Urban Insight
By Sweco

Urban Insight by Sweco is a long-term initiative that provides insights into sustainable urban development as, seen from a citizen's perspective. The initiative is built on a series of reports, based on facts and research and written by Sweco's experts. The initiative provides society and decision-makers with the facts needed to understand and meet both current and future challenges.

This report is part of a series of reports on the topic 'Actions Towards Resilience', in which our experts highlight specific data, facts and science that are needed to plan and build safe and resilient future urban environments.

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From grey to green

Resilient transport infrastructure through nature-based solutions

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Contents

Nature-based solutions support several major EU policy priorities, such as the European Green Deal, biodiversity strategy and climate adaptation strategy, as a way to preserve biodiversity and make Europe more climate-resilient.

Foreword

The EU has one of the densest transport infrastructure networks in the world, but it is ageing and under increasing pressure due to rising traffic. The maintenance deficit is causing deterioration, such as collapses and poor road surfaces.

Nature-based solutions (NBS) are natural solutions provided by healthy ecosystems and green infrastructure that can deliver significant economic and resilience benefits. They offer jobs, higher economic returns, and are faster to implement and more sustainable in the long run compared to traditional infrastructure.[1]

Nature-based solutions are becoming more important as they work at multiple scales. Climate action means not only reducing greenhouse gas emissions but also protecting and restoring nature. The EU's recent Nature Restoration Law adopted in July 2022 underpins the EU biodiversity strategy for 2030 and paves the way for even greater biodiversity and climate action.

NBS investments reduce carbon emissions, strengthen resilience to disasters, decrease biodiversity loss, and benefit human and ecosystem health. Urban planning is shifting from a "people-centric" to a "life-centric" approach, considering planetary boundaries and all forms of life. Holistic and environmentally conscious planning takes a strategic view of the urban area, considering social, economic, and environmental factors. This approach is important for the transformation of cities and informed decision-making.

This publication showcases contemporary projects solving urban challenges and hopes to inspire other planners, engineers and architects worldwide. Together, we can co-create solutions and can make our societies more resilient.

Right now, we have a window of opportunity to create resilience with nature-based solutions. This will require skilled and ambitious planners to design innovative solutions. I also see the need for cooperation between public and private stakeholders on different scales and across disciplines.

Andreas Gyllenhammar, chief sustainability officer at Sweco.

Introduction

Infrastructure losses have profound consequences for the development of our society. According to the Global Commission on the Economy and Climate, approximately EUR 85 trillion is expected to be invested globally in infrastructure during 2015–2030 to meet the world's urban, land use and energy needs.[2]

In Europe alone, we have more than 4.5 million paved roads and 212,500 km of railway lines.[3] Regular maintenance of the current infrastructure is essential to maintain a consistent quality level of Europe's transportation network. It is therefore fundamental that financial investments in infrastructure are disaster-resilient to protect lives and secure socio-economic development. In addition to increasing the safety of users, a well-maintained and modern transport network comes with various environmental benefits.

Increasing risks on infrastructure

The effects of climate change are already hitting our infrastructure hard in many different ways. The recent extreme rainfall around the city of Bologna in Italy caused landslides that led to collapsed roads and bridges and left many residents isolated. The extreme weather conditions in the Netherlands, Belgium and the north-western part of Germany during the summer of 2021 are also fresh in our memories. The money required for repairing the destroyed roads and railways in Germany was estimated to be around EUR 2 billion.[4]

EUR 2 billion
estimated cost of repairing the destroyed roads and railways in Germany after the storm in 2021.

More extreme rainfall due to climate change
Recently in August 2023, over 100 roads closed and thousands of people were evacuated in Norway due to storm Hans. The storm led to a collapsed hydroelectric plant, a train bridge at risk of collapsing and several communities under water. In Sweden the storm caused flooding, power outages and road damages. Denmark encountered strong winds that wreaked havoc. Train and road traffic were disturbed by fallen trees and several ferry departures were canceled. The storm Hans hit Scandinavia hard, with costs amounting to several million euros.

Climate change is causing more frequent extreme rainfall events, and Europe's infrastructure is not prepared for the amount of rain. The design of cities, with an expansion of grey infrastructure, asphalt and hard surfaces, fewer green areas and dense buildings, exacerbates the problem.

"In the future, we will see more weather events like this," says Johanna Alkan Olsson, Associate Professor of Environmental Science at Lund University. "The main problem is, of course, climate change combined with the fact that there is nowhere for the water to go," she says. The storm is partly natural, but more frequent appearance of storms like Hans is not normal. "Rainstorms like Hans usually occur every fifty years, but now they are happening more often and that is not normal. We are now seeing human-caused climate change," says Olsson. She further argues that Swedish cities and towns are not equipped to handle the amount of water that has fallen recently. This is because of how cities are designed, with a lot of asphalt, few green areas and dense buildings.

Asphalt and roofs are like putting a raincoat on a city – the water runs off and causes damage

Johanna Alkan Olsson, Associate Professor of Environmental Science at Lund University

Infrastructure shapes and influences the surrounding environment. All paved surfaces absorb and retain heat, contributing to the urban heat island effect. On a larger scale, transport infrastructure networks divide natural habitats, impacting biodiversity. The vehicles using this infrastructure also generate noise, pollutants and greenhouse gas emissions, decreasing human health and well-being.

Opportunities with nature-based solutions

Great opportunities lie ahead in developing infrastructure to "build back better" by implementing blue-green measures and upgrading infrastructure networks to respond to and mitigate risks during an emergency. At the same time, upgrading infrastructure helps to provide solutions at a local level,

integrating the geographical context, while reconnecting and reinforcing local ecosystems.

Until recently, solutions for reducing the risk of disasters and building climate resilience have mainly focused on grey infrastructure such as storm drains, embankments or retaining walls. However, grey infrastructure is seldom the most resilient, sustainable or most cost effective.[5] Instead, planners are beginning to turn to the use of natural elements and processes, called nature-based solutions.

Nature-based solutions (NBS) are gaining recognition as an innovative approach to increase resilience and provide economic, social and environmental benefits. This involves restoring and using natural resources to mitigate and adapt to climate impacts. The UN has identified NBS as a priority action for a resilient recovery from the current health and economic crisis, as they offer higher economic returns and more jobs, and are more sustainable than traditional infrastructure.[6]

In this white paper, we focus on how stakeholders can seize opportunities to transform road infrastructure from a barrier into a lever for improving nature, people and communities, thereby contributing to a more resilient society. We highlight the benefits of NBS, showcase inspiring and innovative projects, discuss different aspects of NBS in infrastructure and leave you with five key lessons and recommendations for successful implementation.

Turning grey into green

Optimisation of transport infrastructure through nature-based solutions

The IPCC Sixth Assessment Report states that climate-resilient development is more urgent than previously thought. To increase the adaptive capacity of urban and rural settlements, it is essential to have integrated and inclusive planning and investment in social, ecological and physical infrastructures. This can be achieved by taking into consideration the observed impacts, projected risks, vulnerability levels and adaptation limits.

Decades of prioritising motorised transport in European cities, following the post-war car enthusiasm, have led to a heavily mineralised urban landscape. Today, this situation is being strongly questioned by public authorities, professionals and citizens alike, and has become one of the central focus of urban renewal. Imposing tighter speed limits, improving public transport systems and promoting soft transport modes allow fundamental changes of the traditional streetscapes and road networks. Optimisation of the surface area dedicated to private vehicles creates possibilities to free up space and incorporate other uses and qualities, such as green features and nature-based solutions.

Nature-based solutions (NBS) refers to 'actions to protect, sustainably manage and restore natural or modified ecosystems that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits'.[8]

Green and blue infrastructure combine grey infrastructure with nature-based solutions to create hybrid systems (integrating vegetation and water features) that improve resilience to climate impacts. On the other hand, natural infrastructure uses existing or rebuilt natural landscapes to increase resilience to climate impacts, like forests or wetlands.[9]

Given the environmental and social issues at stake, as well as the impacts of climate change in cities, the redesign of transport infrastructure through NBS contributes to the development of wider urban green networks and provides several ecosystem services.

Benefits of blue-green infrastructure:

- Pollution control, improved air and water quality
- Cost savings compared to operations and maintenance of traditional drainage systems
- Community amenities – attractive green areas, health and well-being benefits
- Improved habitats for wildlife
- Flood prevention and reduction
- Encouraging natural groundwater recharge
- Adaptation to climate change

The neighbourhood in 2050

Resilient to heavy rainfall events and flooding

It's 2050 and heavy rain has fallen for an hour. The green roofs are saturated. Excess stormwater is channeled to the pond, which fills up, overflows and recharges the sunken garden and underground water storage. Riverbank embankments and treatments protect the neighbourhood from a rising river. Because of these successful climate actions, the neighbourhood can be dense, liveable and resilient to precipitation and flooding all at once.

The 2006 Millennium Ecosystem Assessment (MA) defined ecosystem services as the many and varied benefits humans obtain from healthy ecosystems and natural environments. Four types of services emerge from this concept, each of which can be provided by well-designed green transport infrastructures.

Supporting services are those which relate to habitat functioning themselves, and therefore influence survival.[10] These services include the overall development of nature on transport infrastructure in terms of both quantity (planted surface area versus mineralised surface area) and quality (diversity of plantings and strata, provision of habitats and resources for wildlife, support for biodiversity and gene pools, etc.)

Regulating services are categorised as any benefit obtained from the natural processes and functioning of ecosystems[10] (for example, climate regulation services). Road networks can include sustainable rainwater management with the joint objectives of reducing the risk of flooding and the negative impact of overflows on the quality of watercourses. These types of interventions are preferably planted, which helps to improve the living environment, combat heat islands and reduce pollution.

Provisioning services are characterised by the ability of humans to obtain products from ecosystems, such as food, water and resources.[10] Including performant landscape features in road infrastructure can be used not only to prevent flooding, but to clean the water so it can be reused or consumed as a resource (for irrigation and for household use). Creating more green spaces in urban streets also encourages local food production at neighbourhood level and community-driven systems for organic waste management through shared composting facilities.

Cultural services include non-material benefits that people can obtain from ecosystems.[10] These include mental health, recreation and aesthetic values. Recreational services as an integral part of the development of green infrastructure networks can be used by children, young people and adults in many ways that go beyond their primary function, and stimulate intergenerational and intercultural encounters.

How can nature-based solutions improve transport infrastructure resilience?

Upgrading road infrastructure with NBS is a necessary step towards building sustainable and resilient cities. While common construction materials like asphalt and concrete absorb and slowly release heat into the surrounding environment, green and blue surfaces reflect heat and create cooler zones within the city. NBS is key in the development of resilient infrastructure because it works as a proactive flood protection, and has a cooling effect during heatwaves.

The detailed masterplan in Norra Djurgårdsstaden results in a 70 percent lower climate impact. The plan includes a marine park with piers and walkways that focus on improving the habitat for aquatic animals. Visualisation by Karavan Landskap.

Demineralisation, creating conditions for resilience in urban areas

Demineralisation describes the un-paving of mineral surfaces, such as removing concrete or asphalt to make streets or squares more permeable. This allows water to be infiltrated and absorbed into the ground below, an essential condition for soil restoration and integrated rainwater management.

During heavy rain, grey infrastructure, pavement and hard road surfaces function as an umbrella over the town, leading to flooding if the water doesn't have anywhere to go. NBS such as swamps can absorb and infiltrate the water, while grey solutions push it away, leading to problems elsewhere.

Restoring natural water cycles

By applying these principles to road design, you can increase the irrigation potential of urban landscapes and mitigate the impact of torrential rainwater during intense rainfall (reducing the polluting impact of stormwater pollution, minimising flooding and consequently the threat to people and damage to property). This covers all development techniques and structures that help to restore the natural water cycle and increase the water retention and absorption capacity of road networks, as close as possible to where the water falls. Water-related measures can include bioswales and rain gardens, which can be incorporated in streetscapes and sidewalks. A bioswale is a ditch with vegetation growing in it and a porous bottom. The water runoff from roads is led into this bioswale via aboveground gutters or ditches. This way, the runoff does not flow into the sewerage system. Other measures include rainwater storage, green roofs on bus shelters, green landscaped car parks, honeycomb or draining load-bearing structures, soil-stone mixes and more.

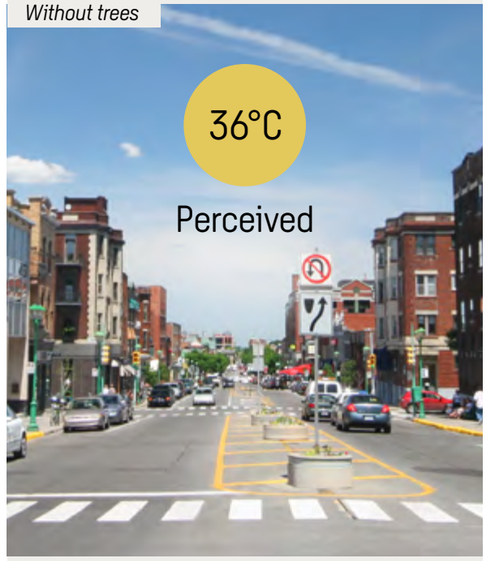
Rainwater management interventions must be accompanied by resource optimisation strategies, such as the promotion of water-efficient green spaces, an appropriate choice of planting species, the rationalisation of watering operations, the recovery of rainwater in storage buffers, the increased use of catchment, and so on.

Park De Motten, Tongeren, Belgium / BUUR Part of Sweco / Photo: Bram Goots

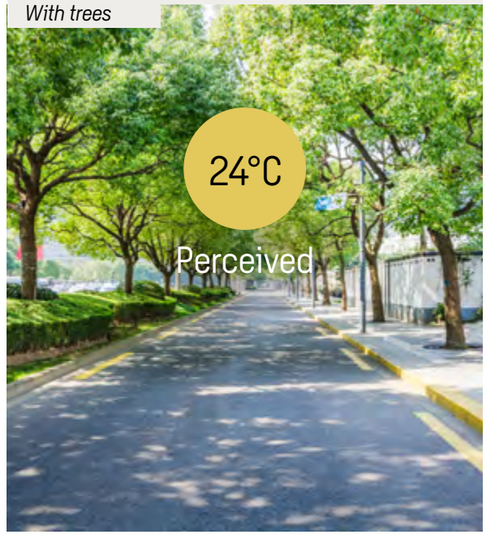
Drongenplein, Gent, Belgium / BUUR Part of Sweco / Photo: Bram Goots

Trees can cool cities by up to 12°C on a hot day[14]

Without trees



With trees



Reforestation of cities

Demineralisation goes hand in hand with soil decompaction and fertilisation to restore biotic and abiotic conditions so that land becomes suitable for plant growth. Demineralisation is therefore an opportunity for the (re)forestation of cities. In an urban context, the planting of trees, green roofs and green walls are small-scale solutions that offer local benefits. However, if these measures are implemented systematically as part of an urban green network, they offer multiple benefits that address many societal challenges.

Increasing the plant canopy (the above-ground part of a plant cropping) in urban environments helps to capture CO2, reduce air pollution, minimise the heat island effect, provide habitats for wildlife and reinforce biodiversity.

Nature-based solutions involve utilising the natural resources of clean air, water and soil in an intelligent manner to address environmental issues. Instead of working against nature, these solutions work with it. Unsustainable land use, natural resource use, deforestation, loss of biodiversity and pollution negatively affect the ability of ecosystems, societies, communities and individuals to adapt to climate change.

The loss of ecosystems and their services has lasting effects on people worldwide, particularly local communities who rely on ecosystems for their basic needs.

Biodiversity can be developed through ecological maintenance of green spaces, diversification of plant species and types of green spaces, where pollinators, winged animals and small mammals can thrive. Possible NBS include the construction of green roofs, green facades, urban gardens and, directly related to road infrastructure, green verges. To ensure the ecological value of roadsides, it is essential to plant a species- and flower-rich composition with native plant species, host plants and nectar-producing plants. These areas should also be managed ecologically. This boosts local insect populations including butterflies and bees.

By adopting tried-and-tested methods to enhance biodiversity on all scales, experts can ensure that cities provide benefits from climate adaptation to human health, as well as contribute to vital ecosystem services which underpin the prosperity of all levels of society.

Greener streets boost the quality of life of communities making road infrastructure more humanised and integrated in their urban context. This ambition questions the current modal split – decreasing the space dedicated to motorised vehicles – and encourages the creation of spaces for play, sport, recreation and leisure in public spaces. The planting of trees and green spaces is therefore an essential component of traffic reduction strategies and encourages users to walk, cycle or use public transport, creating the conditions to support active modes of transport (comfort, shade, cooling, spatial quality, etc.).

Of course, there are plenty of locations where concrete is absolutely necessary. Here, we should consider permeable pavement and eco-friendlier alternatives to concrete. One innovative example is based on using magnesium sulphate, which has the capacity to absorb CO2.[13]

Benefits of urban nature-based solutions

Air quality: Plants absorb and filter pollutants from the air. Reduction of respiratory diseases such as asthma. Improved quality of life for urban residents.

Mental and physical health: Access to green spaces and water reduces stress, anxiety, symptoms of depression and improves cognitive function, while also stimulating physical activity.

Biodiversity: Additional habitats and refuges for plants and animals also improve ecological connectivity and provide opportunities for residents to connect with nature.

Heat reduction: Plants provide shading and cooling. Trees can cool European cities by up to 12°C on a hot day, and an increase in tree coverage by 30% in cities could prevent almost 40% of deaths related to urban heat islands.[14]

Energy saving: The cooling effects of plants and water reduce energy demand for air conditioning and other cooling systems, resulting in lower greenhouse gas emissions and energy costs.

Carbon storage: Plants absorb CO2 from the atmosphere, thereby helping to reduce greenhouse gas emissions. Trees do this most efficiently. Over the lifetime of a tree, 0.5 tons of carbon can be absorbed.[15]

Water management: Plants capture and filter stormwater runoff. Linked benefits include reduced risk of flooding, a reduction in erosion and damage caused by extreme weather events, improved water quality and more habitats for fish and wildlife.

Social cohesion: Accessible green spaces provide opportunities for residents to come together and build social connections. It helps to create a 'sense of place and ownership' leading to increased engagement and responsibility.

Making societies thrive: From an economic point of view, nature-based solutions can offer regional benefits, boosting opportunities for employment, tourism and recreation. Green infrastructure can often provide more benefits at lower costs than single-purpose grey infrastructure. The financial advantages of NBS are also of interest to investors.[16]

Reconnecting nature, increasing territorial resilience

The fragmentation that extended road networks cause has several negative impacts on biodiversity including habitat loss, the barrier effect, roadkill, disturbances and pollution. Large, interconnected green spaces composed of native tree and shrub species, with less intensive management, offer the greatest benefits to wildlife and help nature adapt better to climate change. However, even small areas of vegetation, such as roundabouts and roadside verges, can support a range of fauna and flora. European and global policy bodies set the benchmark at 30% of protected nature on land and in the sea. For Europe, this is the key to a coherent trans-European nature network by 2030.[17]

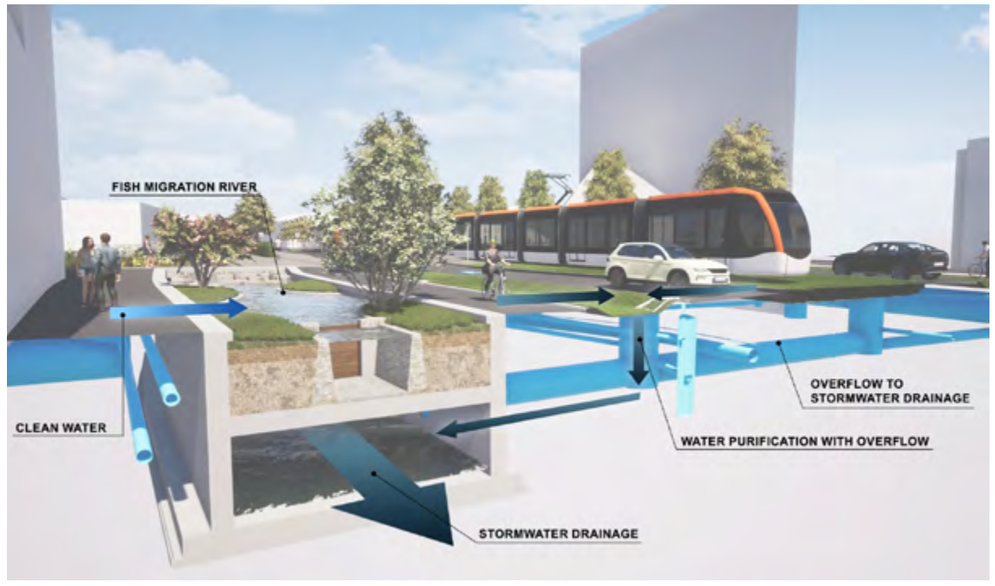
Road infrastructure poses a significant and sometimes insurmountable barrier within the landscape. For people, the barrier effect of roads can be broken by crossings, tunnels or bridges. For animals, however, these grey elements do not offer a solution, so additional natural aspects should be considered.

Fragmentation of nature networks can be minimised by choosing specific infrastructure-related NBS, like viaducts or eco-tunnels, or by creating verges and canal banks adjacent to the road itself. In the case of railroads and road networks, changes can be made to the proposed routes to preserve a larger area of natural land and avoid landscape fragmentation. Moreover, vegetation reduces noise levels by mitigating the propagation of sound, and can sustainably mitigate carbon emissions and boost the disaster resilience of the infrastructure.

In the ongoing refurbishment plan for the Ring North in Brussels, Belgium, a major goal was to integrate the highway in surrounding landscapes, with an emphasis on improvements to the blue-green network and ecological connections. For this purpose, 35 ecological connections will be built over, along and under the Ring, as well as eight open watercourses. By optimising traffic circulation, the infrastructure is expected to free up more than 80 hectares of space in a robust open-space network with an additional 153 hectares of nature reserve and 36 hectares of woodland. Another point of interest in this project was the ability to future proof the design, ensuring that the infrastructure can be adapted to future mobility use.[18]

Refurbishment plan for the Ring North in Brussels, Belgium. Image by Sweco and De Werkvennootschap

Bringing back the sea trout by the restoration of a historically important fish migration route. The fish migration river has been designed in close consultation with a fish biologist. The water speed, waterfalls, water depth and shade spots all determine the success of the route. In addition, the planting plan, including its trees and shrubs, is inspired by the natural vegetation near mountain streams.
Location: Mindemyren in Bergen, Norway. Visualisation: Sweco in the Netherlands



Water system as design issue: Bergen as the wettest city of Europe. The lower channel, a robust system that can drain excess water from the city and surrounding mountain ranges towards the sea as quickly as possible during extreme rainfall, thus protecting the city from flooding. Both the fish migration channel and the rain gardens overflow to the underlying stormwater channel, so that the water safety of the area is guaranteed.
In addition to the fish migration function, this river operates as a green/blue ribbon.
Visualisations: Sweco in the Netherlands

Supporting nature-based transport infrastructure, challenges and solutions

Multilevel urban governance

A key question that planners and decision-makers should ask is, which ecosystems do we want the city to be a part of? Urban planners should work to connect their urban areas with the local ecosystems that add the most value for biodiversity and human well-being, which in turn will aid in climate adaptation.

In this sense, it is imperative to operate using a model that goes beyond traditional geopolitical-territorial divisions. We need to move away from administrative boundaries and connect multiple governance structures around the natural logic of wider ecological systems.

OPEN Brussels, a network of open spaces in and around Brussels. With the help of ecologists, geographers and other technical experts, Sweco succeeded in identifying where existing landscape corridors could be reinforced and new ones created. ©BUUR Part of Sweco / Perspective.brussels

The implementation of NBS strategies to upgrade transport infrastructure networks requires a voluntaristic multiscale and multistakeholder governance. This approach includes several regional agencies (mobility, environment, public works, etc.), local municipalities, urban developers (private and public), multiple technical experts (urban planners, landscape designers, ecologists, hydrologists, engineers) and local communities.

In recent years, the Brussels Capital Region has been taking important steps to reinforce its landscape structure through visions and strategies promoted in cooperation with different government agencies. The trans-regional landscape vision OPEN Brussels, a network of open spaces in and around Brussels, is the product of the collaboration between the Brussels Capital Region and the Flemish Region. The goal is to create a performant landscape structure on the regional scale focusing on climate structures, while also providing possibilities for urban development and reinforcement of local green structures. This vision servers as a framework to support other complementary strategies.

For example, the Brussels Regional Agency for Mobility (BM) manages more than 35,500 trees, 1,200,000 m² of lawns, 400,000 m² of shrubbery and more than 300 km of the most heavily used roads in the Brussels region. These figures demonstrate the scale of the space dedicated to roadways and the potential they offer to contribute to the greening of the city. In this context BM has launched an ambitious plan of demineralisation and greening of regional roads, in consultation with local stakeholders and in line with the other regional urban policies (the Nature Plan, Water Management Plan, Regional Mobility Plan 2020-30 and Regional Sustainable Development Plan). The aim is to increase efforts in the areas of greening, rainwater management, better functional adaptation, and in some cases to reduce public investment and maintenance costs.

Community involvement

Despite the overwhelming benefits of NBS infrastructure, there are some challenges that need to be addressed concerning the long-term consolidation of new natural structures, their maintenance and their appropriation by local communities. These generally concern the social and cultural contexts in which technical solutions are developed, implemented and used.

Community involvement is an essential component of many NBS projects. If local communities are not involved in the planning and implementation of projects, then those schemes might not be effective in addressing the underlying environ-

mental problems in the long run. The community should feel a sense of ownership of the streetscape and responsibility for the care of the greenery in their streets.

Innovative new methods are being applied that focus on community involvement. These methods require opening up decision-making trajectories to wider societal groups. For instance, a new young people's climate change and nature group will be established under the Finnish Youth Cooperation Alliansi in cooperation with the Ministry of the Environment and the Prime Minister's Office. The group will be tasked with supporting the ministries in the planning, implementation and impact assessment of youth participation. The aim is to ensure the fairness of different policy measures from the perspective of future generations.[19]

The cities of Bratislava and Prague are using online tools such as emotional maps, which their citizens use to express their opinion about how they feel in certain places. This information can be then used by public authorities and planners to enhance planning effort and results.[20]

Within the logics of transition, the implementation of NBS in local neighbourhood streets can be considered as urban experimentation that allows proposing innovative alternatives, learning from their implementation and consolidating the good results, setting up trends as a way of creating systemaic change and supporting behavioural change. Clear methodological guidelines, training and participatory approaches are needed to accelerate the transition.[21]

In this sense, nature-based transport infrastructure can be greatly supported through well-organised and prepared communities. These kinds of infrastructure, often urban commons, require supportive strategic policy and decision-making, a robust co-design with multistakeholder approaches as well as long-term provision of technical expertise[22] through capacity building and technological tools.

Digital support

When implementing NBS for infrastructure networks, the role of technology should also be embraced. Actions that facilitate multilevel and multistakeholder cooperation can be supported by digital tools. Geospatial methods, data and mapping approaches – both physical and ecosystem- based – are necessary to ensure that the most suitable NBS infrastructures are created at the most optimal locations and using the most effective design.[23]

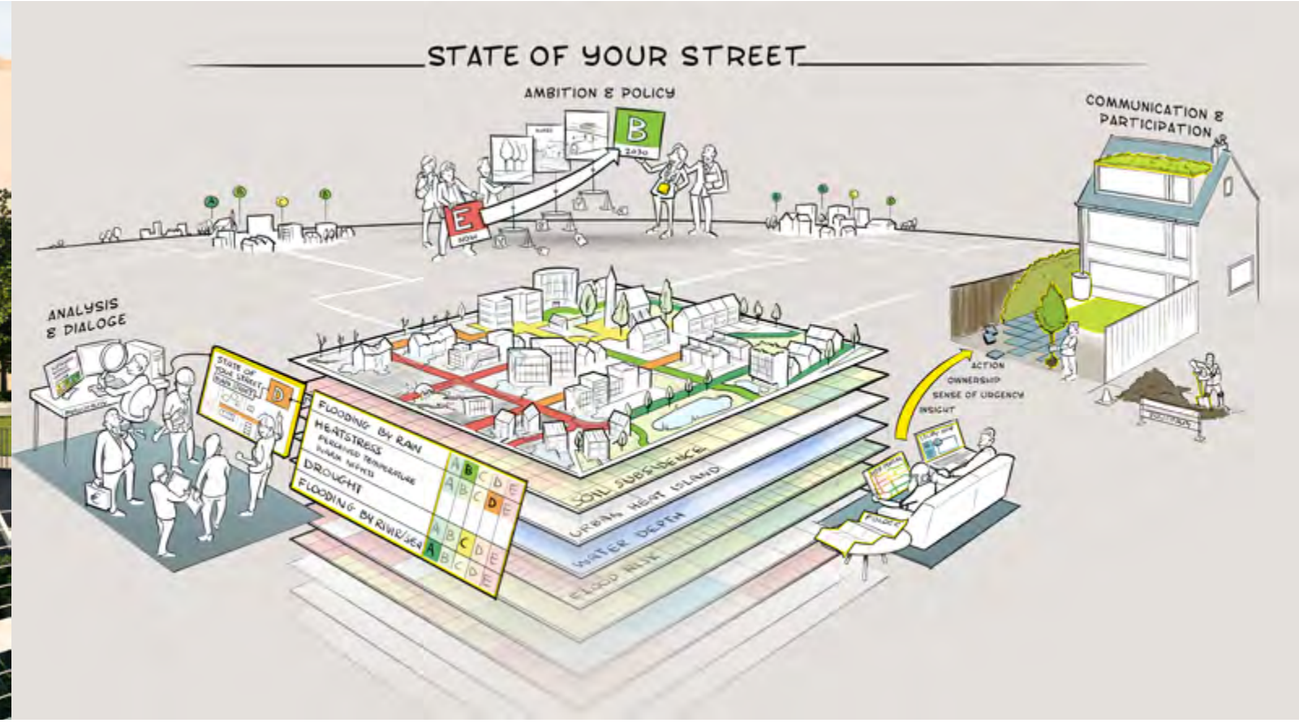
Digital tools are useful for decision makers' ability to make informed choices to adapt public space, but they can also help citizens to identify ways they can play a proactive role in adapting their urban environments.

In the Netherlands, over a dozen municipalities have used the tool The State of Your Street (Sweco) to set adaptation goals. The State of Your Street shows that promoting climate adaptation requires both the use of technology and successfully communicating the results to citizens and decision makers. The system labels each street in a city from A to E depending on heat stress, rainfall flooding, drought and river or coastal flooding. These labels provide citizens with quick insight into how their street is doing in terms of climate robustness. Decision makers can use overview maps showing where the values are lowest to identify where further climate action might be necessary. The labels are always linked to the municipality's broader policies and communication strategy.

About 60% of our cities is private property. Therefore, adapting also means engaging citizens. The State of your Street label offers a common language to discuss current climate state and ambitions.

Martijn Steenstra, consultant Water Management and Spatial Planning, Sweco Netherlands.

Kolkajen in Norra Djurgårdstaden, Sweden. Plans are being made for a marine park with piers and walkways along the water, making approximately 500 meters of quay accessible. The stone material comes, among other sources, from the construction of the new subway. Visualisation by Sweco Architects/Neon Studio Architecture and Images SP. Z O.O.



"Often clear targets for climate adaptation are absent due to the complexity of setting climate adaptation goals. The State of Your Street provides a framework for decision makers to set their goals, which can then be tailored to their specific needs".

A quantitative approach also helps to objectivise complex issues and to reveal hidden potentials in simple terms. ‘Zinloze Verhardingstool’ is a tool developed by Sweco in the Netherlands for calculating the amount of redundant pavement in cities. This tool indicates that, on average, up to 10% of all concrete pavements in the Netherlands are redundant. If this concrete could be eliminated and turned into green space, the heat island effect in the city would be reduced by approximately 0.6°C.[24]

Today there are tools that calculate the amount of redundant pavement in cities. A digital tool used in the Netherlands indicated that, on average, up to 10% of all concrete pavements in the Netherlands are redundant.

Redundant pavement.Images by Joeri Meliefste.

The Green city challenge

Greening goals can also be supported by tools such as the Green City Challenge [25], which uses geodata to provide Dutch municipalities with insights into ways they can make their areas more green. This inspiring tool sets out the challenge to municipalities and prompts local politicians to take action.

Digital tools have also shown great potential to support the ecological performance of large-scale projects by monitoring ecological patterns. Sweden has shown great interest in this type of tool to assess urban development and infrastructure planning.

The ‘Grönytefaktor’tool was developed by Sweco in Sweden to promote biodiversity in dense cities. It works by using a scoring system, where planted areas, trees and green roofs and walls receive higher scores. In Stockholm, the tool is now used for all new projects within the city’s boundaries. Such tools can be a way to transform cities worldwide and create space for more greenery.

The ESTER tool, developed by Sweco for the Swedish National Board of Housing, was designed to assess ecosystem services and visualise the impact of different actions on them. Using this tool, Sweco analysed a green corridor in Fässbergsdalen to ensure the application of ecological values with regards to the ongoing urban planning projects taking place adjacent to this corridor.

Remote sensing technologies can be used to identify areas where NBS can be the most effective, while sensors and data analytics can be used to monitor the success of these solutions over time. Cameras can be installed near eco-ducts (wildlife crossing bridges or tunnels) to monitor and evaluate the use of these nature connections by fauna. Sweco’s Capture tool uses AI to distinguish between different animal species in images from wildlife cameras, thereby greatly increasing the efficiency of the image analysis process.

Visualisation of “Green city challenge”. Image by Sweco, illustrator Anouk Potter.

The Capture AI tool in the service of wildlife research

Sweco collaborated with the Swedish University of Agricultural Sciences, Swedish Transport Administration and Norwegian Institute for Nature Research to create an AI tool that identifies animal species in wildlife camera images. This is needed to plan safe passages for animals over and under roads and railways to avoid collisions with vehicles, and to avoid disturbing animals in their habitat. Image by Fredrik Larsen.

Approximately 3.3 to 3.6 billion people live in hotspots of high vulnerability to climate change

According to IPCC Sixth Assessment Report.

Innovative business models

Infrastructure-related NBS can be expensive to implement, and funding is often a key consideration in development projects. Space and funding are often limited, and there might be competing demands for land use. Governments and other stakeholders need to be willing to invest in this type of solution, but project costs vary significantly and are highly site- and project-specific. Developing new business models can be a powerful solution, as they allow for more direct ownership of assets.

Infra-as-a-Service is a programme in the Netherlands that is looking to develop this business model and new way of co-operation between clients and contractors in the infrastructure sector. In this model, the contractor is the economic owner or operator of an infrastructure item for an agreed period of time (for example, a road section, bridge or section of street lighting). As owner/manager, the contractor has a direct interest in using sustainable, high-quality and low-maintenance materials that reduce maintenance costs, and they are incentivised to sell or reuse materials for the maximum price at the end of the item's service life.

Valuation of a broad range of benefits can work as a lever for a wider array of financing options[26], but more research is needed to develop approaches that combine both monetary and non-monetary valuations to assess the true value of urban green spaces.

However, when considering NBS investment as a disaster risk management measure, there is a certain logic to structurally project the possible dividends, direct and indirect, of investing in resilient solutions. In the report the "Triple Dividend of Resilience", the Overseas Development Institute (ODI) and the World Bank provide evidence for three types of benefits that resilience investment can yield[27]:

1. Avoiding losses when disaster strikes. This entails saving lives, reducing material losses and promoting effective recovery from disasters.

2. Stimulating economic activity thanks to reduced background disaster risk. This enables forward-looking planning, long-term capital investments and entrepreneurship, even if disasters do not occur for a long time.

3. Developing the co-benefits of a specific investment by integrating multi-purpose designs. This can tackle many different needs in mutualised solutions that optimise investments. This last dividend is directly related to the multipurpose nature-based solution in infrastructure projects.

Socio-ecological ambitions

Rural areas and dispersed urban contexts present great challenges to reconcile large infrastructures, urban settlements (medium and small), economic zones and agricultural fields, with the wider natural structures. From a socio-ecological perspective, NBS can have a significant impact on both the natural environment and the human communities that depend on it.

The development of new infrastructure, like highways or new railways, can sometimes displace existing communities and exacerbate existing social and economic inequalities. Furthermore, the impact of infrastructure construction projects on both fauna and people is substantial. Mitigating measures concerning timing (e.g. outside of breeding season), reduction of noise and light, infiltration of drainage water in the vicinity and even translocation of protected species to more suitable habitats can ensure that temporary effects avoid damaging the environment. This tension between infrastructure, the built environment and open landscapes is especially relevant for extreme weather events and natural disasters.

During the flooding in summer 2021 in the Ardennes region in Wallonia, Belgium, critical infrastructure was destroyed, several neighbourhoods were cut off from humanitarian aid and communities were unable to seek out safer areas. Belga News Agency reported that a total of EUR 22.35 million will be required to repair damage to roads, tunnels, engineering structures and waterways[28].

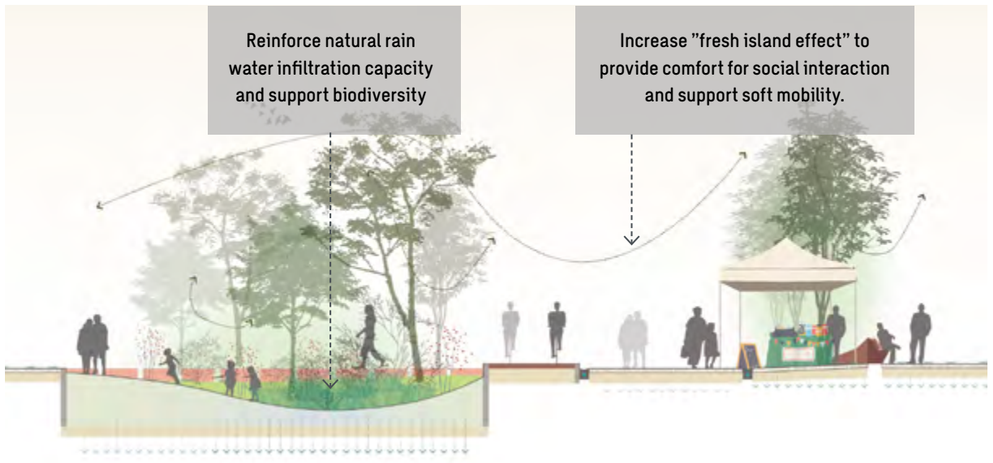
Wallonia is a region characterised by its wide urban sprawl. The existing dense network of transport infrastructure needs

Over €20 million

in estimated costs to repair damage to roads, tunnels, engineering structures and waterways after the 2021 flood in Belgium.

to evolve to become more resilient to future flooding by using demineralisation and integrated water management, but it should also play a role in reconnecting blue-green systems and creating ecological corridors. To better prepare the territory for similar future events, Wallonia's public services (SPW) created a framework contract mission with Sweco to provide an urban hydrologic study to guide and support the affected municipalities. This mission aims to understand the functioning of the hydrologic basins and transpose them into an infrastructural 'logic of the valley'.

From this specific context, the city of Verviers is emerging as a front-runner in climate adaptation plans, highlighting the role of middle-small cities, creating territorial resilience and using climate adaptation measures as levers to address other urban challenges. A new plantation plan for the city and the Innovative Roads project are a few examples of how cities seek to address climate issues, simultaneously providing social and economic benefits such as improved public health, increased property value and enhanced recreational opportunities.



Innovative Streets is a project for a resilient design of 10 streets in Verviers (Belgium) which have been drastically damaged by the floods of 2021. The design of the streets became a pretext to question the city's strategies for developing soft mobilities, managing natural water flows, connecting patches of biodiversity, renewing Verviers' industrial identity.

Successful integration of NBS – five key lessons and recommendations

Meeting the needs of a rising population and a growing economy will require many new road infrastructure projects. To achieve resiliency, a green layer must be structurally present in these infrastructure projects.

Although the use of NBS in the transport sector still faces critical challenges (poor public perception, lack of funding, limited technical capacity), the increased implementation of NBS has also allowed for greater innovation, knowledge base development and the operational capacities needed to help mainstream NBS as a systemic practice. Here are some key lessons learned from using NBS in transport infrastructure[29]:

- NBS can be effectively combined with traditional infrastructure options
- Local communities should get involved in the design and implementation processes
- Benefits should be communicated to stakeholders
- Disaster risk management should be integrated
- Coordination is needed with various agencies and ministries

The contrast with grey infrastructure solutions, which typically fulfil single functions such as drainage or transport, makes nature-based transport infrastructure appealing because it has the potential to tackle several problems simultaneously. To address these goals, here are some recommendations for the successful implementation of NBS in infrastructure projects:

1 **Site-specific conditions:** Project developers and planners should assess the functions and benefits of the desired NBS based on the specificities of the place in order to be able to convince decision makers. The suitability of the NBS, including location considerations and cost estimates, is also necessary for decision making.

2 **Think together:** NBS should not be designed independently, but should be part of an integrated approach that brings different experts together. Planners and project developers should be supported by experts in ecology, integrated water management, infrastructure, architecture or energy. This ensures that the most efficient solutions are designed and implemented.

3 **Protect, then create:** Project developers and planners should adopt the principles of ecosystem conservation. This means that, first of all, existing NBS should be protected and sustainably managed. If that is not possible, restoration and rehabilitation of degraded NBS should be considered to regenerate benefits. The ultimate option is the creation of new NBS.

4 **Solutions with multiple functions:** Project developers and planners need to consider NBS across multiple spatial scales: city, neighbourhood and landscape. That way, problems can be tackled close to the source. For example, during a heavy storm, inland forests can hold water upstream, relieving pressure on downstream villages. At the same time, adaptation measures in the village can be effective to prepare for upcoming floods by strengthening their resilience.

5 **Creative coalitions:** Coordinated action requires clear cooperation frameworks connected to the facilitation of processes, the creation of capacities, the collective formulation of policies and the creation of creative coalitions between different sectors and actors (governments on city and national levels, non-government organisations, civil society, educational institutions and the private sector). This requires innovation and investment in horizontal (multisectoral governance) and vertical coordination (multilevel governance).

Best practices from Europe

Nature-based solutions work at multiple scales and offer multiple benefits that address many societal and environmental challenges.

In the following pages we present selected projects that demonstrate various types of innovations in resilient infrastructure, giving technical and strategic support to different stakeholders, offering concrete solutions and reinforcing capacities. These projects include strategic visions and action plans, neighbourhood-scale design solutions, territorial network assessment, technical solutions for public space projects, and assessment tools that provide strategic support at both governance and technical levels.

Strategic visions and action plans

1. Demineralisation and greening of regional roads/Brussels Capital Region, Belgium
2. Urban planning support for affected municipalities/Wallonia, Belgium
3. Assessment of ecosystem services for a green corridor/Mölndal, Sweden

Territorial network assessment

4. Transformation of the German railway corridor Rhine-Alpine/Middle Rhine Valley, Germany
5. Reindeer and wildlife management plans for railways/County of Norrbotten, Sweden
6. NBS in the design of the light rail system / Bergen, Norway.

Neighbourhood-scale design solutions

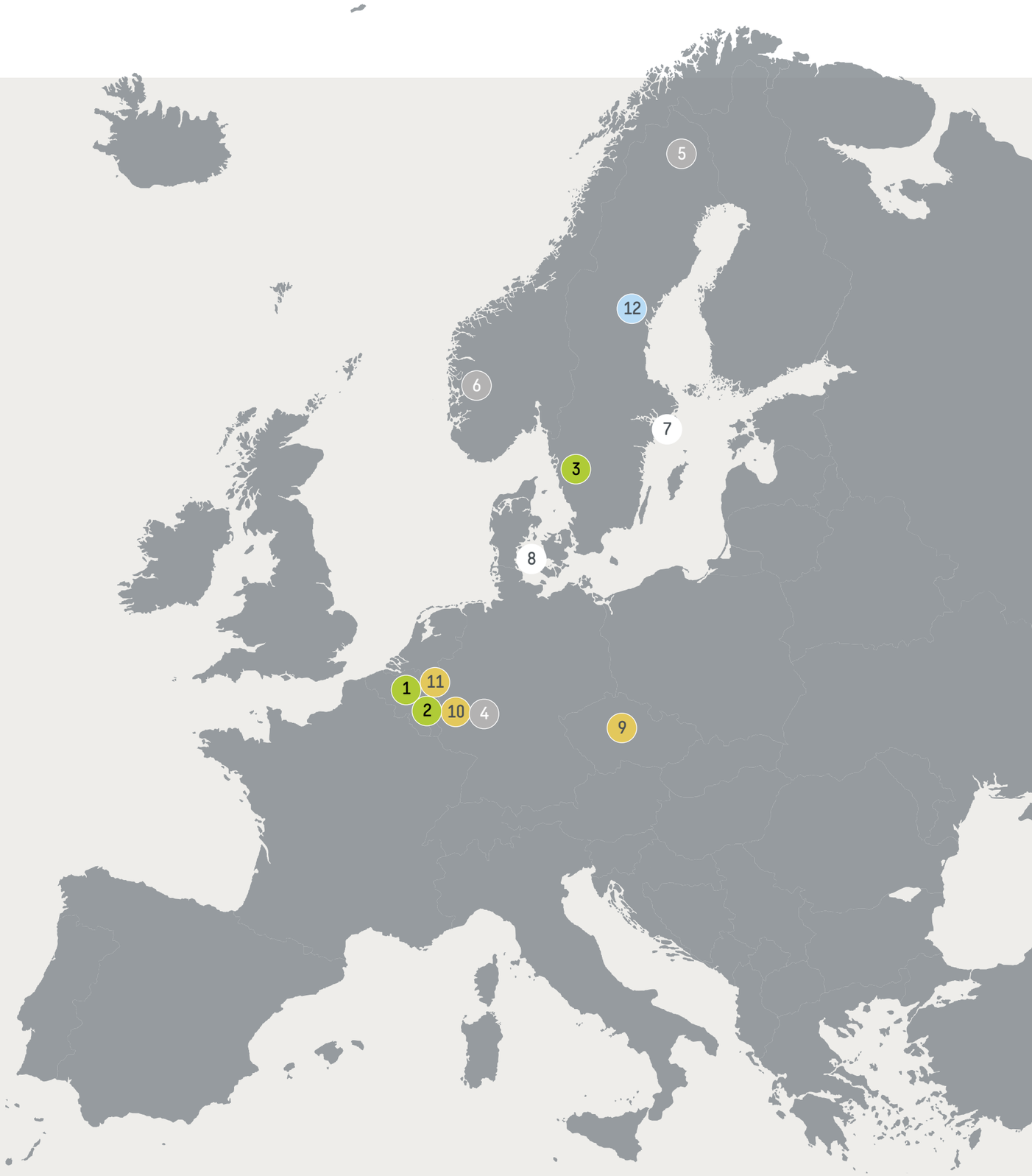
7. Norra Djurgårdsstaden/the Royal Sea Port, Stockholm, Sweden
8. Green urban renewal of the Thomas B. Thriges Gade/Odense, Denmark

Technical solutions for public space projects

9. Comprehensive revitalisation of Wenceslas Square/ Prague, Czech Republic
10. Innovative Streets to create resilience/Verviers, Belgium
11. City Park De Motten / Tongeren, Belgium

Assessment tools

12. Capture: AI preserves biodiversity and prevents wildlife accidents / Sweden

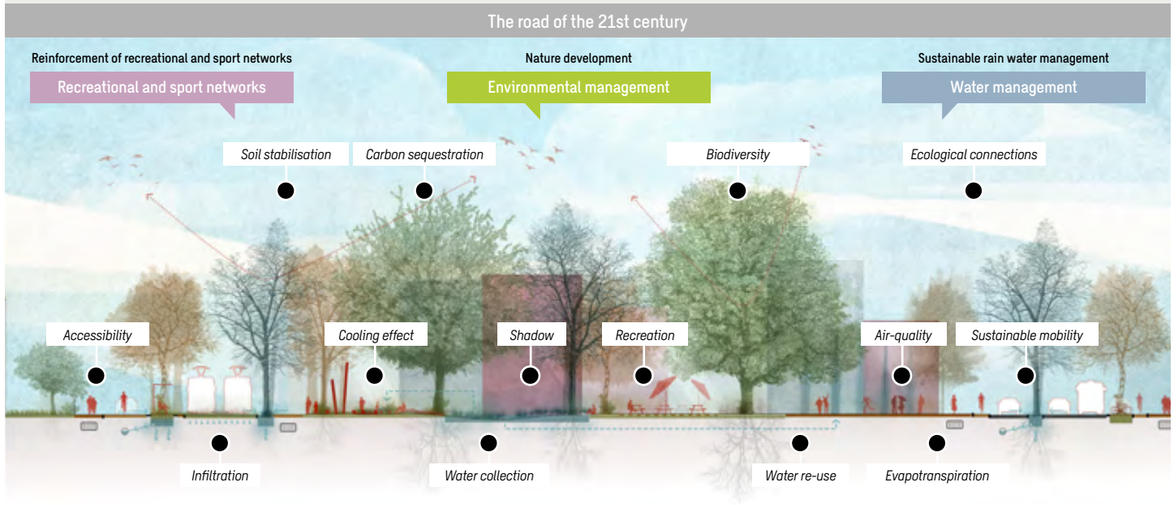


1

Demineralisation and greening of regional roads in the Brussels Capital Region

Many of the public spaces in Brussels are regional roads managed by Brussels Mobility (the regional agency for mobility). Because of their size and location across living environments, valuable natural parks and blue networks, they are a major lever in the transition to a climate-adaptive and healthy city. Brussels Mobility therefore wants to focus intensively on the sustainable renewal of regional roads that can have the most impact in terms of biodiversity, water management, greening and quality of life. The mission includes developing a regional vision and action plan for demineralisation and greening (in the short and medium term); providing technical support for the design of regional roads (from concept to implementation); and drawing up and implementing ecological management plans for all green spaces managed by Brussels Mobility.

Location: Brussels, Belgium
Team: BUUR Part of Sweco (Belgium), Teams Climate Resilient Planning, Landscape & Public Space, Ecosystem Services, Integrated water management
Client: Brussels Mobility
Role of Sweco: Supporting Brussels Mobility for several projects
Image credits: Sweco Belgium + Brussels Mobility



2

Urban planning support for affected Walloon municipalities

Wallonia's Public Services (SPW) and Sweco initiated a framework-contract mission to provide urbanistic and hydrologic guidance and support to the municipalities of Verviers, Trooz, La-Roche-en-Ardenne and Rendeux, which were affected by the 2021 floods. With an integrated and multidisciplinary approach, the mission aims to increase the resilience of these municipalities by mitigating future floods through demineralisation and integrated water management strategies, while at the same time reinforcing their environmental performance by reconnecting blue-green systems and creating ecological corridors.

Location: Walloon region, Belgium, Watershed of the Ourthe and the Vesdre (Municipalities La Roche-en-Ardennes, Rendeux, Trooz and Verviers.)
Team: BUUR Part of Sweco / team Urban Project South (Caroline Custine PL, Louis Bonte PL, Maëlle Vandenbergh PL, Inès Leuger, Yasmin Allaouzi) / team Climate Resilience (Sedaile Mejias PL)
Role of Sweco: Supporting SPW via the missions assigned to the four different communes.
Client: Public Services of Wallonia (SPW)
Image credits: Case Commune Categorie 2 : La Roche-en-Ardenne / Credits : BUUR Sweco & SPW (Client)

3

Assessment of ecosystem services when developing a green corridor in Fässbergsdalen

Sweco has performed an analysis of ecosystem services for a green corridor in Fässbergsdalen that constitutes a critical part of a regional green network from Gothenburg to Kungsbacka. The purpose of the analysis was to ensure preservation of the values in the green corridor and to maintain the biodiversity in the area, where special consideration was given to the habitat needs of five local species. As a second part of the project, Sweco was asked to create a detailed design plan for a part of the green corridor called Lunnagården.

Location: Mölndal, Sweden
Team: Environment and Planning (Marika Karras, Sofia Refsnes, Sandra Olsson, Johanna Rolander-Borlid, Teresia Sibo, Anton Åberg).
Role of Sweco: Consultant to create decision support for designing green values within ongoing urban planning projects
Client: Mölndal municipality
Image credits: Sweco 2021, PM Gestaltning Lunnagården / PeGe Hillinge

4

Transformation of the German railway corridor Rhine-Alpine

DB Netz AG has been commissioned to transform the Rhine-Alpine corridor (Rotterdam – Genoa) through Germany according to the decision of the European Commission to be equipped with ETCS (European train control and train protection technology). The teams from Sweco Germany in Frankfurt (Main) and Koblenz performed ecological field mappings and environmental impact assessments for a distance of more than 120 km to support the authorisation process of the planned technical measures. For this purpose, fauna and flora data was mapped and evaluated to prevent, reduce and compensate potential conflicts with species, nature and the wider landscape.

Photo: Tobias Velten

Location: UNESCO World Heritage Area Middle Rhine Valley (Federal States of Rhineland-Palatinate and Hesse), Germany
Team: Spatial & Environmental Planning from Frankfurt (Main) and Koblenz, Sweco Germany
Client: DB Netz AG
Role of Sweco: Processing the crucial environmental documents.

Photo: Joachim Bender

5

Reindeer and wildlife management plans for railways in Northern Sweden

In the northernmost parts of Sweden, both moose and semi-domesticated reindeer undertake seasonal migrations and can walk long distances between mountainous and inland areas to lowland and coastal grounds. Railways present barriers during these migrations, and many accidents between animals and train traffic occur every year. By combining the expertise of Sweco consultants in reindeer herding and wildlife ecology, we provided plans for reducing the risk of accidents and enhancing green infrastructure along and across railways, identified major migration routes and recommended suitable locations and designs for fences and passages that can also be used by people during outdoor activities.

Location: County of Norrbotten, Sweden
Team: Environment and Planning, Sweco Sweden
Client (developer): The Swedish Traffic Administration
Role of Sweco: Investigating and describing the impact of railroad and train traffic on stationary and migratory moose, as well as on the possibility of performing reindeer herding in the vicinity of the railroad.

6

Bring back the sea trout! NBS solution for designing the light rail system in Bergen, Norway

Water system design in Bergen is a major issue due to the region being the wettest in Europe. The area used to have a mountain river that drained water and allowed for sea trout migration, but industrialization caused it to disappear underground. Our plan includes a two-layer water connection between Solheimsvatnet and the fjords, with the lower channel designed to drain excess water quickly during extreme rainfall to prevent flooding. The upper channel is designed for sea trout migration and includes regnbeds for rainwater infiltration. The project is part of the Interegg program “Blue and Green Infrastructure (BGI)”.

During construction of the light rail in Bergen, Norway, the water supply and drainage were also renewed. The canals connect to a small lake and the fjord. The water channels were made suitable for sea trout to spawn in the lake. To this end, the channels were arranged for the fish (current, water quality and hiding places) and a fish trap was created to bridge the height difference between channel and lake.

Location: Mindemyren in Bergen Norway
Team: Experts of Sweco Netherlands and Norway
Client: Bybanen Utbygging (Bergen Norway)
Role of Sweco: Advising, designing and engineering
Image credits: Sweco in the Netherlands

7

Revised detailed masterplan in Norra Djurgårdsstaden results in a 70 percent lower climate impact

The Norra Djurgårdsstaden urban development area is one of Sweden's largest urban development areas. Here, industrial land is being transformed into an urban city, in interaction with port operations in the area.

The detailed plan was created and adapted to suit the geographical conditions of the surrounding area with reduced climate impact by enabling the reuse of stone material as a foundation for the expansion in water. The stone comes from sources like leftover construction material from a new subway. CO2-reduced concrete is now being tested in a number of ongoing construction projects and will also be used when wharves and other structures are built at Kolkajen. In the centre of Kolkajen, plans are being made for a marine park with piers and walkways that focus on improving the habitat for aquatic animals.

Promenades are being built along the water, making approximately 500 metres of quay accessible, and in the northern part of Kolkajen, jetties are being built for bathing. At the far end of the jetty, plans for building a cold bath house are being considered.

Visualisation by Karavan Landskap.

Location: Stockholm
Project: Kolkajen in Norra Djurgårdstaden
Client: Stockholm Stad
Role of Sweco: Structural plan and vision, environmental assessment, environmental impact assessment (EIA), social impact statement, cultural environment, street design, stormwater management, lighting

Visualisation by Sweco Architects/Neon Studio Architecture and Images SP. Z 0.0.

8

A green transformation project in Odense – Thomas B. Thriges Gade, Denmark

In collaboration with the Municipality of Odense and Realdania, 300 Sweco experts transformed the street Thomas B. Thriges Gade in Odense, Denmark, into a green, cohesive, car-free district with new squares and urban spaces. The area comprises four new neighbourhoods and eight new urban spaces. The unifying identity of the district is a green and lush landscape – on buildings, roofs, balconies and in the urban spaces of the city. Green roofs and LAR solutions in the terrain are used for rainwater management.

Location: Odense, Denmark
Team: Sweco Denmark in collaboration with entasis
Client (developer): Odense Municipality | Realdania
Role of Sweco: Engineering and landscape architecture consultancy
Image credits: Photo Niels Nygaard

9

Comprehensive revitalisation of Wenceslas Square, Prague

The Wenceslas Square revitalisation project addresses the total renewal of all surfaces in the square including a pair of tram lanes with restrictions on car traffic. The green and blue infrastructure is represented by a two-stage tree line irrigation system, where rainwater is channelled from the sidewalks to individual trees. The water is then captured in retention boxes under individual trees and serves as a natural source of moisture. The second part of the system captures rainwater from the square into a retention tank with pre-cleaning and is later used in the dry season for watering trees, local greenery and wetting roads.

Location: Prague, Czech Republic
Client: Prague Public Transit Company, a.s.
Team: Division 151, Sweco Czech Republic in collaboration with Met- roprojekt, a.s. (general designer), Ateliers DUA, s.r.o. and Jakub Cigler architects, a.s. (architectural design)
Designer: Ateliers DUA, s.r.o. and Jakub Cigler architects, a.s.
Role of Sweco: Designing a cyclical system for using rainwater for local trees, watering greenery and wetting roads.
Image credits: ateliers DUA, s.r.o. and Jakub Cigler architects, a.s.

10

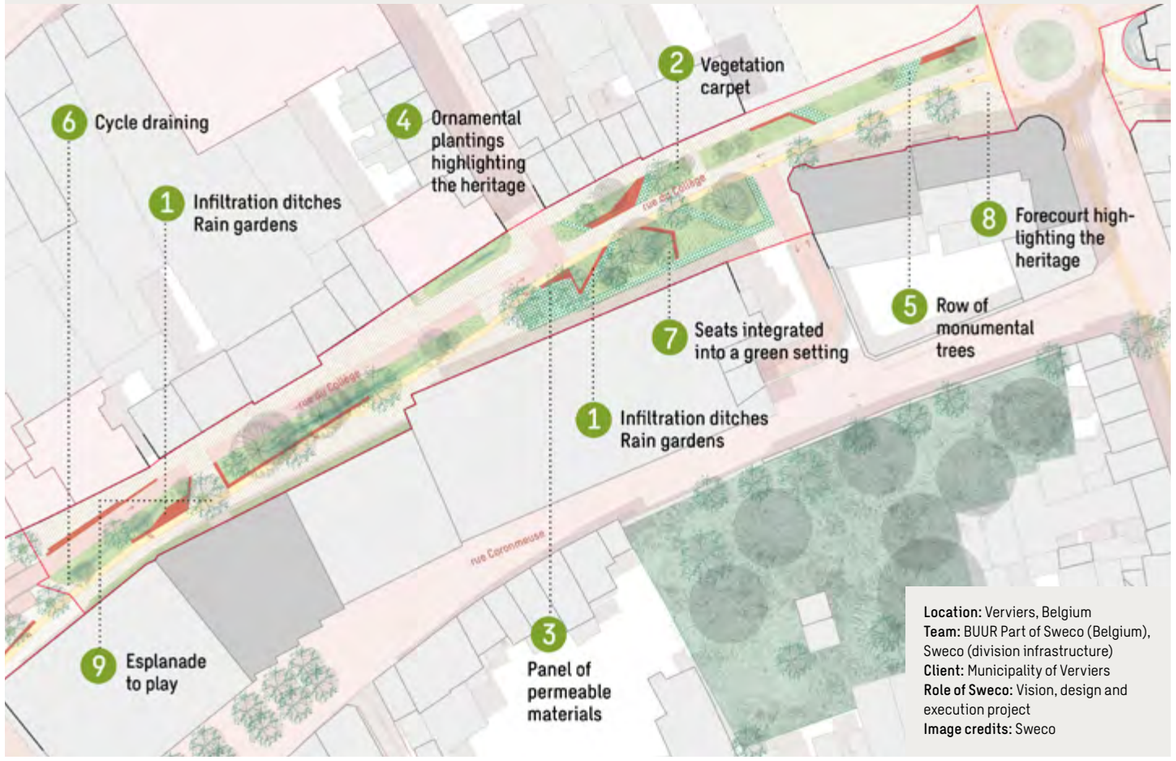
Innovative Streets project creates resilience in Verviers

The city of Verviers (eastern Wallonia) is one of the cities that suffered the most from the floods of July 2021. In response, numerous projects were initiated to rethink the city's resiliency in the Vesdre valley in order to confront the evidence that such events will occur soon again in this area.

Verviers thus embarked on its own project for demineralising the city centre. It turned to BUUR, part of Sweco, which is currently involved in two different projects, the Canopee Plan and Innovative Streets.

Innovative Streets calls for an innovative, resilient design of ten streets that were heavily damaged by the floods. BUUR convinced the municipality with its systemic design and transversal approach, starting from a robust contextual analysis to envision what these innovative streets would look like.

The street designs became a pretext to question the city's strategies for developing soft mobilities, managing natural waterflows, connecting patches of biodiversity and renewing Verviers' industrial identity. Each concerned neighborhood went through a systemic analysis and opened up discussions for a future-proof vision of the public space. The team Urban Projects South worked hand in hand with Sweco's experts in landscape, mobility, hydrology and infrastructure and with local actors such as Cellule Mobilité, Hub Créatif, the regional cell Modélisation Hydro de la Vesdre, and many more.



Location: Verviers, Belgium
Team: BUUR Part of Sweco (Belgium), Sweco (division infrastructure)
Client: Municipality of Verviers
Role of Sweco: Vision, design and execution project
Image credits: Sweco

11

City Park De Motten Tongeren, Belgium

In 2021 Sweco and the Regional Infrastructure division won the Public Space Prize with the renovated city park De Motten in Tongeren. Every year, Infopoint Public Space presents an award to the best public space in Belgium.

The De Motten sports and recreation park in Tongeren is a great example of leveraging water in the city to boost climate adaptation and quality of life. Tongeren's city council implemented this vision in its climate adaptation plan, and now after more than 60 years, the Jeker River will once again flow through the city centre. A city park and water experience square were created around the river. Today, the area is a revitalised meeting area with space for recreation facilities.

Location: De Motten in Tongeren, Belgium
Team: Sweco and the Regional Infrastructure division
Client: City of Tongeren
Role of Sweco: Drawing up a master plan and overseeing design and implementation.
Photo: Bram Goots

12

AI preserves biodiversity and prevents wildlife accidents

Capture is a tool that uses artificial intelligence to distinguish different animal species in images from wildlife cameras that are used by researchers to document animals and their behaviour, for example in wildlife population surveys and wildlife crossing monitoring. This is needed to plan safe passages for animals over and under roads and railways to avoid vehicle collisions and disturbing the animals in their habitat.

Location: Sweden
Team: Sweco Digital Services
Client (developer): Swedish University of Agricultural Sciences
Role of Sweco: Project management of IT platform, applications and related IT architecture from conceptualisation to implementation. Advice on appropriate approaches in agile methods and service design. Support in requirements and needs analysis, and Scrum master role.
Collaboration and funding: Sweco, the Swedish University of Agricultural Sciences, the Swedish Transport Administration and the Norwegian Institute for Nature Research. The project was funded by the Swedish Transport Administration and Vinnova.
Image: Fredrik Larsen

About the Authors

Feel free to contact us with your questions and thoughts.
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Carmen Van Mechelen, PhD and ecologist, is a senior project leader at Sweco in Belgium. She is an experienced scientific researcher on urban green infrastructure, specifically green roofs. At Sweco, she monitors the state of the art, innovations and transitional questions regarding nature-based solutions. By strengthening the network of the various divisions at Sweco Belgium, she aims to ensure that nature is always given a worthy place in Sweco's building and infrastructure projects.

Diego Luna Quintanilla is an architect, urban designer and strategic planner at Sweco in Belgium. As a senior project leader, he works on a wide range of urban revitalisation projects, including project definitions, feasibility studies, master plans, planning tools and regional spatial visions. Since 2020, he has been in charge of coordinating Sweco's transition programme, Inclusive Neighbourhoods. In 2023, Diego was appointed Group Expert Leader to co-develop the Resilient Societies theme for Urban Insight, Sweco's knowledge-sharing platform.

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