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Green May Be Nice, but Infrastructure Is Necessary

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Abstract: Green infrastructure is presented as a novel and innovative approach in the current environmental planning discourse, but how new is it really? An historical overview of planning ideas in both the urban and the rural contexts indicates that the concept, if not the term, "green infrastructure" has a very long and distinguished pedigree in the field of landscape and open space planning. To determine how far the concept is indeed new, definitions of green infrastructure from the literature are examined. While "green" has long been loosely used as a synonym for natural features and vegetation in the planning context, "infrastructure" is the part of the term which is really novel. Infrastructure is otherwise understood as being either "technical" or "social", and the common features of these otherwise very different forms are considered in order to gain a better understanding of how they might also relate to a new interpretation of green infrastructure. A number of international case studies of different "green infrastructure" projects are then presented, again to better understand their common features and potential relationship to other infrastructure types. Finally, the necessity to consider green and blue areas together and to take them as seriously as other forms of infrastructure is emphasized. The developing climate and biodiversity crises underline the urgency of implementing a flexible and multifunctional green-blue infrastructure system. This must be carefully integrated into the existing fabric of both urban and rural landscapes and will require an appropriately resourced administration and management system, reflecting its beneficial impacts.

Keywords: green infrastructure; landscape and open space planning; climate change; biodiversity crisis; gray and social infrastructure; green corridor; green infrastructure elements

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1. Introduction

Although the idea of green infrastructure has become widespread in the context of the current environmental planning discourse and it feels as if it has always been with us, in fact, the first reference to the term in the literature is relatively recent and is traced back to a mention in a 1994 report on land conservation to the governor of Florida [1].

Since then, the idea of green infrastructure has spread worldwide and has been adopted by, amongst others, the European Union in the Commission's 2013 Communication to the European Parliament: "Green Infrastructure (GI)—Enhancing Europe's Natural Capital" [2].

But while welcoming this new development, one is somehow left with a feeling of déjà vu, a suggestion of old wine being marketed in new bottles. Does not concern with green infrastructure, both in the rural and the urban contexts, have a long and illustrious history which pre-dates the use of the term itself by a long way? A short history lesson and good practice examples shall allow us to discuss the real novelty of the concept and recall that the term itself may not be so important but rather the idea it symbolizes; indeed, as Shakespeare reminds us: "That which we call a rose would by any other name smell as sweet . . . ".

2. Materials and Methods

This paper takes an essentially discursive approach to questioning the understanding and interpretation of the term "green infrastructure" in different societal contexts and the way it is employed in environmental planning today. It makes use of critical reasoning on the basis of an examination of the key terms used and an analysis of their meaning in the context of the current discourse on green infrastructure. Perceptions of green infrastructure are compared with those concerning technical and social infrastructure. Examples from the history of green space and landscape planning, as well as contemporary international case studies, are used to provide evidence, to draw conclusions, and to make recommendations for future policy.

2.1. A History Lesson: Planning Urban and Rural Landscapes

Urban green infrastructure was surely what William Pitt the Elder, British prime minister during the middle of the 18th century, was referring to when he reportedly described the city's parks and squares as "the lungs of London" [3]. Only a few decades later in 1829, the Scottish plantsman and designer John Claudius Laudon made proposals for a system of green infrastructure for London in his publication *Hints for Breathing Places for the Metropolis* [4], and it was under the pseudonym of Armenius that another urban green infrastructure pioneer, the Countess Dohna-Poninska, called for the creation of "green rings around cities" in a German publication dated 1874 [5]. Only a short time afterwards in 1878, on the other side of the Atlantic, Frederick Law Olmstead began work on his proposal for a green infrastructure project for the city of Boston, the parks system which he christened the "Emerald Necklace" [6].

At the start of the new century, establishing a system of urban green infrastructure was surely the purpose of the city of Vienna's designation in 1905 of a "Woodland and Meadow Belt" around the city [7]. A similar idea was pursued by Martin Wagner—later head of the Berlin city planning department—when he proposed the idea of "Sanitary Greenspace for Cities" in his 1915 doctoral dissertation [8]. When, from 1923 onwards, the Ruhr District Regional Authority in Germany purchased land to protect a series of broad green wedges separating the main cities of the region, what else were they doing than establishing a system of regional green infrastructure, which in 1966 was given legal protection [9]? Patrick Abercrombie, author of the groundbreaking 1943 *County of London Plan*, was also promoting green infrastructure when he defined the London Green Belt [10]. These excerpts from the history of significant developments that we would call urban green infrastructures today are shown in Figure 1.

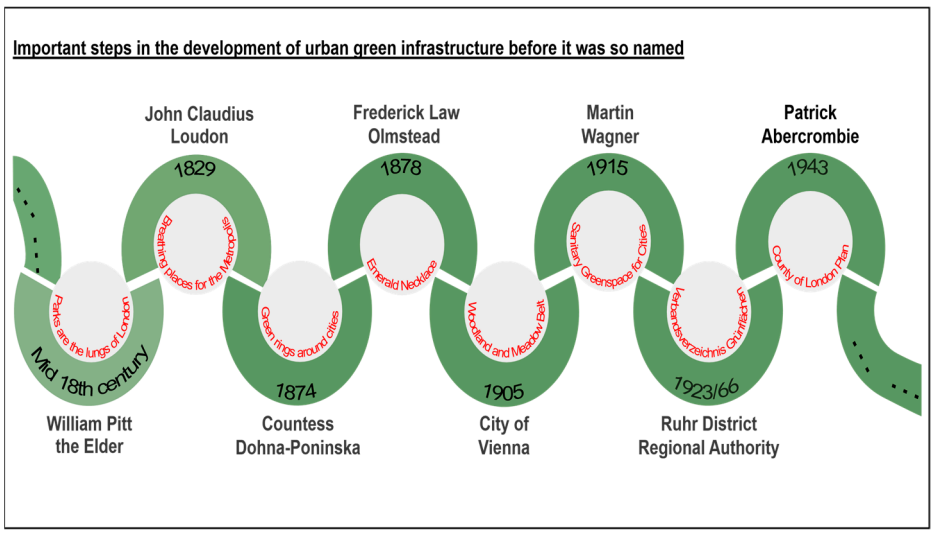

Figure 1. Important steps in the development of urban green infrastructure before it was so named; selected path-breaking projects (authors).

One could continue citing examples of historic urban green infrastructure initiatives which have led to the current field of green and open space planning and which clearly pre-dated the first mention of the term green infrastructure by decades and, in some cases, centuries.

But what about green infrastructure in the rural environment? Perhaps this is indeed a recent innovation? The European Commission's Communication of 2013 refers to it being "a strategically planned network of natural and semi-natural areas with other environmental features . . . ", which strongly suggests a rural context, as natural and even semi-natural areas are a rarity in the urban environment.

A strategic approach to planning natural and semi-natural features sounds suspiciously like "landscape planning", which is defined in the European Landscape Convention [11] as "strong forward-looking action to enhance, restore, or create landscapes". The history of landscape planning in the rural context can, however, be traced back somewhat further and is associated with concepts such as natural landscape regions and plant sociology, which together gave an important spatial basis to the emerging field of ecology. The term "landscape ecology" was coined by the German geographer Carl Troll in 1939 [12] and later widely popularized in the English-speaking world by Richard Forman [13], who defined generic green infrastructure concepts by other names, such as patches and corridors, networks and matrix.

But the idea that such elements of the landscape structure could be "strategically planned" as green infrastructure can be traced back to, amongst other things, the Commission on Landscape Planning of the International Union for the Conservation of Nature (IUCN). Although it contains no specific reference to "green infrastructure", in the report of the 1970 annual meeting of the Commission in Brno, then in Czechoslovakia, the aim of the Landscape Planning Commission is described as being "to promote and maintain an optimum relationship between the landscape as a resource and the human activities planned therein in order to achieve the best possible long-term social and economic benefits for man, as well an ecologically balanced, diversified landscape as a healthy environment for man and other forms of life". This publication lists the Commission's illustrious international membership, which included Ian McHarg and Dame Sylvia Crowe and was chaired by Roelof J. Benthem of the Netherlands. Other members included representatives from as far afield as Australia and Nigeria, South Korea and the USSR, Brazil and Canada, among other countries [14].

The chair of the meeting, Vlastimil Vaníček, subsequently contributed a definition of landscape planning to the first issue of a new scientific journal of the same name which began publication in 1974 [15]. Czechoslovakia was particularly advanced in developing the concept of green infrastructure, although it was also described using another name: "LANDEP"—short for landscape ecological planning. In a 1993 paper, Milan Ruzicka, the "father" of LANDEP, wrote, "during the last three decades, the theory and methodologies of landscape ecological planning (LANDEP) have been developed as a specific form of complex landscape ecological investigations. A degree of application to the requirements of planning has been worked out. The knowledge so far obtained opens possibilities for developing a new branch of basic research as well as for more complete application of ecological viewpoints in the elaboration of documentation for territorial planning" [16].

Two years later, landscape planning moved from being the subject of an international commission and a new academic journal with the title *Landscape Planning* to becoming a legal requirement. In Germany, the 1976 Federal Nature Conservation Act for the first time legislated for the preparation of statutory landscape plans which were to present proposals for, amongst other things, conserving and developing green infrastructure at different scales and levels of detail [17].

When the aforementioned academic journal—now renamed *Landscape and Urban Planning*—published its first special issue on "greenways" reporting on policies and projects for linear green routes and networks nearly two decades later in 1995, there was still no

reference to the term "green infrastructure", although it would now be considered central to the topic [18].

Similarly, more than three decades on from the German Federal Nature Conservation Act, in 2008, when the Federal Agency for Nature Conservation published a brochure presenting the now mature system of landscape planning as "the basis of sustainable development", it contained no reference to the term green infrastructure despite referring to "new opportunities for landscape planning" [19].

It should be clear then that issues which are essentially concerned with what would today be referred to as green infrastructure have been a central concern of landscape and open space planning for decades in relation to the rural landscape and, indeed, for more than a century in the context of urban areas, even though they have long not been referred to as such. So, is the sudden appearance of the term "green infrastructure" at the end of the 20th century really just a case of putting old wine into new bottles in order to sell it as something fresh and innovative, or, alternatively, is today's use of "green infrastructure" really something new and different, bringing with it new approaches and insights? In order to seek an answer to this, it is necessary to look at how today's green infrastructure is defined.

2.2. Contemporary Definitions of Green Infrastructure and Their Assumptions

The term "green infrastructure" is now widely used in urban and rural planning processes. It seems to have originated in the understanding, since the 1980s, that ecosystems could be considered as infrastructure. The concept recognizes that natural systems or systems based on natural interdependencies can be seen as analogous to gray infrastructure, which is recognized as providing the basis for societal and economic well-being. Over the years, many other terms have been developed and used, such as ecological, natural, green, and blue infrastructure, nature-based solutions, ecosystem services, or biomimicry, but green infrastructure has become the dominant term in the academic literature [20].

Before adopting the term "green infrastructure" in its 2013 Communication, the European Union had already established the idea of habitat networks in the context of the 1992 Habitats Directive [21]. In line with this, in a study commissioned by the EU's DG Environment in 2007 [22] the focus was almost entirely on the biodiversity and nature conservation aspects of green infrastructure, predominantly in a rural context. The final summary referred only briefly to two urban roles of green infrastructure, namely connecting urban nature with the surrounding countryside as well as helping to prevent urban pollution from reaching it.

An internal Commission discussion paper drew attention to the ambiguity of the term and its meaning: ""Green infrastructure" is a relatively new and flexible term, and it has been used differently in different contexts. Thus, to date, there is no universally established definition of the term; green infrastructure means different things to different people depending on the context in which it is used." It goes on to say, "some people refer to trees in urban areas as green infrastructure because of the "green" benefits they provide, while others use green infrastructure to refer to engineered structures (such water treatment facilities or green roofs)" [23].

With the publication of the Commission's Communication on Green Infrastructure, it had settled on the following definition: "a strategicfally planned network of natural and semi-natural areas with other environmental features designed and managed to deliver a wide range of ecosystem services such as water purification, air quality, space for recreation, and climate mitigation and adaptation. This network of green (land) and blue (water) spaces can improve environmental conditions and, therefore, citizens' health and quality of life. It also supports a green economy, creates job opportunities, and enhances biodiversity" [24]. The development of different approaches and definitions to green infrastructure in Europe is summarised in Figure 2.

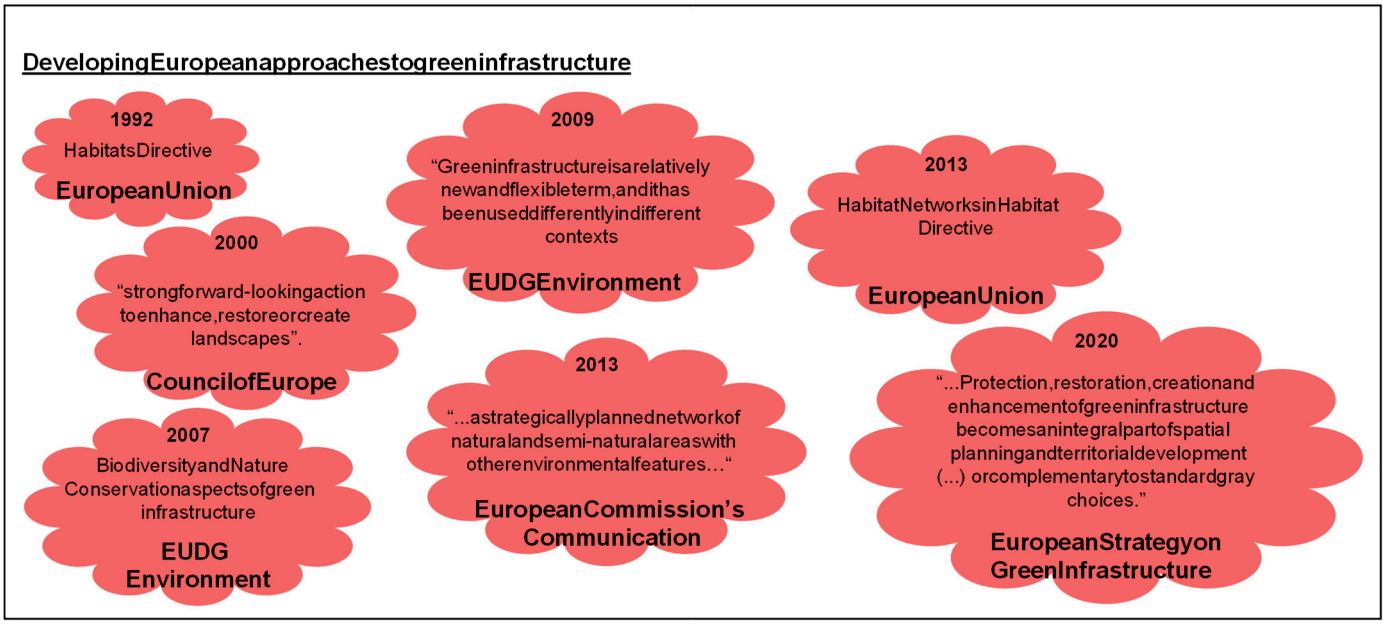

Figure 2. Developing European approaches to green infrastructure (authors).

Green infrastructure elements are seen as differing in their functions and scale, but all are regarded as forming part of an all-encompassing network. In the rural context, the Natura 2000 network is the core of the European Union's green infrastructure network. It includes large forests and mountain areas of the Central European border regions, large rivers, and sea coasts as important transnational green infrastructure resources. They form a diverse network with potential, especially in times of rising sea levels. At the regional level, green infrastructure includes protected areas along rivers, large forest areas, and large water bodies.

Green infrastructure at the local level tends to be the most diverse. The form and function are highly dependent on local conditions. It should be planned with respect to its diversity of forms and functions according to local needs. Local green infrastructure elements can include ponds and hedges as well as less natural elements, such as green roofs or green facades. The concept of green infrastructure elements is applicable at all scales.

The European Strategy on Green Infrastructure implicitly argues for an equal treatment of green and "gray" infrastructure and urges member states to "ensure that the protection, restoration, creation, and enhancement of green infrastructure becomes an integral part of spatial planning and territorial development whenever it offers a better alternative, or is complementary, to standard gray choices." [2].

Like the better known "gray" infrastructure—the technical facilities and utilities for supply and disposal and social infrastructure, such as schools, care facilities, hospitals, sports grounds, and cultural facilities—in the urban context, green spaces are equally viewed as a form of infrastructure that serves important needs. Green open spaces such as parks and gardens not only provide recreational opportunities for city dwellers but are also recognized as serving other functions, such as ecological compensation areas for sealed surfaces, fresh air corridors for ventilating the city, and retention, infiltration, and evaporation surfaces for maintaining the water balance. In addition, they can act as buffers for increasingly recurrent extreme weather events during either heavy rainfall and storm surges or heat waves and extended dry periods. They are generally accessible to the public as places to meet and are usually provided and looked after by the public sector, even if the land does not always belong to the city.

Any form of infrastructure only functions effectively if well maintained and kept in optimal condition on an ongoing basis. Green infrastructure, when properly managed, even becomes more valuable over time as vegetation grows and because the effect it brings

improves as plants mature, compared with when they have just been planted. A further important quality of infrastructure is flexibility, especially in the context of climate change. Many gray infrastructure assets, such as road and rail structures or canals, flood protection walls or dams, as well as larger buildings, are static and can adapt only with great difficulty to changing conditions.

Green infrastructure, on the other hand, has a high degree of spatial and temporal flexibility, and its functions can adapt more quickly to new environmental conditions, such as climate change. In addition, green infrastructure serves multiple functions: alongside being spaces for urban recreation, they help keep cities cool, retain groundwater, and bind and convert CO_2. While the wider remit of green infrastructure has been increasingly embraced, in practice it still often fails to fully utilize the spectrum of available sustainable opportunities, such as rainwater harvesting, green roofs and facades, natural shading using tree canopies, and urban gardening [25].

The world is rapidly urbanizing. It is estimated that more than six billion people will live in cities by 2050. According to this, all natural resources, especially water resources, will be adversely affected, and productive rural production areas will be consumed due to urban expansion. The catastrophic issues which have been recently experienced on a global scale, such as climate change, the COVID-19 pandemic, biodiversity loss, and mass international migrations, showed that our world is fragile.

Especially in cities, many people face the risks of being injured by or losing their belongings in natural catastrophes. Thus, the "resilience" of an urban settlement in the face of any problem has become the main issue for the people living in the city and, more importantly, for those who design and manage the cities. In the traditional urban planning, "green" assets (trees, parks, gardens, etc.) and "blue" assets (streams, drainage areas, floodplains, etc.) are mostly planned separately. "Green" and "blue" assets outside the city especially are included in completely separate management processes, and gray infrastructure projects have often led to a fragmentation of green spaces and loss of their ecosystem services, for example, the degradation of the natural regimes of streams. Making cities, urban peripheries, and rural/natural areas more resistant by implementing green and blue infrastructure should now be a "main target" for local governments.

All the ongoing natural functions, processes, and services in the countryside support the city as well as the functions of rural landscapes. Therefore, a better approach is needed to strengthen the existing ties between cities and the countryside in order to ensure their easy flow into the city. All parties designing and managing the city now have to accept green infrastructure as their tool for planning and design, namely, the approach that will help to understand "the new nature of the city" without making the distinction between city, rural, and nature.

The core principles of green infrastructure are multifunctionality, connectivity, ecological and social inclusion, and integrity. With these claims, it clearly covers demands of society and does not only function within already existing green and ecological structures. Green and blue systems have to become interwoven with the urban and rural building structures, infrastructures, and social spaces. As it works on all levels of scale and in rural as well as urban surroundings, it needs to be implemented in most of our open spaces.

2.3. Green or Infrastructure

The above exposition of the many benefits of green infrastructure emphasizes its undoubted value to society, but what if "society" does not recognize it as infrastructure at all? From an environmental point of view, the term "green infrastructure" is now taken for granted, but perhaps environmentalists are alone in making the assumption that the term is widely accepted. Circumstantial evidence, at least, suggests that to the international infrastructure community, green infrastructure simply does not exist. Thus, a report on "global infrastructure" by the international statistics company Statista is divided into the following sections: Telecommunications, Energy, Transportation, Roads and Bridges,

Railroads, and, finally, Airport Infrastructure—not even a hint of a mention of green or blue infrastructure [26].

There is no doubt that society as a whole accepts the importance of "green": no politician is ever against "green". More often than not, however, it seems that it is viewed as an optional extra—nice to have but often just too expensive, a luxury which society frequently has to do without in order to be able to fund more important things, such as infrastructure, for example.

Sewerage systems, airports, electricity supply, health services, or the road network, on the other hand—that is to say, "infrastructure"—may be less glamourous than "green", but all of them are generally recognized as being essential for a healthy economy and a thriving society, and the necessary resources have to be found to provide them. Indeed, they are the recipients of large and ongoing investments of public money. There has been no better illustration of this fact than US President Biden's recent high-profile USD one trillion "infrastructure package". According to a report in the *Financial Times* from 10 August 2021, this was to be spent on:

" . . . upgrading America's roads, bridges and tunnels, as well as airports, rail networks and the power grid. The proposal also includes investments to improve Americans' access to broadband and clean drinking water." [27]

No mention whatsoever is made, for example, of upgrading urban green space networks, restoring river corridors, habitat creation, or woodland planting in rural areas, which, given the simultaneous promotion of the "green new deal", is surprising to say the least. Clearly, when it comes to serious investment and even to long-term maintenance, "green" is one thing, but "infrastructure" is another.

Seen from the perspective of the "infrastructure community", perhaps the main intersection with "green" issues has traditionally been in relation to the integration of technical infrastructure projects into their surroundings. Thus, there are largely considerations of reducing the "environmental impact" of, for example, major road-building projects or industrial plant on the landscape and of minimizing their effects on the habitats of protected flora and fauna (cf. EU Environmental Assessment Directive) [28].

However, the Commission's Communication on a Green Infrastructure Strategy offered an indication that it might be considering raising green infrastructure to the same status as other forms of technical infrastructure. In Section 3 on developing a EU strategy, it explicitly states that "to date, large-scale infrastructure initiatives have been devoted to transport, energy, and ICT. Developing an equivalent instrument, the trans-European priority axes for GI in Europe, TEN-G (based on trans-European networks in gray infrastructure sectors), would have significant benefits for securing the resilience and vitality of some of Europe's most iconic ecosystems, with consequential social and economic benefits."

The Green Infrastructure Communication also committed the Commission to undertake "a study to assess the opportunities for developing a EU TEN-G initiative" by the end of 2015. The Commission also, however, delivered a "cold shower" in its conclusions, where it stated: "The best way for the EU to promote the development of GI is to create an enabling framework to encourage and facilitate GI projects within existing legal, policy, and financial instruments. Member States are encouraged to build on these opportunities . . . " [2].

The question which, therefore, needs to be urgently asked is: if most of what environmentalists have been deluding themselves as being "green infrastructure" is regarded by society in general, politicians, and economists in particular as being just "green", what could be expected if "green" really were to be taken seriously as "infrastructure"? Before trying to answer this question, it should be instructive to consider exactly what it is that characterizes traditional infrastructure. In practice, the term infrastructure is commonly applied to a wide range of superficially very different phenomena. According to the Oxford English Dictionary "infrastructure" (b) comprises:

"the installations and services (power stations, sewers, roads, housing, etc.) regarded as the economic foundations of a country."

There are various ways of categorizing infrastructure, and considering these can be helpful to try to make sense of this diversity. Generally, though, two broad classes are distinguished: technical infrastructure and social infrastructure. Technical (sometimes known as 'gray') infrastructure is used to describe the physical networks supplying us with power and water, removing waste, and enabling transport and communication. Social infrastructure provides society with, amongst other things, education, health care, and perhaps even culture and entertainment.

So, what does a sewage works have in common with a concert hall, or an electricity substation with a kindergarten which allows them all to be grouped under the common heading "infrastructure"? What is more, how might the answer help us to discover what the difference between "just" green and "green infrastructure" might be.

Both types of conventional infrastructure require a combination of physical and human resources, but it could be said that in the case of technical infrastructure, the humans are only there to provide the necessary support for the physical systems, whereas in the case of social infrastructure, it is the other way around. However, this still does not answer our question as to what characteristics they fundamentally have in common, what makes them all infrastructure. The answer, it is suggested, is that—apart from their essential nature, and as diverse as they are—they are all systems, integrated and indivisible systems. Infrastructure refers to man-made (artificial) integrated systems made up of different interacting components which are designed with the purpose of delivering certain results which meet essential societal needs. In each, the whole is greater than the sum of its many parts and can only reliably provide society with their essential services if their systems are whole and intact.

This insight makes it clear that it is, in fact, misleading to refer to, for example, a sewage works or a kindergarten in itself as infrastructure. Instead, each is merely an individual component of a wider system and cannot deliver its services in isolation from the wider system of which they are an integral part. Thus, the sewage works is one, albeit important, part of the wastewater disposal and treatment system, an example of "technical infrastructure". As an infrastructure system, it comprises a network of underground pipework which collects wastewater from human habitations and other buildings and often from precipitation as well. This is then channeled, usually with the help of gravity but occasionally by pumping through the sewerage system to the treatment plant. Here the water is cleaned by a combination of physical, chemical, and biological processes before being discharged to a nearby watercourse.

Before considering what all of this means with regard to green infrastructure, it is instructive to consider some case studies of "green infrastructure" projects. This international overview provides an insight into the extent to which the current understanding of green infrastructure is a shared one, within the discipline at least.

3. Results: Green Infrastructure Case Studies—A Selection of Best Practice Examples

One major aspect of the urban climate is the urban heat island. It is intensified by climate change; causes health problems of urban dwellers; and can lead to deaths of sensitive persons. M. Žuvela-Aloise and others have shown that the heat could be reduced by introducing vegetation and open water surfaces in urban design. The best efficiency can be reached by targeted implementation of combined measures such as a decrease in building density of 10%, a decrease in pavement by 20%, and an enlargement in green or water spaces by 20% [29].

According to the Turkish green infrastructure guide for municipalities, on the urban scale, rain harvesting, rain gardens, constructed wetlands, bioswales, permeable pavement, wet ponds, dry ponds, green roofs, green walls, tree planting, and riparian buffer zones are the most suitable urban green infrastructure elements for cities [30].

In Medellín, Colombia's second largest city, the "Green Corridor" program transformed the verges of 18 roads, 12 waterways, and three tutelary hills into cooling zones by implementing green infrastructure. The green corridors were mainly planted in areas

without sufficient green space. For example, along 2.3 km of the Avenida Oriental, 308 trees, 240 palm trees, and more than 90,000 species of plant were planted and created a green corridor. The vegetation lowers the ambient temperature by up to 2 °C, improves the air quality, provides shade, and creates habitat for insects and birds. The mayor, Federico Gutiérrez, states that the citizens can feel the heat reduction of the corridors. Juan Bello, head of UN Environment in Colombia, calls this project an excellent example of the use of nature for smart urban design. The green corridors improve the climate conditions and strengthen biodiversity. In addition, 5000 m^2 of concrete walls and columns in strategically situated public spaces were changed into vertical gardens in the form of green walls with climbers and a large number of different species to regulate the climate, capture CO_2 and particulate matter, produce oxygen, reduce noise, and enrich biodiversity.

Toronto, Canada has set up a "Green Streets" program [31]. About one-quarter of the city's land area is covered by streets, approximately 5600 km. Green streets incorporate green infrastructure, which includes trees, green walls, and low impact development stormwater infrastructure, for the use of ecological and hydrological functions and processes. They are designed to collect rainwater and to lead this water to the plants and trees; they serve as filters to clean the water before it is sent to any sewer or canal. Green streets support the urban forest; reduce the urban heat island; help manage and reduce stormwater runoff; support the infiltration of water into the ground to sustain groundwater systems; and enhance the quality of the water. With the improved water supply for the plants, and especially for the trees, their evapotranspiration rate and other ecological functions can be improved. The city of Toronto developed *Green Streets Technical Guidelines* to provide guidance, standards, and tools for the planning, design, integration, and maintenance of green infrastructure. Individual solutions for the sites guarantee that the new designs are appropriate in their urban context, attractive, and functional at the same time. In addition to the "Green Streets" program, Toronto also developed a "Complete Streets" program [32]. Complete streets are streets designed to meet the needs of all users with different means of transportation as cars, public transport, and bicycles or walking. People of all ages are considered as well as their different levels of abilities for the use of sidewalks. Also, uses such as cafés, street furniture, and street trees as well as utilities and stormwater management are taken into account. One aspect among their uses is that they also have an important function for stormwater management. In the sense of sustainability, complete streets integrate social, economic, and ecological aspects of planning and design for streets and their urban environment. The "Complete Streets" guidelines help prioritize the different demands people and the city have, and they shall be applied when streets are constructed or reconstructed.

In Brazil, Rio de Janeiro's first green corridor in the Recreio district was designed to restore and design a sustainable ecosystem in an ecologically sensitive area after damages due to building and other ecologically non-sensitive activities in the past. The aims were to create new habitats for flora and fauna and to connect different areas with new green structures as new open spaces for the people living in this area. This green corridor covers more than 320 hectares of protected areas and 60 hectares of public outdoor spaces. The water bodies in the project area are home to locally endangered species, such as caymans, capybaras, and beach butterflies. The finances to implement the green corridor came from the compensation programs for the Olympic Games, which took place in this district in 2016.

While the project aims to improve and preserve biodiversity, it also improves the resilience of this western fringe of the city to the expected impacts of climate change. A significant aspect here is to reconnect the previously fragmented nature landscapes while creating greened streets as buffer zones and green islands as ecological stepping-stones. Developed areas are also to be greened, by both planting native woody species and promoting green roofs and facades. New bike lanes, sidewalks, and better public transportation options aim to encourage the use of "clean" mobility. Involving local residents in the project planning and investing in raising environmental awareness are also

key components of the project. Initial results and goals of the planning process, which began in 2012, were presented to the residents in various public events. After all, the long-term success of the project can only be guaranteed if the people either involved or affected become more aware of the importance of biodiversity and ecosystems for their own quality of life and well-being.

Eight years after starting the project, the measures have not yet been fully implemented. So far, the protection of conservation areas has been enhanced, invasive plant species removed, and native species planted. Endangered animals have been given more space and protection by fencing off core areas, and they can also be better monitored as a result. A large favela adjoining one of the canals poses a bigger challenge, as the lack of sewage treatment and eutrophication of the waters have a negative impact on aquatic life. The caymans, for example, are predominantly male, because the decay of organic material means that the water temperature is too high for the female eggs to mature. The capybaras, in turn, pose a risk for humans, because they carry ticks that can transmit Lyme disease. Overall, however, the project has had positive results. Its nature-oriented approach is appropriate for enhancing outdoor spaces and connecting biotopes, in turn supporting the ecosystem. At the same level, green infrastructure helps improve biodiversity, and conservation areas have been stabilized and can act as a buffer to climate change.

The urban development, with focus particularly on the coastal region west of the original city, greatly changed the original landscape in recent decades. The draining of wetlands and the channeling or underground routing of most of the 267 rivers and streams passing through the city have heavily affected the original water cycles and water balance especially. Most of these areas are disconnected from one another, and many are threatened by the continuing expansion of the city and the demand for land for building. This situation, the ongoing construction and densification on one hand and the accompanying destruction of the natural system, contributes significantly to the natural threats to which the city is exposed. The biggest challenge is the water, in the form of heavy rainfalls, storm surges, or flooding with ensuing erosion. Realizing this situation, the city has identified 11 areas as important ecosystems and plans to connect those under the name of "Carioca Mosaic". The Ministry of the Environment developed the Carioca Mosaic to preserve and restore the very sensitive Atlantic Rainforest ecosystem and the equally sensitive system of lagoons and canals [25].

4. Discussion

As the above case studies indicate, despite being important and innovative project initiatives in their own right, much of what is considered today as green infrastructure may or may not meet the condition of being "infrastructure" in the generally accepted meaning of the term. Examining the historic roots of the concept has illustrated that both in the urban and rural contexts the idea of green infrastructure, as a key concept in landscape and open space planning, has long pre-existed its contemporary emergence as a term in the environmental planning discourse.

As has been remarked, its current usage is very flexible, referring to a wide range of natural and near-natural features, structures, and elements at various scales and in differing situations. Indeed, from the point of view of the landscape and open space planning usage, the concept appears to be much broader and more all-encompassing than a conventional "infrastructure"-based interpretation, in that it is multi-functional in the urban context and territorial in its rural application.

What has perhaps changed, however, is that the term "green infrastructure" has in recent decades become an important focus in relation to addressing the growing climate and biodiversity crises. From this narrower point of view, it could perhaps indeed be seen as a concept which differs somewhat to the previous approaches and also one which corresponds more closely to ideas of technical or social infrastructure, in that corresponding projects are aiming to address these concrete issues as a way of solving specific defined societal problems.

Blue infrastructure, in particular, corresponds to this analysis. It is usually mentioned, almost automatically, in the same breath as green infrastructure, but in practice it has often tended to be treated as a poor relation. Green and blue infrastructure, if both exist on one site, need to be seen, developed, and integrated with one another. If they are developed either in ecologically sensitive environments or in urban areas, where the original natural systems were destroyed by urban development, they can serve to support the much-needed biodiversity as well.

In fact, it could be argued that blue infrastructure potentially meets the criteria for a tighter definition of infrastructure better than green infrastructure, as water, unlike green space, is automatically part of the wider hydrological cycle and, thus, requires to be considered as part of a systems approach, but the two can rarely be considered separately. Green and blue infrastructures need to be developed within existing spatial structures, as green and blue spaces serve as multifunctional areas. They also cannot be separated from existing open space systems and, thus, cannot be considered independently from these. Therefore, green infrastructure includes green spaces and forests, inside and outside cities, and it gives a special focus to their functions. Areas containing blue-green infrastructure must be seen and connected to other kinds of infrastructure as well, for example, green roofs and facades, filters for rainwater, and ones for social and recreational needs.

As in the case of technical and social infrastructure, green (and blue) infrastructure, when taken seriously, can only function effectively if well maintained and kept in optimal condition on an ongoing basis. Unlike the conventional forms of infrastructure, green infrastructure, when properly managed, in fact becomes even more valuable over time as vegetation grows and because the effect it has improves as plants mature, compared with when they have just been planted.

A further important quality of all infrastructure is flexibility—especially in the context of resilience to climate change. However, many technical infrastructure assets, such as road and rail structures or canals, flood protection walls or dams, as well as larger buildings, are static and can adapt only slightly to changing conditions. Green infrastructure, on the other hand, has a high degree of spatial and temporal flexibility, and its functions can adapt more quickly to new environmental conditions, such as climate change. In addition, green infrastructure serves multiple functions: alongside being spaces for urban recreation, they help keep cities cool, retain groundwater, enhance biodiversity, and bind and convert CO_2.

Unlike gray (or social) infrastructure, green-blue infrastructure has no standard solutions and must respond to the specific conditions of each place and be regularly reviewed, adjusted, and redeveloped, especially with regard to climate resilience. Adapting green infrastructure to changing climatic conditions as well as changing demands for the use of open spaces in society is, therefore, an iterative process of ongoing development and management. It is no longer enough to maintain the green and blue areas, but rather to strategically manage their development and growth of plants for the future, having in mind the constant improvement and adaptation of the functions of green infrastructure.

5. Conclusions: Future Implications for Green Infrastructure

Whichever view is taken regarding the novelty or otherwise of green infrastructure, its advent as a concept in environmental planning calls for a rethink of our approach. If one chooses to accept that it is, broadly speaking, largely a synonym for what the proponents of landscape and open space planning have long been advocating, then it should be clear that the expertise of the professionals behind these disciplines provides an essential resource for spearheading the development and realization of green (and blue) infrastructure as a means of responding to the climate and biodiversity crises.

If, however, "green infrastructure" is accepted as being something new and different, then it needs to be treated with at least the same seriousness as other forms of infrastructure, either technical or social. Green and blue infrastructures in both urban and rural areas need to be conceived and planned as a series of integrated goal-orientated systems to be aimed at ameliorating the worst impacts of climate change (predominantly in urban areas) and

protecting and furthering biodiversity (largely in the rural context). Given the urgency of tackling them, it cannot be sufficient to hope that these functions can simply continue to be fulfilled as by-products of existing urban parks and gardens or rural nature reserves and Natura 2000 areas.

In practical terms, though, these "new" blue and green infrastructure systems will not be able to be created independently of existing parks, green spaces, and open space systems. The reason for this is simple: in urban areas, at least, they would need to occupy significant areas of additional land which do not exist, except perhaps in a few "shrinking cities" where such resources are unlikely to be distributed so as to meet the necessary functional requirements. The consequence of this is that the additional functionality required of the new green infrastructure will have to be overlaid onto the existing urban land use patterns and rural landscape structures.

What this means in practice is that, at least to some extent, new wine will have to be poured into the old bottles after all. Much of any new green infrastructure will have to incorporate existing urban parks, gardens, and green spaces together with today's protected landscapes in the rural environment. However, these will only provide potential elements as part of a new green and blue infrastructure system, and, thus, business-as-usual cannot be an option if the pressing climate and biodiversity crises are to be successfully addressed.

Increasing both the quantity and quality of green space and vegetation in both urban and rural areas should also be an important objective if there is to be a "true" green infrastructure system which can seriously aim to ameliorate the impacts of climate change and respond to the biodiversity crisis. But it will also be necessary to link together existing structures to create effective green and blue infrastructure in the form of enhanced open space systems and habitat networks.

To achieve these pressing new and more ambitious aims, new organizational structures will be necessary. These will have to be dedicated departments, provided with the necessary specialist staff resources, appropriate budgets, and political support and dedicated to achieving these goals.

Their management as green infrastructure, therefore, needs more than just the conventional budget and labor resources for maintaining spaces: mowing lawns, picking litter, and pruning trees or shrubs. It needs smart planning and interconnection; it needs to be seen as a growing and, in its parts, differently developing system. Usually, cities use or develop a digital green space information system (GRIS), which needs to be as flexible as the green spaces and the demands on them are. This information system should also include all data and management plans on blue infrastructure. The management has to see the green spaces in the present as well as their development in the future, and it needs to ensure that all plants and animals can live and grow in the best conditions to fulfil their functions as best as possible. The management needs to differentiate between areas that might not be able to fulfil their functions anymore, maybe due to a lack of appropriate care in the past, and the improvement of neglected green spaces. Older vegetation can often be revitalized and will serve much better than newly planted trees, for example. Investments in new infrastructure elements will take time to pay off.

It would be helpful in many cases if a GRIS could calculate the benefit of green spaces in terms of ecosystem services, such as producing fresh air, evapotranspiration, enrichment of groundwater, and more. Since the quantification of the benefits of ecosystem services in monetary terms is still in its infancy, providing data for the credit side of the balance is difficult. The costs on the debit side, by comparison, look as if green infrastructure generates only expenditure but has no benefit. Green and blue infrastructures are sustainable in the best sense; they meet social, ecological, and economic demands. However, the value needs to be seen, and green and blue infrastructure needs better support in cities and ministries, preferably a new administration which integrates many of what are today separate roles. It, too, needs specialists in different fields to design and develop the green infrastructure in accordance with the new and more ambitious goals and which responds to multiple needs and changes over time.

Compared to technical infrastructure such as canals, sewerage systems, or large traffic infrastructure, e.g., roads and public transport—including built structures such as subway tubes or high lines—green areas still are not seriously recognized as infrastructure, in one serious respect at least: the amount of resources devoted to them; and maybe this is the crucial question: why has green infrastructure not been developed with as much political support as other forms of infrastructure? For these, large budgets for building, improvements, and maintenance have been granted over the years without question, as President Biden's recent infrastructure package has again reminded us.

On the other hand, the budget of existing departments responsible for green space management has always been much smaller and less secure. This has led to insufficient care of green and open spaces and their very often underdeveloped plant growth; neglected green spaces; and losses in biodiversity and the ecosystem services that these deliver.

But the discussion should not even still be about better funding to maintain the status quo. What is needed instead is a wholesale investment in a new system of green and blue infrastructure in both towns and cities and in the wider landscape in an attempt to compensate for the impacts of climate change and biodiversity loss. This needs to have the same level of ambition as a trillion-dollar spending project on technical infrastructure.

Finally, in case the idea of a large-scale and seemingly unprecedented investment program in urban green and blue infrastructure to address a pressing environmental problem seems something of a distant and unrealistic pipe dream, it is important not to forget that it has been done before. As the city of London grew during the first half of the 19th century, the sanitary conditions became worse and worse, and diseases such as cholera were widespread. The streets were running with human waste, and the pollution of the city's rivers, including the Thames, reached such an unpleasant peak in the summer of 1858 that it became known as the year of the "Great Stink", as the stench of decaying waste and human excrement made life in the city increasingly unbearable.

Enter engineer Joseph Bazalgette with his project for a sewerage system for the city. Having long postponed taking action due to the high costs, within 18 days of the "Great Stink" a law was passed in parliament (located beside the banks of the stinking Thames) which initially made today's equivalent of up to USD 1.3 billion available to finance the project [33].

In the same way that green infrastructure has multiple additional benefits beyond ameliorating the impacts of climate change, London's sewers also turned out to be a multi-functional infrastructure project, with long term architectural, urban design, and transport benefits: parts of the interceptor sewer were incorporated into the Thames Embankment, a new imposing riverside promenade which also housed an underground railway line, while many of the associated pumping stations are now protected as architectural monuments.

The state of green infrastructure today can be compared to the sewage situation of London in 1858. The environmental problems are visible and acute, but finding a sustainable solution requires a bigger effort. There is a long way to go to build a real green infrastructure network, as the practice is now to build single green infrastructure elements or single projects as best practice examples. There is need for a green infrastructure network connected to blue systems and all other infrastructures throughout the world. This would also include re-naturalizing ecological damage which has happened in the past.

There seems no better time than today to start green infrastructure on a bigger scale throughout cities and rural landscapes, build a big and effective network, sustain its management and care, and give it the needed support and budget. In many countries, a sewage system and the budget needed to sustain it are taken for granted. Today's environmental crises demand a new system of green infrastructure of the 21st century.

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