the air quality?
18. Is GI planning coordinated with cultural assets conservation?
19. Is GI planning coordinated with other domains?

Multifunctionality

20. Are social functions considered in the plan?
21. Are ecological functions considered in the plan?
22. Are economic functions considered in the plan?
23. Are cultural functions considered in the plan?

Connectivity

24. Is structural connectivity considered in the plan?
25. Is functional connectivity for animal and plant species considered in the plan?
26. Is functional connectivity for humans considered in the plan?

Multi-scale planning

27. Does the plan refer to GI as part of a national network?
28. Does the plan refer to GI as part of a regional network?
29. Does the plan refer to GI elements at local/municipal level?
30. Does the plan refer to GI elements at neighbourhood level?
31. Does the plan refer to GI as site specific?

Diversity of green objects

32. Are large natural and semi natural areas mentioned?
33. Are large artificial or managed areas mentioned?
34. Are medium and small natural mentioned?
35. Are medium and small artificial or managed mentioned?

Identity

36. Is the GI designed to allow users (citizens) to establish/strengthen local identity?

Appendix C. Data used as an input for Hierarchical Cluster Analysis.

GI planning principles	Sub – categories	Reviewed strategic spatial plans of the urban regions[c]													
		Edi	Lon	Dub	Bar	Sto	Hel	Cop	Ber	Han	Mil	Tur	Lyo	Bru	Lis
7. Coordination[a]	i) Built-up development	2	4	4	3	4	4	4	4	4	1	1	4	4	4
	j) Water management	3	4	4	1	3	1	1	4	4	1	1	4	4	4
	k) Climate change mitigation	3	4	3	2	2	2	4	1	4	1	1	4	1	2
	l) Food provision	1	4	1	1	1	1	4	3	4	3	1	4	1	4
	m) Quality of life	4	4	4	4	1	4	4	3	4	3	4	4	4	4
	n) Air quality	1	3	1	1	1	1	1	1	3	1	1	3	2	2
	o) Cultural assets conservation	1	4	4	1	3	4	1	4	4	1	4	3	4	3
8. Multi-functionality[b]	e) Social functions	3	3	3	3	3	3	3	3	3	3	3	3	3	3
	f) Ecological functions	3	3	3	3	3	1	2	3	3	3	3	3	3	3
	g) Economic functions	2	3	2	1	2	1	3	3	3	2	3	3	3	1
	h) Cultural functions	1	3	3	1	3	3	1	3	3	1	2	2	3	2
9. Connectivity[b]	d) Structural connectivity	3	3	2	3	3	3	3	3	3	3	3	3	3	3
	e) Functional connectivity for animal and plant species	3	2	2	3	3	1	1	3	3	3	3	3	3	3
	f) Functional connectivity for humans	3	3	3	2	3	3	3	1	3	2	3	3	3	1
10. Multi-scale planning[b]	a) GI part of a national network	3	2	3	1	3	3	1	3	3	1	3	3	3	3
	b) GI part of a regional network	3	3	3	2	3	3	3	3	3	3	3	3	3	3
	c) GI planning at local (municipal) level	3	3	3	2	3	1	3	1	3	3	3	3	2	3
	d) GI planning at neighbourhood level	3	3	3	3	1	3	1	1	3	1	3	3	3	3
	e) Site specific GI planning	3	3	3	3	1	1	3	1	3	3	3	3	3	3
11. Diversity[b]	e) Large natural and semi-natural areas	3	3	3	1	3	2	1	3	3	3	3	3	3	3
	f) Large managed areas	3	3	3	1	3	3	3	3	3	3	3	3	3	3
	g) Medium and small natural and semi-natural areas	3	2	3	1	1	1	1	1	3	3	1	1	3	3
	h) Medium and small managed areas	3	3	3	3	1	3	3	3	3	1	3	3	3	3
12. Identity[b]	a) Identity building	2	2	1	1	1	1	1	2	2	1	2	2	2	1

[a]Categories represent: 1–Domain not considered in the plan; 2–No coordination; 3–Weak coordination; 4–Strong coordination

[b]Categories represent: 1–Not considered; 2–Poor consideration; 3–Detailed consideration

[c]Urban regions: Edinburg, London, Dublin, Barcelona, Stockholm, Helsinki, Copenhagen, Berlin − Brandenburg, Hannover, Milan, Turin, Lyon, Brussels, Lisbon.

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