

Green infrastructure in metropolitan planning: a comparative analysis of the plans of three European capitals

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Abstract: Green infrastructure has become a central axis of contemporary spatial planning. However, European cities display significant differences in the way they conceptualise and classify their green systems. This article comparatively analyses the conceptual frameworks and typologies of green infrastructure present in three reference planning documents: the Plan de Infraestructura Verde y Biodiversidad of Madrid, the London Environment Strategy of the Mayor of London, and the Berlin documentary ensemble formed by the Charta für das Berliner Stadtgrün and the Handlungsprogramm Berliner Stadtgrün 2030. The analysis reveals paradigmatic convergences around the systemic-reticular approach and ecosystemic multifunctionality, but also substantive divergences regarding the scale of recognised components, classification criteria, and the integration of blue and grey infrastructure. The findings contribute to the debate on standardisation and contextual specificity in the planning of urban green infrastructure at the metropolitan scale.

1. Introduction

Over the past two decades, the concept of urban green infrastructure has undergone a profound epistemological transformation. It has evolved from a descriptive designation for parks and gardens into a strategically planned network of natural and semi-natural areas with environmental features that integrates ecosystem services, climate resilience, and social well-being (Benedict & McMahon, 2006; European Commission, 2013). This conceptual evolution has been reflected, albeit with distinct characteristics, in the planning instruments adopted by major European cities.

Increasingly, European capitals have addressed green infrastructure through a variety of planning instruments. Examining the conceptual frameworks through which cities define and classify green infrastructure is important because these frameworks determine which elements are considered part of the system, shape the indicators and standards used in urban planning, and facilitate metropolitan cooperation as well as the transfer of best practices (Tzoulas et al., 2007; Hansen & Pauleit, 2014; Laforzezza et al., 2018).

The aim of this study is to provide a set of practical lessons for improving the metropolitan planning of green infrastructure. To this end, the study analyses the convergences and divergences among the planning documents of three European capitals: Madrid, London, and Berlin. The analysis is based on qualitative methods, including document review and content analysis, and is organised around two analytical categories: (1) conceptual and institutional frameworks and (2) the specific regulations governing green spaces. The research adopts a comparative case study approach to examine how green infrastructure is incorporated into metropolitan planning.

The selection of the three case studies is based on three criteria. First, they are among the largest capitals in the European Union in terms of population, each characterised by highly complex metropolitan systems. Second, all three adopted dedicated green infrastructure planning instruments during the period 2018–2020, enabling a synchronic comparison. Third, they represent distinct planning traditions and regulatory frameworks — Anglo-Saxon (London), Latin (Madrid), and Germanic (Berlin) — thereby providing an opportunity to explore conceptual diversity within a shared European paradigm (Pauleit et al., 2017; Mell, 2016). While this heterogeneity offers analytical value by revealing how a common European paradigm is translated into different planning architectures, it also represents a methodological limitation, which is addressed in Section 4.

For Madrid, the Plan de Infraestructura Verde y Biodiversidad (PIVB) approved by the Ayuntamiento de Madrid is analysed (Ayuntamiento de Madrid, 2019a). For London, the London Environment Strategy (LES) produced under the mandate of Mayor Sadiq Khan and published in May 2018 (Mayor of London, 2018). For Berlin, the documentary system comprising the Charta für das Berliner

Stadtgrün and the Handlungsprogramm Berliner Stadtgrün 2030, approved in May 2020 by the Senatsverwaltung für Umwelt, Verkehr und Klimaschutz (SenUVK, 2020).

The article is structured in five sections. Following this introduction, the historical and conceptual context of green infrastructure is reviewed. Subsequently, the green infrastructure strategies of each plan are analysed. Finally, the results are discussed and the article closes with concluding reflections.

2. Green Space Systems: Concepts and Contexts

The Industrial Revolution marked the exponential growth of many large cities. To address the adverse effects of this expansion, concepts such as the ‘Garden City’ (Howard, 1965), the ‘Parks Movement’, and ‘City Beautiful’ emerged, assigning a leading role to green spaces in the configuration of cities. By 1933, the Athens Charter established that residential areas should incorporate vegetation and open spaces, consolidating a functionalist vision in which green areas were conceived primarily as components of the physical urban order: recreational green areas, land reserves, or devices for regulating growth.

The concept of landscape ecology, introduced by Carl Troll in 1939 and subsequently developed by McHarg (1971) through a layered approach to territorial analysis, marked a fundamental epistemological shift by positioning ecology as the foundation of territorial planning and design. In the 1970s, following the Stockholm Declaration of 1972, the oil crisis, and subsequent United Nations conferences, environmental issues entered governmental agendas. Then, in the 1980s, the Brundtland Report (1987) consolidated the concept of ‘sustainable development’ as a central premise of planning. This report questioned the development model of industrialised countries, highlighting the incompatibility between production and consumption patterns, the rational use of natural resources, and the carrying capacity of ecosystems.

In Europe, the 1992 reform of the Common Agricultural Policy, the Fifth Environmental Action Programme (EU, 1992), and subsequently the European Landscape Convention of 2000 progressively incorporated ecological and landscape concerns into spatial planning. In the late twentieth and early twenty-first centuries, territorial plans incorporated notions such as ‘ecological networks’, ‘environmental systems’, and ‘ecosystem services’ — defined by the United Nations as ‘the benefits that people obtain from ecosystems’ (Millennium Ecosystem Assessment, 2005).

In this context, and following Wickham et al. (2010), plans began to incorporate the notion of ‘green infrastructure’, which still lacks a universally accepted definition in the scientific and technical literature. Benedict and McMahon (2006, p. 1) originally described it as an interconnected network of green spaces that preserves the values and functions of natural ecosystems and provides benefits

associated with human populations. The European Commission (2013) broadened this definition by explicitly incorporating artificial environmental management systems — such as green roofs or sustainable urban drainage systems — and by emphasising multifunctionality as a defining characteristic.

The EU Biodiversity Strategy for 2030 (European Commission, 2020) and Regulation (EU) 2024/1991 on Nature Restoration have gone a step further: by introducing obligations of ‘no net loss’ of urban green space and tree canopy cover before 2030. Thus, European legislators have transformed green infrastructure from an analytical concept into a governance instrument supported by binding monitoring indicators (European Parliament and Council, 2024, Art. 8). This development forms part of a broader policy framework that extends beyond biodiversity conservation and ecological restoration objectives.

Recent initiatives such as the New European Bauhaus and the Urban Agenda for the European Union 2030, particularly through the Greening Cities Partnership, have helped position green infrastructure at the centre of debates on urban quality, design, social inclusion, governance, and implementation. Within this framework, green infrastructure is conceived not only as a means of enhancing the ecological resilience of cities but also as a strategic instrument for promoting more sustainable, inclusive, healthy, and aesthetically attractive urban environments.

From the perspective of classification, the literature proposes different typological criteria. Tzoulas et al. (2007) distinguish between freely accessible green areas, private areas with significant vegetation, and linear elements such as river corridors and tree-lined streets. Hansen and Pauleit (2014) propose a functional classification based on predominant ecosystem services: climate regulation, water management, biodiversity, recreation, and social cohesion. Laforzezza et al. (2018) argue that the most useful classification for operational planning is one that combines spatial scale (from the patch to the metropolitan network) with degree of naturalness (from semi-natural spaces to constructed elements such as vegetated facades).

This typological diversity reflects the multiple ways in which green infrastructure has been conceptualised as an object of study. Situated at the intersection of landscape ecology, urban planning, environmental engineering, and public health, it defies any single-disciplinary perspective. In this regard, the planning documents analysed in this article represent applied attempts to synthesise these conceptual approaches and therefore warrant detailed examination.

3. Plans

3.1. The Plan de Infraestructura Verde y Biodiversidad of Madrid: Green Infrastructure as an Infrastructure System

The Plan de Infraestructura Verde y Biodiversidad (PIVB) of the Ayuntamiento de Madrid constitutes the most specific planning instrument of the three analysed. The document is built on an explicit epistemological premise: green infrastructure must cease to be considered ‘equipment’ and come to be recognised as ‘infrastructure’ in the full sense, on the same level as water supply networks, sewerage, or electricity supply. The definition adopted by the PIVB conceives green infrastructure as ‘the network of natural or semi-natural spaces, as well as street trees and other environmental elements — green walls or roofs, urban allotments, green balconies — that not only links green spaces and biodiversity, but is integrated into the DNA of the city’ (Ayuntamiento de Madrid, 2019b, p. 9).

The Plan also introduces the notion of a tripartite system: the city’s infrastructure is organised into a brown substrate (soil), green (vegetation), and blue (water), whose articulation constitutes the biophysical support of urban metabolism. This triad synthesises the influence of the Anglo-Saxon literature on blue-green infrastructure (Barbosa et al., 2007) and represents a conceptual advance over earlier visions that treated the green as an autonomous category disconnected from water systems and associated primarily with recreational or aesthetic functions. In the PIVB, by contrast, vegetation, soil, and water are conceived as interdependent components of a single urban ecological system.

From this perspective, watercourses, infiltration areas, sustainable urban drainage systems (SuDS), and ecological corridors linked to the hydrological network are no longer regarded as sector-specific infrastructures but rather as elements of a multifunctional network designed to enhance biodiversity, climate regulation, hydrological cycle management, and urban resilience. Consequently, the Plan shifts its focus from the isolated provision of green spaces to the integrated management of the ecological processes that sustain urban functioning.

The PIVB classifies Madrid’s green infrastructure according to three complementary criteria: the nature of the space, the territorial scale, and the predominant ecosystemic function. From the perspective of the nature of the space, the Plan distinguishes between: (a) green zones in the strict sense, including city parks, district parks, historic gardens, and forest parks; (b) street trees, conceived as linear corridors connecting the nodes of the system; (c) singular urban vegetation elements, a category that integrates vegetated roofs and facades, urban allotments, and green balconies; and (d) water spaces and riverbanks.

From the perspective of territorial scale, the PIVB works with three levels: city, district, and neighbourhood. This multi-scalar structure is particularly relevant to the Plan’s territorial equity objectives, which propose differentiated provision indicators by neighbourhood. In quantitative terms, the Plan documents that Madrid directly manages approximately 6,000 hectares of municipal green surface, with more than 1,760,000 trees under maintenance and an average of 18.3 m² of green zone per inhabitant (Ayuntamiento de Madrid, 2019b).

One of the most distinctive features of the PIVB is the central role of ecology. The Plan postulates that green spaces ‘multiply their beneficial effects if they are connected to one another through corridors and green streets’ (Ayuntamiento de Madrid, 2019b, p. 9). This ecological network perspective connects with the tradition of landscape ecology (Forman, 1995). The most ambitious operational proposal in this regard is the RED ARCE, which envisages 289 km of main green corridors ensuring that 80% of the population has access to one within 1,000 metres.

Alongside connectivity, resilience emerges as the second conceptual axis of the Plan. The PIVB adopts the United Nations International Strategy for Disaster Reduction (UNISDR, 2009) definition of resilience and applies it to the design and management of green spaces as a tool for adaptation to climate change. The Plan advocates criteria of resilient gardening and a progressive replacement of lawn surfaces with diversified, less irrigation-dependent vegetation models, anticipating the EU Biodiversity Strategy for 2030.

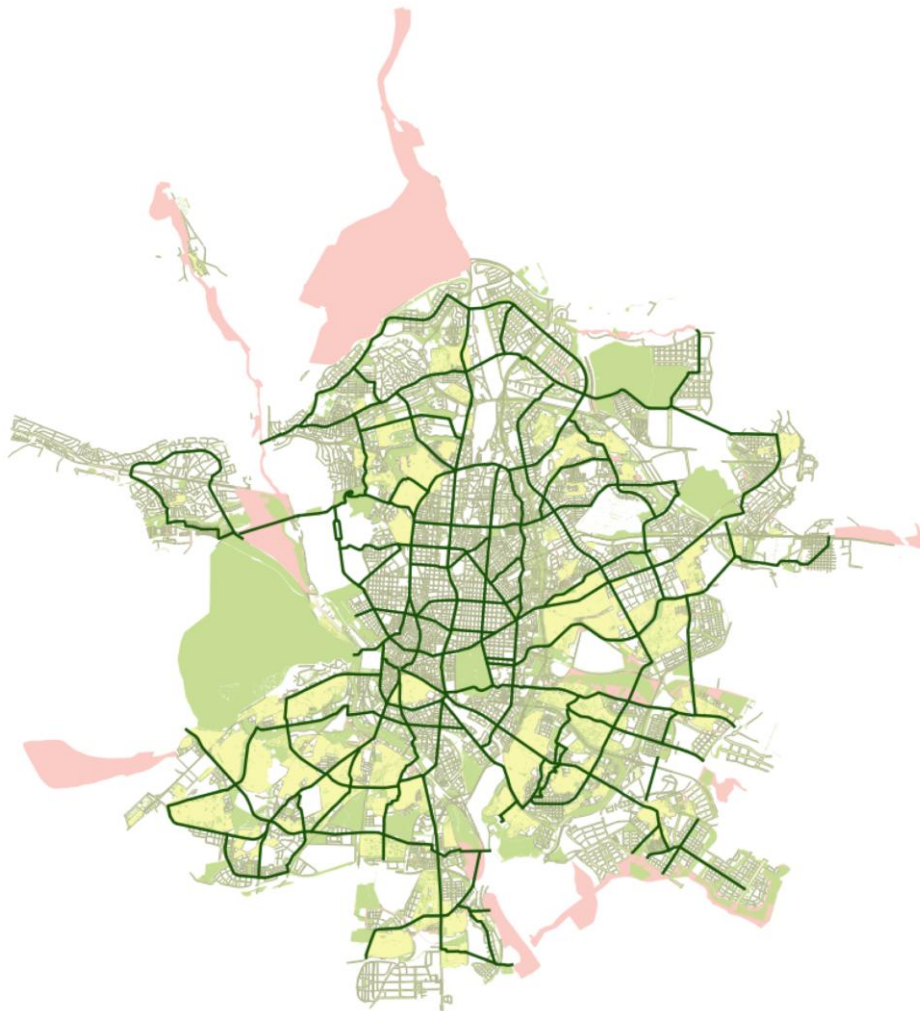


Figure 1: General plan of the proposed RED ARCE (Green Cycle Ring) in Madrid, showing the integration of green zones (APIRU-2017), the Red Madrid Regenera, and the proposed RED ARCE network.

Source: Ayuntamiento de Madrid (2019c, p. 18).

3.2. The London Environment Strategy: Green Infrastructure as the Foundation of the National Park City

The London Environment Strategy (LES), published by Mayor Sadiq Khan in May 2018, constitutes the first integrated environmental planning document in London's history (Mayor of London, 2018). The LES defines London's green infrastructure as 'a network of parks, green spaces, gardens, woodlands, rivers and wetlands, as well as urban green elements such as street trees and green roofs' (Mayor of London, 2018, p. 132). To this physical dimension is added a more ambitious conceptual one: the recognition that green infrastructure is 'as important to the city as its grey infrastructure of rail, roads, pipes and cables' (Mayor of London, 2018, p. 133). Beyond this physical dimension, the Plan introduces a more ambitious conceptual one by recognising that green infrastructure is "just as important to the city as its grey infrastructure of rail, roads, pipes and cables" (Mayor of London, 2018, p. 133).

The LES's most distinctive policy ambition is its proposal to transform London into the world's first National Park City: a city in which more than 50% of its surface area is green by 2050, where the natural environment is protected and the green infrastructure network is managed for the benefit of all Londoners. This declaration radically expands the perimeter of what is considered green infrastructure, equating the totality of urban natural space — including private gardens, landscaped cemeteries, and green roofs — with the large protected areas of nature.

The range of green spaces encompassed by the LES's green infrastructure is the most comprehensive among the three cities analysed. It is organised around four main families of components: (I) publicly accessible open green spaces, comprising Royal Parks, neighbourhood parks, urban woodland spaces, sports grounds, and play areas; (II) natural and semi-natural conservation spaces, including Sites of Importance for Nature Conservation (SINCs), ecological corridors, and wetlands; (III) privately owned green spaces, a category in which the LES recognises 'the importance of street trees, private gardens and the growing number of green roofs and facades' (Mayor of London, 2018, p. 133); and (IV) green elements integrated in buildings: vegetated roofs, green facades, and sustainable urban drainage systems (SUDS).

The LES also explicitly incorporates the blue dimension, recognising rivers, canals, and wetlands as integral components of blue-green infrastructure. The Thames and its tributaries are treated not only as water resources but as ecological corridors and recreational spaces that structure the metropolitan green system (Mayor of London, 2018).

The LES incorporates the natural capital approach — already well-established in the literature on green networks (Benedict & McMahon, 2006; Natural Capital Committee, 2013) and in the European

Union's Green Infrastructure Strategy (European Commission, 2013) — into its classification of London's green infrastructure. The document advocates integrating the economic and social value of natural capital into territorial decision-making processes (Mayor of London, 2018), thereby aligning with the field of environmental economics, which seeks to account for and, where appropriate, assign economic value to ecosystem services (TEEB, 2011).

From the perspective of planning policy, the LES articulates with the London Plan (Greater London Authority, 2021), whose Chapter 8 introduces the Urban Greening Factor (UGF) — a quantitative greening standard for new developments — and establishes that each borough's green infrastructure strategies must identify key green assets, their current and potential functions, and opportunities for strategic intervention.

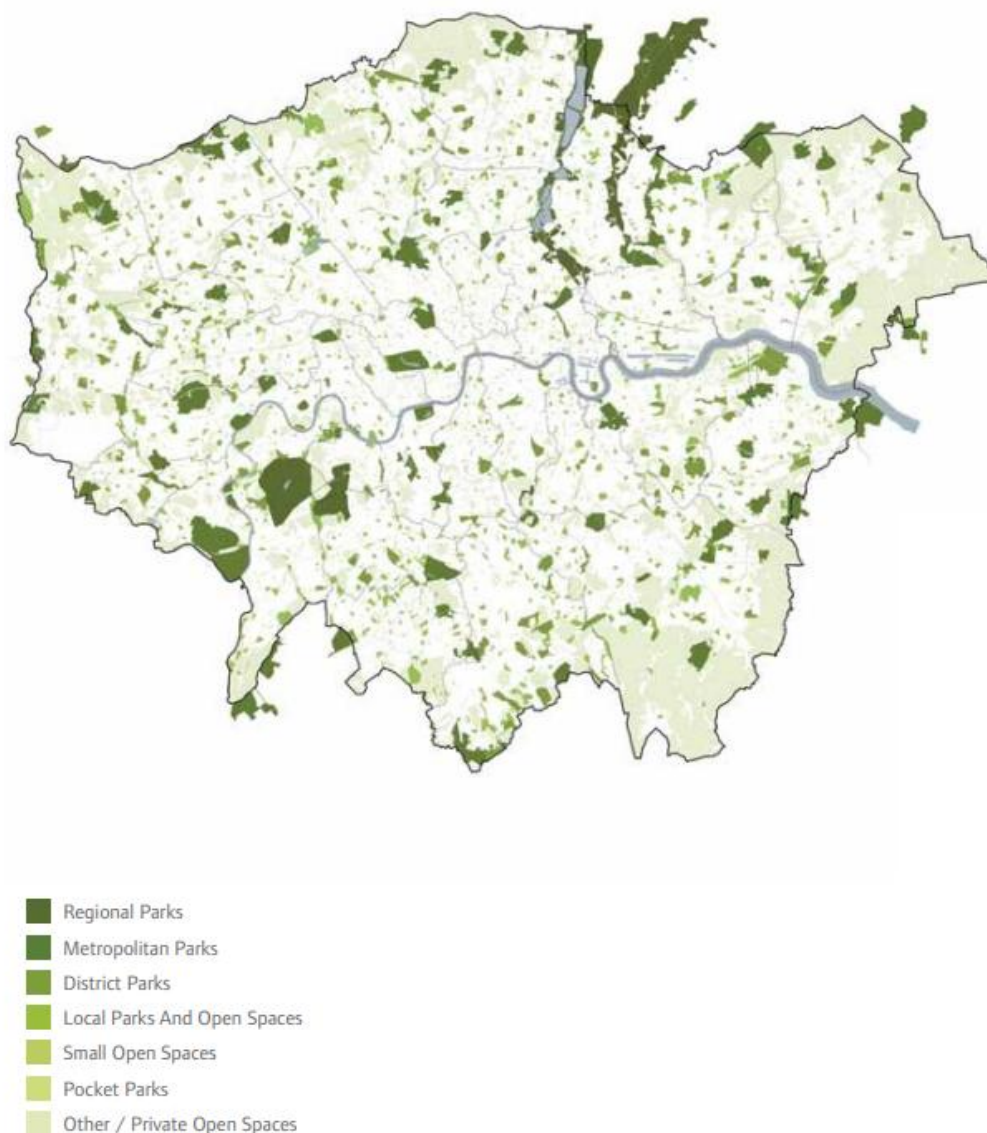


Figure 2: London Landscape Planning — All London Green Grid.
Source: Greater London Authority (2012).

3.3. The Charta für das Berliner Stadtgrün and Handlungsprogramm 2030: Green Infrastructure as Civic and Political Commitment

Green infrastructure planning in Berlin is articulated through a two-tier documentary system. The Charta für das Berliner Stadtgrün — adopted by the Berlin Senate on 21 April 2020 — establishes the guidelines and long-term objectives as a formal political commitment (Selbstverpflichtung) of the federal state of Berlin (SenUVK, 2020). The Handlungsprogramm Berliner Stadtgrün 2030 — approved simultaneously — develops that framework through concrete projects, measures, and instruments to be implemented by 2030, elaborated by the Senatsverwaltung für Umwelt, Verkehr und Klimaschutz with the participation of the twelve Bezirksämter and civil society.

The central concept of the Berlin documentary system is that of Stadtgrün (urban green), which functions as a functional equivalent to the term ‘green infrastructure’ used in Madrid and London, though with partially different connotations. The ‘Charta für das Berliner Stadtgrün’ defines Stadtgrün as the totality of the city’s open and green spaces — large and small, public and private, formal and informal — whose mission is to simultaneously fulfil ecological, climatic, social, health, and economic functions (SenUVK, 2020). The Berlin documentation uses the term grüne Infrastruktur as a subcategory of the broader Stadtgrün, reserving the first designation for those elements of the system that fulfil network and structural support functions.

The Programme organises the classification into three structural blocks. The first block, ‘Stadtgrün sichern und Potentiale nutzen’, identifies: (a) the structural framework (Grundgerüst) comprising the twenty main green routes (20 grüne Hauptwege), urban forests, and biodiversity corridors; (b) new green and natural spaces, including residential parks, Naturerfahrungsräume, and community gardens; and (c) the potential of grey infrastructure, with the ‘1,000 Grüne Dächer’ (1,000 Green Roofs) programme, facade vegetation, bioretention in courtyards, and the naturalisation of school grounds.

The second block, ‘Veränderten Anforderungen Rechnung tragen’ (To meet changed requirements / To respond to altered demands), introduces a functional classification: social coexistence and management spaces, climate adaptation spaces (rainfall management, heat island reduction), and biodiversity spaces (habitats for pollinators, wildlife corridors). The third block, ‘Gemeinsam Qualität und Pflege sichern’ (Securing quality and maintenance together), proposes a typology by management agents: public green, incentivised private green, and collaborative green generated by citizen initiatives and community allotments (SenUVK, 2020).

The Berlin Programme explicitly incorporates the blue dimension of blue-green infrastructure, proposing feasibility studies for the activation of the main urban canals (Spree, Teltowkanal,

Landwehrkanal) as blaugrüne Infrastruktur and for the creation of bathing spots (Badestellen) within the city (SenUVK, 2020). A particularly relevant functional classification element is the Biotopflächenfaktor (BFF) (Biotope area factor/Biotope surface factor), a planning instrument of German origin that quantifies the proportion of bioactive surface area in urban plots. The Programme proposes the introduction of an updated BFF 2.0 for the inner city, the operational equivalent of London's Urban Greening Factor.

The Berlin case is particularly relevant because it illustrates how green infrastructure is incorporated into operational planning instruments. The '*Charta für das Berliner Stadtgrün*' is primarily strategic and programmatic in nature, establishing long-term principles and objectives to guide public action. By contrast, the '*Handlungsprogramm Berliner Stadtgrün 2030*' translates these principles into concrete projects, measurable targets, and mechanisms for territorial implementation.

In this way, green infrastructure becomes a guiding principle for specific urban interventions. First, it supports the protection and expansion of the structural network of green spaces and ecological corridors. Second, it is operationalised through regulatory instruments such as the BFF, which establishes minimum requirements for biologically active surfaces in selected urban developments and thereby influences development intensity and land use. Finally, it is implemented through targeted greening programmes, including green roofs, vegetated façades, and the renaturalisation of public spaces.

As a result, green infrastructure emerges as a planning principle that directly shapes urban land management, the design criteria for new developments, and the prioritisation of public investment. Ecological, climatic, and social functions are thus embedded within conventional urban planning instruments.

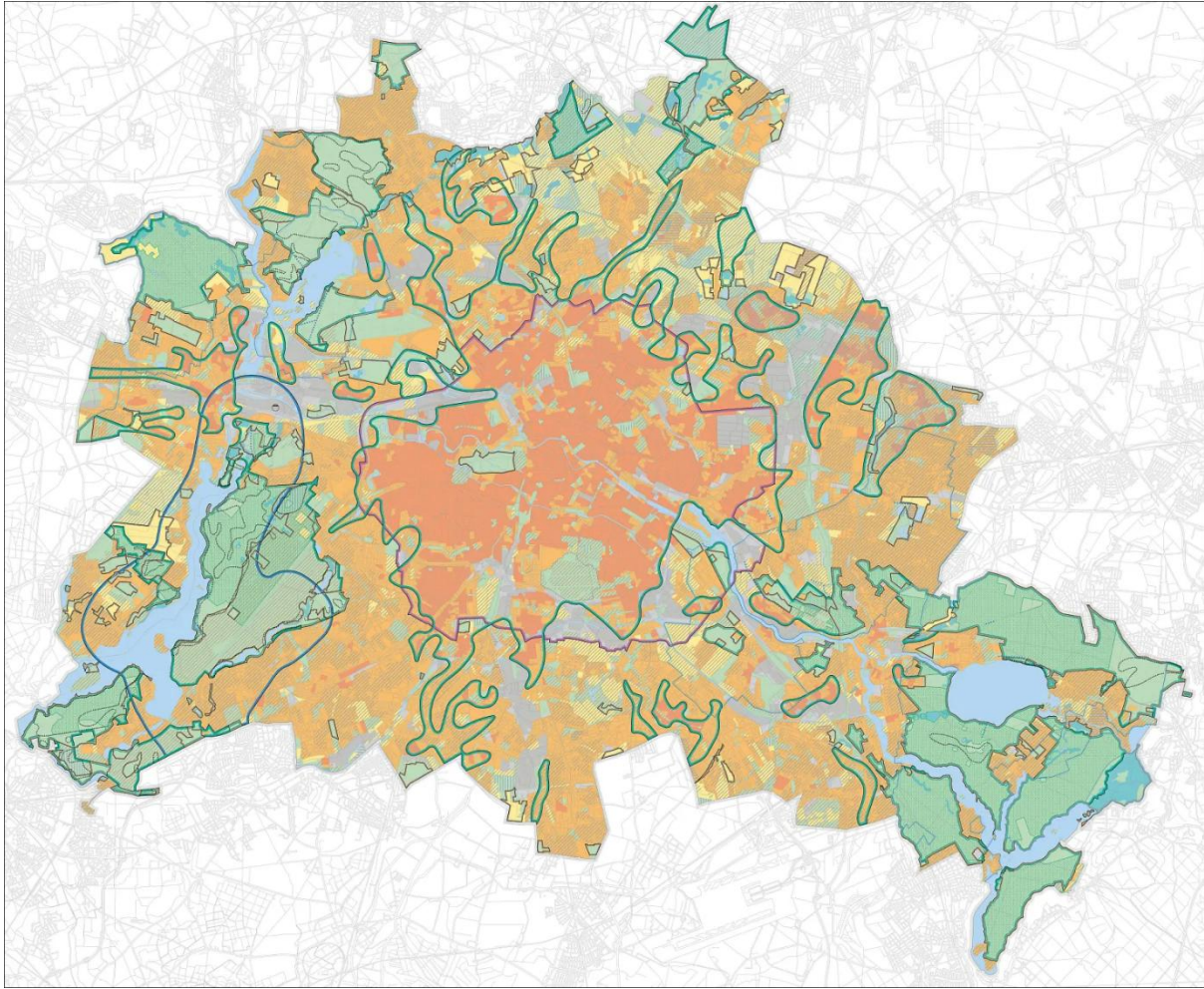


Figure 3: Programme for the protection of natural resources and the environment; the delimited areas indicate precautionary zones for climate (green), air (purple), water (blue), and soil (brown). Source: Cartographic visualization based on the Handlungsprogramm Berliner Stadtgrün 2030 (SenUVK, 2020), as updated in the Geoportal Berlin (Senatsverwaltung für Mobilität, Verkehr, Klimaschutz und Umwelt, 2026).

4. Discussion: Comparative Analysis, Convergences, and Divergences

The comparative analysis of the three plans is structured around five dimensions that shape the operationalisation of green infrastructure in urban planning: (1) the legal status and policy function of the planning document; (2) the scope of the classification; (3) the spatial scale of reference; (4) the assessment criteria; and (5) the implementation instruments. Table 14 summarises how each plan is positioned across these dimensions.

Table 1. Comparative analysis of conceptual and classificatory frameworks, representative plans, and relationship to Regulation (EU) 2024/1991 in Madrid, London, and Berlin.

<i>Dimension</i>	Madrid (PIVB, 2019)	London (LES, 2018)	Berlin (Charta + Handlungsprogramm, 2020)
<i>Primary term</i>	Urban Green Infrastructure (UGI)	Green Infrastructure (GI)	Stadtgrün (urban green) + grüne Infrastruktur
<i>Key definition</i>	Network of natural, semi-natural spaces and street trees (tripartite system: brown, green and blue)	Network of parks, green spaces (gardens, woodlands, rivers, wetlands and urban green elements)	Public and private open and green spaces with ecological, climatic, social and health functions
<i>Dominant classification criterion</i>	Ecological connectivity and territorial equity (m ² /inhabitant per neighbourhood)	Natural capital and green coverage (%); Urban Greening Factor (UGF)	Typology by agent (public/private/collaborative) and functional quality; Biotopflächenfaktor (BFF)
<i>Scope of classification</i>	Focused on municipally managed green (parks, trees, corridors, green roofs, allotments)	Most inclusive: private gardens, cemeteries, roofs/facades, informal spaces, SUDS	Gradation public / incentivised private / collaborative; includes woodlands, courtyards, allotments
<i>Blue dimension</i>	Water spaces and riverbanks as fourth category of the system (blue substrate)	Explicit blue-green infrastructure; Thames and tributaries as ecological corridors and recreational spaces	Blaugrüne Infrastruktur; feasibility of canals (Spree, Teltowkanal, Landwehrkanal) and urban Badestellen
<i>Key quantitative instrument</i>	RED ARCE: 289 km of corridors; 80% of population within <1,000 m of a green route; 18.3 m ² /inhabitant	Urban Greening Factor (UGF); target >50% green coverage by 2050	BFF (Biotopflächenfaktor) → updated BFF 2.0; 1,000 Grüne Dächer programme
<i>Strategic goal</i>	Connected, balanced and resilient green network. RED ARCE: 289 km of corridors.	National Park City. >50% green surface area by 2050, leader in natural capital.	Protect, qualify and expand Stadtgrün (urban green).

Source: Prepared by the authors based on data from Ayuntamiento de Madrid (2019); Mayor of London (2018); SenUVK (2020); European Parliament and Council (2024).

The three plans analysed share a common conceptual substrate that can be synthesised in three principles: the systemic and reticular vision of green infrastructure, ecosystemic multifunctionality as a value criterion, and the recognition of the functional equivalence between green infrastructure and conventional grey infrastructure. These convergences reflect the influence of a shared European policy framework — the European Commission's Green Infrastructure Strategy (2013) and the Biodiversity Strategy for 2030 — as well as the international circulation of ideas within city networks (C40, ICLEI). Nevertheless, this discursive coherence does not translate into a uniform modelling of

ecosystem service provision. None of the three plans incorporates an integrated spatial modelling system — such as InVEST (Sharp et al., 2020; Hamel et al., 2021), ARIES (Villa et al., 2014), or SolVES (Sherrouse et al., 2011) — that quantifies the actual capacity of green spaces to provide regulatory, supporting, or cultural ecosystem services in a differentiated and georeferenced manner. Multifunctionality therefore remains an attributive property of the *Stadtgrün*, green infrastructure, or urban green infrastructure, but not a measured property through composite indicators that simultaneously weigh the climatic, hydrological, biological, and social capacity of each spatial unit. In Madrid, protected areas within the General System of Open Spaces are classified according to criteria of public use and ecological value, without any functional disaggregation. In London, the Urban Greening Factor quantifies the extent of biologically active surfaces but does not assess the ecosystem productivity of those surfaces. In Berlin, the BFF measures the proportion of permeable and vegetated land without evaluating the quality of the habitats created or the ecosystem service flows they sustain. Although composite indicators of multisystemic capacity remain largely absent, the Berlin BFF represents a partial exception by assigning each surface type within a plot (green roofs, permeable pavements, ground-level vegetation, and green façades) a weighted ecological effectiveness coefficient ranging from 0 (completely sealed surface) to 1 (natural soil with vegetation cover), thereby generating a composite indicator of the plot's ecological performance. However, the BFF should not be interpreted as a spatial ecosystem-service model, but rather as a composite ecological weighting system applied at the plot scale.

On the other hand, the three analysed plans also exhibit significant differences among themselves. Before examining these, it is worth acknowledging that the three documents analysed are not equivalent in legal status or political function. The PIVB of Madrid is a sectoral urban planning plan with binding effects on buildability and zoning; its function is normative-prescriptive and its scale is the city with district and neighbourhood disaggregation. The LES of London is an integrated environmental strategy (mayoral strategy) that sets metropolitan objectives but depends on transposition by the 32 boroughs and the London Plan to acquire legal force; its function is strategic-coordinating. The Berlin system — *Charta* and *Handlungsprogramm* — operates as a formal political commitment (*Selbstverpflichtung*) and an administrative action programme (*Verwaltungsprogramm*): the former lacks binding force, and the latter binds the Senate budgetarily but does not impose obligations on the districts, whose implementation depends on competitive fund allocation (*Mittelzuweisung*). These differences partly explain some of their divergences.

The first divergence concerns the scope of classification. The inclusion of private gardens and informal spaces in the London LES responds to its strategic nature: it must mobilise non-state actors without direct competencies over private land. In practice, monitoring depends on voluntary

inventories and satellite estimates; accountability is diluted among multiple owners; and financing relies on fiscal incentives (Community Infrastructure Levy) rather than direct public investment. The Madrid PIVB, by contrast, allows rigorous administrative control of public provision, but excludes from the normative protection system a significant fraction of existing green coverage — private gardens, inner courtyards, roofs — that in high-density neighbourhoods may represent up to 30% of total green surface area (Davies et al., 2009).

The second divergence concerns the reference scale. London approaches green infrastructure fundamentally at the metropolitan scale; Madrid works with a three-tier structure (city/district/neighbourhood); Berlin operates mainly at the neighbourhood (*Kiez*) and *Bezirk* scale, articulating the city-wide network through the 20 green corridors. The metropolitan scale of London enables strategic corridors that transcend municipal boundaries (All London Green Grid), but generates tension with the 32 boroughs that hold local planning powers: the Mayor's strategy requires voluntary transposition, and only a minority of boroughs have developed strategies aligned with the LES (Mayor of London, 2021). Madrid, with its three-tier structure, links indicators to the neighbourhood (18.3 m²/inhab.), which facilitates the detection of equity deficits but fragments ecological planning across 21 districts with unequal technical capacities. Berlin, operating at the *Kiez* and *Bezirk* scale, achieves local adaptation but depends on *Mittelzuweisung*, which generates territorial asymmetries documented in the literature (Bezirksamt Pankow, 2022; Bezirksamt Neukölln, 2023).

The third divergence concerns the comparability of the three systems. While Madrid measures distributional equity through square metres of green space per inhabitant and neighbourhood, London assesses the percentage of metropolitan green cover, and Berlin evaluates the functional quality of green corridors — with the latter being the only one of the three cases to employ a quality-based rather than a purely quantitative indicator, through the BFF mechanism described above — it is methodologically challenging to establish direct comparisons between the three systems. This highlights the need for a harmonised indicator framework, such as that proposed by the Urban Green Spaces Index developed by Eurostat (Eurostat, 2019). However, harmonisation based exclusively on metrics of extent or accessibility — such as area, green cover, or distance — primarily captures the quantity and spatial distribution of green infrastructure, while overlooking important dimensions such as ecological functionality, structural diversity, habitat quality, ecological connectivity, and ecosystem service provision (Herath and Bai, 2024; Hu and Wu, 2024; Khalili et al., 2024). An indicator of m²/inhab. may correspond to impermeable monocultural lawn or to semi-natural forest with multiple strata; a percentage of green coverage may integrate sedum roofs with 5 cm of substrate or forest canopies of 50 cm; a green corridor may be a linear tree-lined route with ecological discontinuities

or a stretch of continuous riparian vegetation. Therefore, harmonised indicators should be complemented with metrics that evaluate whether green infrastructure is ecologically functional, connected, and capable of sustaining biodiversity — for example, indices of structural complexity, functional connectivity for pollinators, or differentiated ecosystem service provision — beyond its mere extent or accessibility.

The fourth divergence relates to the criteria for organising the components of green infrastructure: Madrid prioritises ecological connectivity and territorial balance; London privileges ecosystem functionality and natural capital value; Berlin combines spatial characteristics with the actors responsible for their management. In practice, the typification by management agents in Berlin — public, incentivised private, collaborative — enables the mobilisation of community resources (*Bürgerschaftliches Engagement*) but introduces coordination complexity: collaborative green space is not always integrated into municipal maintenance, generating abandonment risks when citizen initiatives cease. London, with the Urban Greening Factor, links building permits to greening standards, which constitutes effective land-use regulation for new construction but is inoperable for the existing fabric. Madrid, with the RED ARCE, establishes protected corridors with binding effects, but implementation depends on expropriation or negotiation with private owners, a process that in the Madrid real estate context may extend over decades without guarantee of political continuity.

Regarding operationalisation instruments, the three cases present different governance that conditions the translation of concepts into territorial transformation. In Madrid, the PIVB is articulated vertically and hierarchically with the General Urban Development Plan: the municipal plan establishes corridors and binding standards for district development plans, but metropolitan coordination is non-existent (36 municipalities), fragmenting regional ecological connectivity. In London, coordination is horizontal and negotiated: the London Plan (2021) imposes the Urban Greening Factor as a mandatory standard for boroughs, but the LES functions as a statement of intent requiring voluntary adherence, and the National Park City Foundation depends on persuasion and funds, not legal mandate. In Berlin, coordination is federal and competitive: the *Land* sets the framework, the *Bezirke* compete for state funds (*Mittelzuweisung*), and civil society participates through participatory budgets (*Bürgerhaushalt*), which generates local innovation but budgetary instability in the face of changes in political majority.

These institutional differences produce structural trade-offs: Madrid achieves normative coherence at the cost of metropolitan fragmentation; London attains strategic vision but depends on voluntary adherence; Berlin fosters local innovation but suffers budgetary instability. The transferability of policies does not lie in identifying a superior model, but in combining normative prescription

(protection), metropolitan strategy (vision), and participatory programming (implementation) according to the institutional tradition of each context.

Regarding the social dimension of green infrastructure, it requires greater integration into conceptual and classificatory frameworks. The Madrid PIVB incorporates the indicator of m² of green space per inhabitant and neighbourhood but does not distinguish between publicly accessible green space and invisible private green space, nor does it evaluate ecological quality or perceived safety. A neighbourhood with 18.3 m²/inhab. of private gardens may register the same indicator as one with 18.3 m²/inhab. of public park, although effective access and benefits are asymmetrical. The London LES, by including private gardens, acknowledges their contribution to metropolitan coverage, but poses the risk that “greening” policies concentrate on high-income neighbourhoods, reinforcing territorial inequality. The literature documents that greening in European cities may act as a gentrification catalyst, displacing vulnerable populations (Anguelovski et al., 2024; Rigolon, 2023). The LES does not incorporate mechanisms for protecting affordable housing linked to green infrastructure investment, an omission that limits its capacity to promote environmental justice. The Berlin plan, with its collaborative green typology and emphasis on citizen participation, addresses equity through democratic access to decision-making. However, evidence shows that participatory processes in German cities have an exclusion bias towards residents with high educational levels and German-language proficiency, marginalising migrant and low-income populations (Senatsverwaltung für Stadtentwicklung, 2019). Furthermore, inter-district competition for funds (*Mittelzuweisung*) favours districts with greater technical capacity, perpetuating inequalities between central and peripheral areas.

5. Conclusions

This article has comparatively analysed the conceptual frameworks and classifications of urban green infrastructure present in three European capital city plans. All three plans share a common conceptual core derived from the European green infrastructure paradigm: a multifunctional network of natural, semi-natural, and artificial spaces whose systemic integration generates ecosystem benefits greater than those of its components separately. All three recognise the functional equivalence between green infrastructure and grey infrastructure, and all three incorporate the blue dimension in their conceptualisation.

However, all three plans present significant differences in terms of the scope of classification (more inclusive in London, more focused on managed public space in Madrid, and more oriented towards the public/private/collaborative gradation in Berlin), in terms of the reference scale (metropolitan in

London, multi-scalar in Madrid, neighbourhood-city in Berlin), and in terms of the dominant classification criteria (connectivity and equity in Madrid; natural capital and green coverage in London; agent typology and functional quality in Berlin).

From the analysis, five recommendations emerge that could be applicable to other European cities:

(1) Articulate typology by scale, function, and ownership. Explicitly distinguish between public green (direct municipal management), regulated private green (binding standards for new construction), and collaborative green (citizen initiatives with protocols for integration into municipal maintenance).

The absence of this articulation in Madrid excludes a significant fraction of green coverage from the system; its presence in Berlin, albeit imperfect, enables more flexible governance.

(2) Link classification to indicators with binding legal or budgetary effects. The London Urban Greening Factor and the Berlin *Biotopflächenfaktor* exemplify quantitative standardisation, but their effectiveness depends on integration into building permit regulation (London) or fund allocation (Berlin), not merely on their existence as technical recommendations. Madrid could strengthen its system by incorporating a “minimum biologically active surface area per plot” indicator into development planning.

(3) Develop metropolitan coordination mechanisms. Fragmentation into 36 municipalities (Madrid), 32 boroughs (London), or 12 *Bezirke* (Berlin) constitutes an obstacle to functional ecological connectivity. The experience of the All London Green Grid suggests that coordination may operate through voluntary agreements enhanced by fiscal incentives, although evidence of its effectiveness remains limited.

(4) Incorporate spatial justice safeguards. Investments in “greening” must be accompanied by measures for protecting affordable housing and inclusive participation of vulnerable communities, to prevent environmental improvement from translating into residential displacement. Monitoring indicators must include not only green coverage, but also effective accessibility, perceived quality, and socio-spatial distribution.

(5) Articulate conceptual frameworks with the spatial modelling of ecosystem services. Ecosystem service priorities vary across territorial contexts; therefore, no single tool is equally suitable for assessing them all. Consequently, planners should select spatial ecosystem service modelling tools according to the ecosystem services they intend to evaluate in each specific context. Incorporating these approaches into Strategic Environmental Assessment (SEA) processes would enable planning decisions to be informed not only by land protection objectives, but also by the effective provision of climate regulation, water management, biodiversity conservation, and other ecosystem services delivered by green infrastructure.

Finally, this analysis suggests that the transferability of good practices between European cities regarding green infrastructure cannot operate through the mere importation of classificatory typologies but rather requires the adaptation of conceptual frameworks to the institutional architectures and political functions of planning instruments in each context. The comparison of strategies, plans, and programmes not equivalent in legal status reveals that the effectiveness of green infrastructure depends less on the precision and exhaustiveness of the system for organising and classifying components than on the coherence between its function (normative, strategic, or programmatic) and the implementation mechanisms available.

Use of AI tools

The authors used ChatGPT (GPT-5, OpenAI) for language editing support.

Declaration of competing interest

The authors declare no conflict of interest.

Data availability

All data supporting the findings of this study are included in this published article.

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