

# PRINCIPLES AND SOLUTIONS FOR GREEN INFRASTRUCTURE ELEMENTS IN EUROPEAN CITIES

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## Abstract

Green infrastructure is one of the most important and most addressed types of infrastructure in the last decade, also in relation to addressing the climate crisis and the related stormwater management and drought impacts. However, cities in Europe approach the application of green infrastructure elements or the application of the whole water management system very differently, which is also due to the very structure of urban development. The aim of this paper is to present the principles of green infrastructure solutions on the examples of several European cities and in the context of the Czech Republic and to specify where implementation is insufficient or what are the specific problems why implementation is not successful.

## Keywords

Green infrastructure, infrastructure, city, urban development, water management

## 1 INTRODUCTION

Green infrastructure is a valuable tool for achieving the environmental, economic and social benefits that are key pillars of sustainable development. It harnesses the power of nature and provides ecosystem services that significantly improve the quality of life and well-being of people. Thus, it also improves the quality of the built environment, which should be accessible to everyone [1], [2].

Green infrastructure is able to perform multiple functions and deliver multiple benefits in the same spatial area. These functions can be economic, social or environmental. For example, functions for biodiversity conservation, climate change adaptation, drainage, traffic calming, job provision and property price appreciation are just some of the benefits of such infrastructure [1], [2].

Green infrastructure also has an important role to play in protecting against flooding and heavy rainfall. Due to its water retention and absorption capacity, it can reduce the amount of runoff and thus minimise runoff from arable land, pollution of watercourses and the burden on wastewater treatment plants. In addition to its function against flooding, it also has the opposite function of protecting against long-term drought and climate change. This type of infrastructure also contributes to cleaner air, reducing airborne dust, mitigating the urban heat island effect and creating additional recreational areas that enhance the appearance of urban and suburban areas. In addition, green infrastructure is a less costly alternative to "grey infrastructure" solutions and can provide multiple benefits and advantages from a single solution. These elements further support the local economy, social cohesion of residents and improve the quality of the environment [1], [2], [3], [4].

In order to reap the full benefits of green infrastructure, it is important that the elements are functional and located in the right places. This means that they need to be large enough and well connected to be effective.

An important element of green infrastructure on a European scale is especially Natura 2000 and in the Czech Republic the related territorial system of ecological stability, which forms the backbone system of green infrastructure in the landscape. In cities, green spaces and green infrastructure in general should be addressed in spatial planning documentation, i.e. in land-use plans. The urban green space system has an important function in the city, just as we see in the ecological stability system in the open countryside [5], [6].

Natura 2000 is therefore important for the protection of the landscape and its elements not only in the Czech Republic. Natura 2000 is a system of protected areas created by the countries of the European Union. This system serves primarily to protect the rarest and most endangered species of animals, plants and natural habitats throughout the territory of the European Union. The main aim is to protect biodiversity, which is very important for the countries of the European Union. It is so important that the aim is not just to maintain the current state, but to improve and diversify biodiversity overall by a given horizon. The Natura 2000 system is made up of two types of protected areas – bird areas and sites of European importance. "There are 41 bird areas on the territory of the

Czech Republic, which represents about 8.91% of the territory of the Czech Republic, and there are 1,112 sites of European importance, which represents about 10.8% of the territory of the Czech Republic. In total, the Natura 2000 system accounts for approximately 14% of the Czech Republic's territory, as bird areas and sites of European importance overlap in many places in the Czech Republic. The area is set at 703,437 ha of bird areas and 795,640 ha of sites of European importance. "[5], [6].

## 2 METHODOLOGY

The subject of the research and the article are the principles and solutions of green infrastructure elements in European cities. In order to achieve this, the theoretical sources of the issue were initially investigated, as they are the basic building blocks. The materials were reviewed not only from the perspective of the Czech Republic and binding documents or methodological recommendations, but mainly focused on European materials and legislation that determine the future direction in this area. The article mainly examines green infrastructure in cities, i.e. outside the open countryside. It discusses trends that are currently observable and the follow-up to new methodologies.

One of the most important documents at European level is the Landscape Convention, which defines landscape as "that part of the territory, as perceived by people, whose character is the result of the action and interaction of natural or human factors". Another important document is currently the Green Deal and the New European Bauhaus, which are driving instruments and initiatives. It is primarily an environmental, economic and cultural project with the aim of improving and transforming the built environment and improving its quality [7], [8], [9].

These findings were further used during physical surveys in the selected Czech and European cities. Within the Czech Republic, the cities of Prague, Brno and Ostrava were identified to demonstrate these principles and solutions. Other cities were Bratislava in Slovakia, Graz in Austria and Barcelona and Cuenca in Spain. In terms of selection, the cities were chosen to offer an example from different parts of Europe while representing larger and medium-sized cities and solutions for green infrastructure elements in a true urban environment. As part of the review, there is also an example of a medium-sized city, Cuenca, which offers a view of the environment of an inland Spanish city with a different climate.

## 3 RESULTS

### Czech Republic

The concept of green infrastructure has not been anchored anywhere in the Czech legislation for a long time. There was no definition and within the Czech environment we heard about green infrastructure in several mutations of the word. In Act No. 183/2006 Coll., on spatial planning and building regulations (Building Act), we have only the terms public infrastructure, which include transport infrastructure, technical infrastructure, civic equipment and public spaces [3, § 2, paragraph 1, letter m]. There is no mention of green infrastructure. It was only with the new Act No 283/2021 Coll., the Building Act, that the concept of green infrastructure in the Czech Republic was anchored in legislation. And it was classified as a type of public infrastructure. Specifically, according to Section 10, paragraph 1, letter c) of Act No. 283/2021 Coll., the Building Act, "green infrastructure is a planned, predominantly continuous system of areas and other elements of vegetation, water and water management, of natural and semi-natural character, which by their target state enable or significantly support the fulfilment of a wide range of ecosystem services and functions; green infrastructure also includes the territorial system of ecological stability of the landscape" [4, Section 10, paragraph 1, letter c]. Thus, the concept has been given a great importance, because already in the planning of the territory, this infrastructure also needs to be taken into account and evaluated. In the Czech Republic's Spatial Development Policy, in the section of the republican priorities, there is a talk about public infrastructure, so green infrastructure will also be evaluated in spatial planning activities [10], [11], [12].

### Prague

Prague, like other cities, is undergoing a transformation and in the construction of new districts or brownfield sites, it combines modern architectural approaches within a quality built environment set in quality public spaces with multiple functions not only for the inhabitants of a particular place, but also for visitors in general. Public spaces are used to plant green spaces not only for water management and absorption during excessive rainfall, but also for recreational use, as elements to cool the city and absorb dust and pollution particles. There is an emphasis not

only on the working environment of the buildings, but also on out-of-hours activities during lunch and break times. In addition, these spaces are complemented by amenities in the form of cafés, restaurants and other amenities. Sample in Fig. 1.



Fig. 1 Selected public areas in Prague.

## Brno

The City of Brno has been following the principles of water management for many years and has been trying to involve citizens in participatory budgeting when voting for interesting projects. Green infrastructure is highly visible in Brno. In addition to solitary trees, alleys, parks, we can also find green belts by tram lines or significant changes in existing public spaces where green elements are highlighted. Sample in Fig. 2.

However, Brno's plan is also to increase the amount of green roofs and facades in the urban environment, with these systems being implemented mainly on urban buildings.



Fig. 2 Approaches to the implementation of green infrastructure elements in Brno.

## Ostrava

Ostrava emphasizes green infrastructure also thanks to its polycentric urban structure. At the same time, it tries to implement green infrastructure in areas where industrial production is declining and where new large urban parks and public spaces are to be created in the future. Even within Ostrava, we can find habitats of wetlands and alders, which are unique refuges for a variety of animal and plant species. In the Czech Republic, floodplain vegetation formed a regular vegetation cover on wet to waterlogged soils near watercourses. Due to human influence, these areas have disappeared and the water regime of large areas has been disturbed. Ostrava is taking this step not only to return to nature and thereby mitigate the symptoms of climate change, but also to educate the public about the reason why these areas are so important. Sample in Fig. 3.





Fig. 3 Wetlands and alder woodlands in Ostrava.

### Slovakia – Bratislava

Slovakia does not have a Green Infrastructure Strategy or principles for its implementation, but, as in the Czech Republic, Natura 2000 is an important element. Natura 2000 sites in Slovakia include 223 species and 66 habitats from the nature conservation directives. The number of species and habitats protected in each site varies depending on the location of the site, the biodiversity in the region, the designation used and the elements that the site is designed to protect [6].

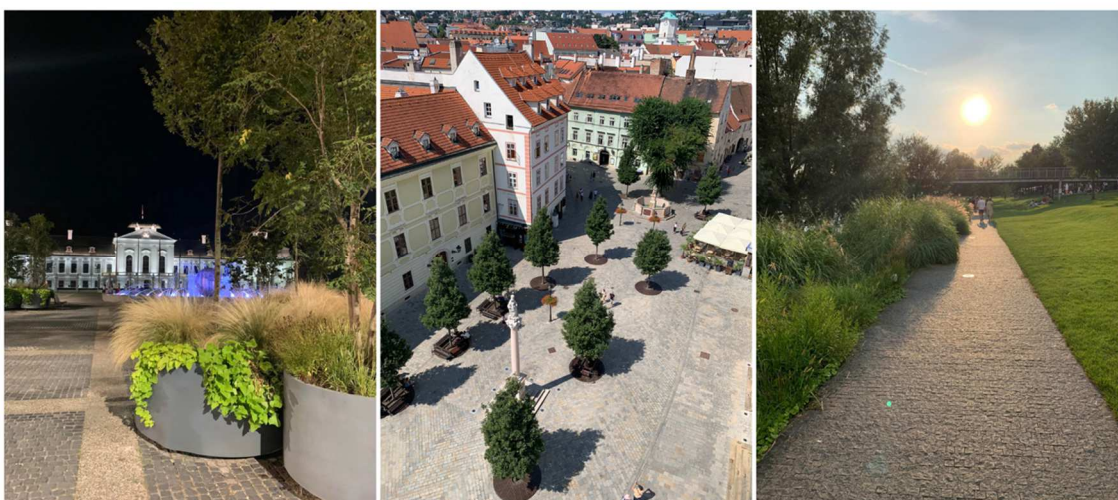


Fig. 4 Examples of the diversity of green infrastructure in public spaces in Bratislava.

Over the last decade, Bratislava has been transformed into a major European city that applies the principles of modern planning and implementation of sustainable solutions, including green infrastructure elements. The Danube area has been transformed into a quality public space that comes alive every day in the morning hours and sustains life well into the night. Sample in Fig. 5. The waterfront contains a large number of diverse green elements and at the same time is complemented along its length by other amenities including several large shopping centres with all amenities. Sustainable solutions can also be seen in other parts of the city, again more in the context of new modern buildings and shopping centres such as Mlýnské Nivy. Sample in Fig. 4. The area, which offers a bus station, amenities and recreational potential, attracts a huge number of visitors. The roof of this area serves as a large public park for moments of relaxation and sporting activities.





Fig. 5 Multipurpose use of the roof of the multifunctional centre NIVA.

## Austria – Graz

In Graz, Austria, the implementation of green infrastructure is mainly manifested in the planning of buildings or urban areas. Green elements are implemented in common areas, atriums, public spaces around buildings and overall buildings are designed in a more sustainable and modern way. Sample in Fig. 6. Austria is striving to fulfil the principles of the New European Bauhaus as well as to improve the quality of the built environment and thus the quality of life of the inhabitants [9].



Fig. 6 Incorporation of greenery in buildings.

## Spain

Spain does not have a green infrastructure strategy as such, but the concept of green infrastructure is quite explicitly incorporated in various places in existing national legislation. Law 42/2007 (Natural Heritage and Biodiversity) imposes a general obligation on the Autonomous Communities to adopt measures aimed at ensuring environmental connectivity, while various regional laws focus on the connectivity of natural areas. Prior to the adoption of Law 42/2007, the Autonomous Communities had already introduced some initiatives for the development of corridors. Spanish policy focuses on implementing measures to ensure connectivity between existing protected areas rather than promoting the development of a comprehensive and integrated ecological network.

Green infrastructure is recognised in several laws on the provision of ecosystem services, such as Law 9/1995 on Territorial, Land and Urban Policy Measures in the Autonomous Community of Madrid. The Ministry of Environment and Rural and Marine Affairs is implementing the "Projects of the National Plan for the Restoration of Rivers in the Confederación Hidrográfica del Cantábrico", which links green infrastructure to the Water Framework Directive and the Floods Directive. The Spanish coastal zone strategy relates to green infrastructure

through two main objectives: to restore physical functionality in the natural coastal zone and to adapt to climate change [2].

## Barcelona

Within Spain, Barcelona has been very quick to stand out in terms of green infrastructure solutions. It has presented the Barcelona Green Infrastructure and Biodiversity Plan 2020, which includes more than 70 projects and actions with the following objectives: to provide environmental and social services, to bring nature into the city, to increase biodiversity, to increase connectivity between disparate green infrastructure and to increase the resilience of the city [1], [2].

## Cuenca

Cuenca is a medium-sized city that is greatly influenced by the surrounding landscape and high temperatures. Within the urban area, there is a call for the implementation of green spaces in any open space, whether it is the city centre, the riverbed or more sloping areas. More resilient types of greenery are selected, but at the same time, efforts are made to manage stormwater as economically as possible. At the same time, modern planning features are seen in new parts of the city where public spaces are one of the key places to live. The only absence of green spaces is in the historic part of the city, which retains its identity and character. Sample in Fig. 7.

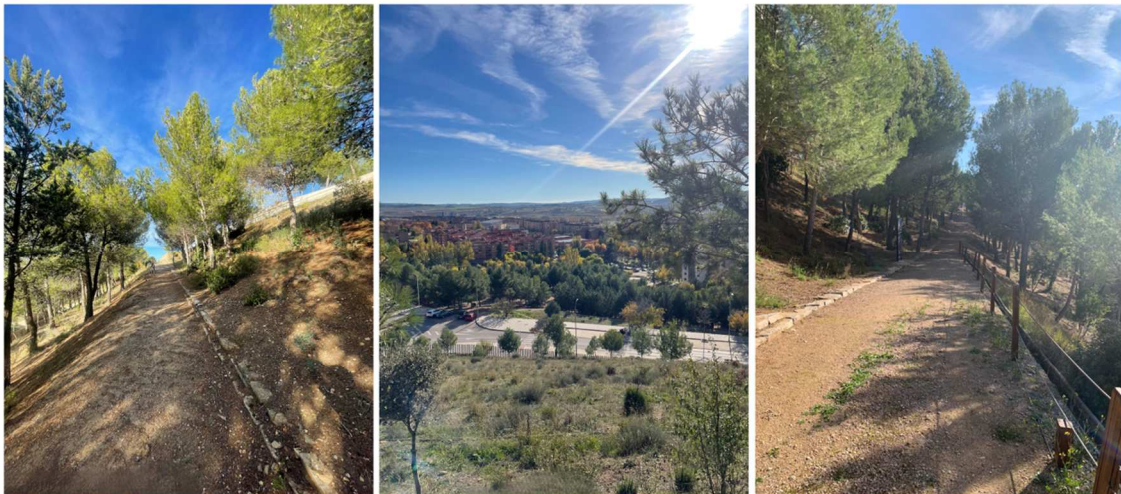


Fig. 7 Different type of green space in the inland city of Cuenca.

## 4 DISCUSSION

Green infrastructure is now an important topic and element to mitigate and adapt to climate change. Unfortunately, the concept is still not clearly anchored in the professional community. It will certainly take time for each generation to realise that this issue needs to be addressed and that everyone has the opportunity to make a contribution to the whole.

Green infrastructure elements have great potential, but also limits, which are manifested in cities. Not every space can accommodate these elements. These are mainly limits affecting other types of public infrastructure, such as the coordination of green and technical infrastructure in the street space. This is currently also being addressed legislatively, with efforts to change buffer zones and introduce new principles for planning street space so that green space also has its place [4], [11].

In the future, the environment needs to be addressed comprehensively, not just the urban environment and subsequently the open countryside. Increasingly, this needs to be integrated into a single functional unit, as settlements are part of the landscape. These ideas are linked to the introduction of the article, where the whole area should be addressed within the spatial planning documentation, i.e. linking the systems in the landscape with those in the city. Landscape management concepts should be developed and also focus more on a high quality system of settlement greenery. There is also a 'Methodology for defining green infrastructure in spatial planning

documentation, especially in the master plan'. This should promote more in the future the design of green infrastructure elements, where multidisciplinary experts will be needed to deal with the complex tasks ahead [13].

The research also found that high quality green infrastructure is found mainly in the newly built urban environment, which in recent years has been trying to meet the demands for a high quality built environment in line with the goals of sustainable development and climate change adaptation. Developers are more compelled not only to be concerned with the construction of buildings, but also to be concerned with the surrounding environment, which can substantially increase the value of surrounding areas and their attractiveness.

## 5 CONCLUSION

The principles and solutions of green infrastructure elements in each of these countries are influenced by the possibilities of legislation, but especially by the approach of the developers or cities themselves. In the Czech Republic, we have several materials for evaluating the effectiveness of individual green infrastructure elements, e.g. the Methodology for the Evaluation of Ecosystem Services in Human Settlements in the Czech Republic or the Methodology for the Economic Evaluation of Green and Blue Infrastructure in Human Settlements. These materials can also significantly influence investors' understanding of why to place these elements in public spaces and on buildings. Over the last decade as green infrastructure elements have begun to be addressed we have seen an increase in high quality examples and solutions. A large number of European cities located close to watercourses are trying to make them accessible and create new spaces for the public as quality public spaces. Europe is setting ambitious and important targets to avoid losing our quality of life and to reverse the negative trends in climate change. In conclusion, the countries of the European Union are influencing each other and learning how best to implement green infrastructure elements in their environment [3], [4], [8].

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