BISON

BIODIVERSITY & INFRASTRUCTURE SYNERGIES AND OPPORTUNITIES FOR EUROPEAN TRANSPORT NETWORKS

STRATEGIC RESEARCH AND DEPLOYMENT AGENDA

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EXECUTIVE SUMMARY

Transport infrastructure and related mobility are key drivers of global economic development. However, their negative impacts on climate change and biodiversity are significant and deserve consideration as they impact global growth. Yet, the relationship between infrastructure and biodiversity is often confined to a narrow technical perspective, disregarding its fundamental multidimensional nature. The complexity of the involved systems and their constant interrelations and interactions make understanding and exploring potential solutions challenging. This complexity also has a strong potential for conflict, making identifying research or innovation priorities difficult. The BISON project has surpassed the initial expectations of the 45 international members, encompassing diverse sectors such as public, private, and research.

Formulating a concrete holistic vision, as manifested in the present Strategic Research and Deployment Agenda (SRDA), required the integration of various interconnected factors, which may seem disconnected from biodiversity – such as governance, economic models, societal engagement, evaluation of biodiversity impact reversibility, and support for innovative operational approaches. The collaborative mobilisation of the research and innovation sectors anchored this diverse array.

The realisation of the BISON project's agenda is a blend of its various deliverables and extends beyond the strict confines of its framework. As a pioneering effort, it marks a significant step toward actively deploying the collected contributions and preparing for medium-to-long-term research implementations and shorter-term operational actions.

The agenda is split into two main sections. The first, addressing cross-cutting issues, delves into governance and strategy for transformative changes, outlining the framework for cross-cutting actions. The second section concerns operational implementation, specifically targeting sustainability goals across the entire lifecycle of infrastructure.

The SRDA is not a ready-made solution for achieving full environmental integration in transport infrastructure. Rather, it serves as an essential step to initiate dialogue and cooperation with stakeholders who often work in isolated silos. Therefore, the relationship between infrastructure and biodiversity needs to be evaluated on a broader territorial scale, extending beyond the immediate impact of each individual project. Networks must collaborate, moving beyond a natural inclination for technological solutions, to develop an integrated territorial approach that addresses economic, societal, and policy objectives of transport networks while considering biodiversity protection and climate change mitigation. To be effective, the legal, technical, and societal recommendations presented in this agenda must mobilise available resources comprehensively, and ongoing research in political and legal aspects should be encouraged and supported for the future.

Beyond recommendations, the BISON project also seeks to provide short-term responses to simplify the adoption and implementation of recommendations by a wide range of field actors. Online tools have been developed to facilitate direct operational use, including an operational manual[1] providing up-to-date knowledge on biodiversity consideration throughout the infrastructure lifecycle and a dynamic European defragmentation map.

The produced results have already demonstrated their vast potential. The global adoption of these results signifies the work's quality and the subject's significance. The United Nations Environment Programme leads the way through the Sustainable Infrastructure Partnership. Notable contributions have also come from the World Road Association, contributing to its global research agenda, and the International Union of Railways, alongside the International Organization for Standardization for the TC 331 Biodiversity and the International Union for Conservation of Nature in the context of its large landscapes' conservation working group.

In less than two and a half years, this conceptually daring project, supported by the European Commission, has garnered broad national, European, and international resonance. The diversity, and magnitude of actors that joined and supported the action highlight how BISON catalysed needs and gaps. The period from 2021 to 2023, marked by a paradigm shift due to COVID-19, demonstrated that environmental issues cannot be confined to climate alone. Moreover, the Biodiversity Strategy for 2030, a central component of the European Green Deal adopted in March 2022, exerts significant pressure on all stakeholders and further underscores the imperative for societal transformation. Thus, climate AND biodiversity are the obverse and reverse of the same global issue, and both must be approached in tandem to address the challenges the future holds.

BISON is the first step in an ongoing process, where focusing on several future challenges will be vital: real coordination of stakeholders, accurate impact assessment with consideration of biodiversity as an essential topic to be included, use of standardised data, development of effective performance indicators (KPI's), and societal considerations.

1. See part 3.1 Biodiversity and infrastructure: a handbook for action

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BISON FRAMEWORK, VISION AND OBJECTIVES

Transport infrastructure is one of the drivers of global economic development. However, through its impact on land use change and ecosystem fragmentation, it is also one of the main causes of and the decline in biodiversity. Although, very heavy investments are currently being made to address this and meet the objectives of the Paris Agreement. The impact on biodiversity is much less well known and understood. Given the heightened global concern over this issue, new regulations and approaches with stricter biodiversity standards are expected in the wake of the concrete goals and targets on securing ecological connectivity included in the Kunming-Montreal Global Biodiversity Framework as decided at the COP 15 of Convention on Biological Diversity in December 2022.

At the same time, the transportation sector is undergoing revolutionary changes that have the potential to create a safer, cleaner, more equitable and resilient infrastructure. Mainstreaming biodiversity into this process presents significant opportunities to benefit both people and landscapes where infrastructure is located while enhancing durability and reducing costs associated with avoiding, reducing and compensating impacts.

The decarbonization process, the need to adapt to climate change, and current technological advances offer huge opportunities to reshape transportation and upgrade or replace existing infrastructure. Nature-based Solutions, investing on Green Infrastructure development, and finding synergies allowing to benefit biodiversity must be part of this process.

Yet given the dearth of research-based guidance on how to address biodiversity concerns through the development of transportation infrastructure, no broad consensus exists on how to create a biodiversity-friendly transportation sector.

As a result, the implementation of the Global Biodiversity Framework in sustainable infrastructure and biodiversity practices has significant implications for the infrastructure sector. It offers numerous opportunities to leverage the lessons learned and good practices developed over the past decades to mitigate the impacts of infrastructure on nature. These solutions can simultaneously benefit mobility, trade, energy, climate change and biodiversity policies. By adopting these practices, both biodiversity and infrastructure resilience can be enhanced, contributing to a more sustainable and harmonious coexistence between human development and natural ecosystems, by addressing in particular land use change and ecosystem fragmentation.

- The infrastructure sector should now contribute to biodiversity conservation and ecological restoration through appropriate management and adaptation of existing infrastructure. Defragmentation plans can increase infrastructure permeability and reduce other effects such as risks of accidents involving wildlife or disturbances to adjacent habitats.

- Numerous solutions have been developed in recent decades and are being implemented to reduce impacts of infrastructure on nature while providing positive benefits both for biodiversity and infrastructure resilience. Innovative practices and new measures are being developed to address emerging trends and new scenarios resulting from global change, which will require observatories to evaluate the long-term efficiency of these measures in the context of global change.

The digitalisation and automatisation of infrastructure offer opportunities for cost-efficient cooperation between engineering and ecological sectors. Leveraging information from the design, construction, and operation phases through automated sensors, supported by Modelling, Artificial Intelligence (AI) and other innovative tools can facilitate the integration of ecological information and solutions into Building Information Modeling (BIM) or Digital Twin (DT) platform for the design and operation of infrastructure. This integration can contribute to cooperation and application of best practices, such as reducing the risk of accidents involving animals or addressing flood risks.

The BISON project

The European Union has funded from 2021 to 2023 through H2020 the BISON project to address for the first time the research and innovation challenges associated with biodiversity mainstreaming in the whole life cycle of transport infrastructure. The European Commission's support for the BISON project represents a major breakthrough at the international level to establish an objective basis for the available knowledge and which should be supported in the future.

This pioneering project, situated within the realm of climate, energy, and mobility research, exemplifies the integration of biodiversity considerations in a sector that extends beyond traditional environmental frameworks. Over a span of two and half years, 2021-2023, the project brought together a diverse array of stakeholders, ranging from influential decision-makers to esteemed researchers and seasoned practitioners, united in their pursuit of strategic thinking at the intersection of various transport modes and the distinct challenges posed by European landscapes.

BISON's primary objective was twofold: to investigate methods of mitigating the impacts of infrastructure on biodiversity throughout all phases, from strategic planning to decommissioning, and to explore the significant opportunities that arise from preserving biodiversity within the transport sector. This holistic approach aligns with the Sustainable Development Goals (SDGs) set forth by the United Nations, specifically SDG 7 (affordable and clean energy), SDG 9 (infrastructure), SDG 10 (reduced inequalities), SDG 13 (climate action), and SDG 15 (life on land), the Decision 14/3 of CBD COP14 (2018) for mainstreaming of biodiversity in the energy and mining, infrastructure, manufacturing and processing sectors, as well as the objectives outlined in the European Green Deal and the EU Biodiversity Strategy for 2030.

It should be noted that the relationship between biodiversity and infrastructure has long been considered from a technical and operational point of view, but without giving it any particular importance. While mainstreaming biodiversity across policy sectors has gained international traction[2], the lack of homogeneity of research scope among key fields such as biodiversity, climate, transport, and energy, along with their associated objectives, poses a significant challenge. Infrastructure planners, designers and operators are primarily targeted decarbonising the sector to meet global climate change mitigation targets. However, biodiversity considerations have largely been neglected, and potential synergies, such as the application of nature-based solutions, remain unexplored. There is scope to further explore the potential synergies, such as application of nature-based solutions at scale.

To answer these challenges, **the BISON project envisages a symbiotic relationship between two key commons: biodiversity and infrastructure,** promoting resilience in both areas. To realise this vision, the project has developed the present Strategic Research and Deployment Agenda (SRDA) comprising several key elements: (1) it synthesises existing knowledge, making it accessible to stakeholders and facilitating its widespread adoption. (2) it proposes a clear research path to address environmental challenges in a holistic way, encompassing ecological, societal, developmental and governance aspects and avoiding duplication of funding and effort. (3) it identifies gaps and opportunities in policy and funding, paving the way for a coherent, action-oriented approach.

Building upon a 30-year incremental process, the BISON project capitalises on previous efforts to mainstream biodiversity and transport, such as the publication of the European Wildlife and Traffic Handbook in 2003, which emerged from a European Union-funded COST Action. As mobility patterns have evolved over the past two decades, necessitating biodiversity mainstreaming beyond roads and rail to encompass waterways, ports, airports, powerlines, pipelines, and even renewable energy infrastructure, **the project compiles current best practices and updates evidence-based guidelines.** Additionally, it recognises the growing urgency of addressing specific issues at the interface of biodiversity loss and climate change, such as barrier effects on wild species populations and the spread of invasive alien species.

2. see UNEA decision 2022, CBD COP 15, GEF 8

Moving forward, the BISON project emphasises the need to bridge the gap between local ecology and broader societal issues by addressing planning, multi-stakeholder interactions, psychology, governance, and long-term observatories. It acknowledges that despite the wealth of existing knowledge, challenges persist due to fragmented approaches across technical, scientific, and administrative silos. Exploring synergies and implementing long-term actions on the ground necessitates scenario modelling and policy integration within the framework of Horizon Europe. Furthermore, it underscores the importance of incorporating social sciences and humanities in biodiversity and infrastructure research, as well as enhancing monitoring, data sharing, and effectiveness assessment of mitigation solutions.

The BISON project is the basis for a transformative process seeking to contribute to the evolution of transport and biodiversity policies by promoting a paradigm shift. By merging biodiversity considerations with infrastructure development, the project strives to enhance positive effects for biodiversity while mitigating and adapting to climate change. It envisions a future where resilience, sustainability, and the preservation of biodiversity are at the forefront of infrastructure planning and decision-making. **Through its comprehensive strategic agenda and collaboration with diverse stakeholders, the BISON project endeavours to catalyse transformative change and pave the way for a harmonious coexistence between biodiversity and infrastructure.**

Organisation of the Strategic Research and Deployment Agenda

The subject covered by the BISON project is evolving rapidly, and the development or adaptation of environmentally friendly infrastructure (in terms of climate and biodiversity) presents contradictory challenges. The challenge of a coordinated European approach to this issue is a very ambitious one, especially when considering the substantial disparities in the situation from one country to another.

The realisation of the BISON project's strategic agenda is the result of the contributions from various project deliverables. During the process of realisation, great attention was given to consultation with specialists and contributors to the project. The proposed recommendations are often disruptive or subject to debate. The Strategic Research and Deployment Agenda (SRDA) itself represents a step forward rather than a completed work; it is a living object that will need to be embraced by actors from different areas and perspectives. By outlining these issues for the first time, albeit preliminarily, the agenda lays the foundations for concrete and coordinated actions on the subject.

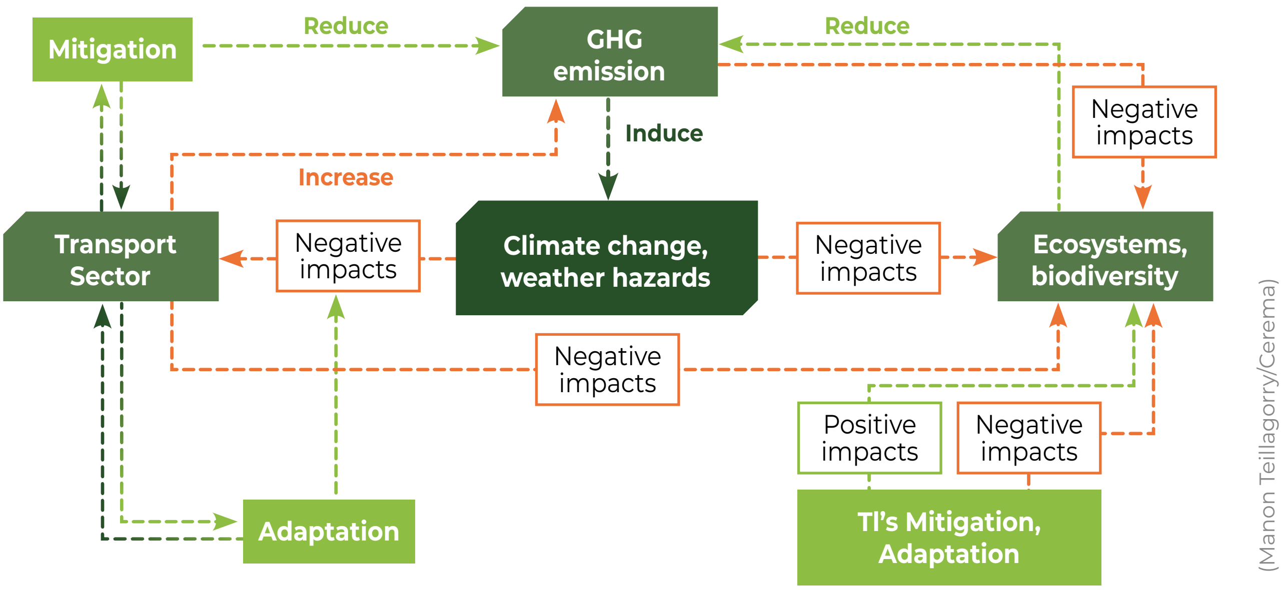


FIGURE 1:
Diagram depicting the complexity of the relationships between the transport sector, biodiversity and climate change.

The SRDA also includes original proposals that have not been developed in the various deliverables. It focuses specifically on suggestions covering the intersection of infrastructure and biodiversity issues. The choice has deliberately been made not to overlap with topics specific to the strategic agendas of other EU initiatives or partnerships such as Biodiversa+, STRIA, SRIA, FORx4, which have, however, influenced its overall structure. As the first of its kind on the subject, this agenda is an important step in laying the foundations for actively implementing the contributions gathered throughout the project and preparing for implementation.

This agenda is not a ready-made solution for achieving full environmental integration with transport infrastructure, but it is an essential step towards initiating dialogue and cooperation among stakeholders who often work within isolated silos. However, the interrelationships between infrastructure and biodiversity must be assessed on a broader territorial scale, going beyond the immediate impact of each individual project. Beyond a natural inclination for technological solutions, these networks must dialogue to develop an integrated territorial approach that addresses transport networks' economic, societal, and political objectives for biodiversity protection while considering climate change. To be effective, the legal, technical, and societal recommendations presented in this agenda are meant to mobilise all available resources in a cross-cutting manner, and ongoing research on the political and legal aspects should be encouraged and supported for the future.

This ambition of symbiosis, or coexistence of biodiversity and infrastructure, which the agenda aims to convey, potentially involves challenging and competing issues that need to be addressed rather than avoided or minimized. While some issues are considered 'classic' in the field of research and innovation (e.g. fauna passages design), others require reflection on the research support system itself and the collective determination to achieve them.

The aim of this agenda is to bring together resources and actors across different areas to proactively develop a different way of addressing the issue. Unless specifically indicated, the actions presented apply to all infrastructure and have a generic and cross-cutting dimension. The problems and solutions concern a wide range of modes and can be shared more widely, regardless of the vehicle or infrastructure type.


Reutte/Tirol 41 km
Füssen 32 km

SCENARIOS FOR ACTION

Navigating Sustainable Futures: The Power of Scenarios in Balancing Biodiversity and Transport Infrastructure

Building scenarios to project into the future is a regular but complex practice. Biodiversity has been mentionned on many occasions in the context of transport and climate, but it has never really been a paradigm considered sufficiently important to carry out such an exercise. The synthesis of the findings obtained at the end of the many workshops[3] held throughout the BISON project is an important step in supporting readers' thinking and looking at the future from unusual angles.

These subjects can be challenging to grasp due to their potentially negative or pessimistic implications. By exploring plausible futures between biodiversity and transport infrastructure, the scenarios developed in the BISON project make it possible to anticipate future relationships between biodiversity and ecosystem services, on the one hand, and transport infrastructure, on the other. The BISON scenarios glimpse:

- 😐 the "possible",
- 🙂 the "desirable",
- ☹️ and, conversely, the futures we must strive to avoid.

They shed light on the inherent tensions between stakeholders with divergent interests and worldviews and highlight our ability to adapt to new, ecologically focused public policies. They are intended to provide food for thought on potential development trajectories, all of which involve trade-offs. Some trajectories are not sustainable, and it is necessary to highlight the path to follow to make transport infrastructure more sustainable for biodiversity.

	Scenarios			
Expected impact on biodiversity	**Coping with emergencies**	**Business as usual**	**Focus on solutions for carbon emissions**	**Finding solutions to all environmental challenges**
Defragmentation	😐	😐	☹️	🙂
Natural habitats related to TI	😐	😐	☹️	🙂
Rare species conservation	☹️	😐	😐	🙂
Invasive species control	☹️	😐	😐	🙂
Climate change impact	🙂	☹️	🙂	🙂

FIGURE 2:
Synthesis table of Scenarios in Balancing Biodiversity and Transport Infrastructure

3. see deliverable 5.5 - https://bison-transport.eu/deliverables/

Scenario 1:
Coping with emergencies

In the 2020s, no environmental forecasting due to global change (extreme weather conditions, etc.) have really been anticipated. The maintenance of transport infrastructure has become problematic. Combined with increasingly frequent crises such as epidemics, shortages of primary resources and rising energy prices, mobility have declined considerably by the 2030s. Environmental management standards and regulations have become increasingly disjointed in response to economic challenges and emergency situations.

Between 2025 and 2050, the transport infrastructure sector contributes to the isolation of wildlife populations and the deterioration of habitat quality. The decline in whole swathes of economic activity, reduced or slower mobility, particularly in rural areas, and frequent natural disasters mean that more and more transport infrastructure is being abandoned because it is too expensive to maintain. Paradoxically, these disused technical facilities may become beneficial for biodiversity, as they provide new wildlife habitats. Biodiversity is slowly beginning to recover in certain areas that have been particularly depopulated by this process.

EXPECTED IMPACT ON BIODIVERSITY	
Defragmentation	😐
Natural habitats related to TI	😐
Rare species conservation	😐
Invasive species control	😐
Climate change impact	☹️
Variability beetwen countries	

Scenario 2:
Business as usual

Although European populations are becoming increasingly aware of biodiversity issues, the European Union is failing to implement any real ambition to restore biodiversity. Over the 2020s freight has found digital solutions to support its multimodal transition, with certain advantages in terms of reducing carbon emissions.

However, this trend does not apply to the mobility of individuals, which remains as in 2020. In the transport infrastructure sector, this situation is reflected in the partial integration of biodiversity into practices, particularly during the design phase; data is collected but not properly exploited to improve biodiversity management; biodiversity sometimes competes with grey solutions or renewable energy solutions; and private funding exists but is limited. Anthropogenic pollution increases in 2045, causing environmental and health problems for both humans and non-humans.

By 2050, biodiversity has been lost by around 50% compared with the baseline year of 2000, leading to concrete failures in the provision of ecosystem services. As the transport infrastructure sector is not directly affected by this situation, no real change in its usual activities is envisaged, and biodiversity remains a pious hope.

EXPECTED IMPACT ON BIODIVERSITY	
Defragmentation	😐
Natural habitats related to TI	😐
Rare species conservation	☹️
Invasive species control	☹️
Climate change impact	🙂
Variability beetwen rural vs urban areas	

Scenario 3: Focus on solutions for carbon emissions

In the 2020s, with strong political support, a carbon-free energy alternative is found to support current uses of mobility at a good price. Individual mobility still remains the norm, however. The European Union has the ambition to restore biodiversity but fails to disseminate its objectives at national levels. New transport infrastructure are being developed cumulatively, without any concrete harmonisation or planning. Public funding for transport infrastructure exists, but biodiversity management is not one of the key performance indicators. As a result, the impact of infrastructure on biodiversity continues to increase.

As in scenario 2, the loss of biodiversity by 2050 is around 50% compared with the reference situation in 2000, and the services provided by ecosystems are significantly diminished. The adverse effects of carbon storage actions on the provision of ecosystem services and on the water cycle emerge as a major challenge for the next 50 years.

EXPECTED IMPACT ON BIODIVERSITY

- **Defragmentation**
- **Natural habitats related to TI**
- **Rare species conservation**
- **Invasive species control**
- **Climate change impact**

Variability beetwen local areas

Scenario 4: Finding solutions to all environmental challenges.

In the 2020s, a strong European political willingness make cross-sectoral planning and stakeholder cooperation the two fundamental principles of their programmes. In terms of regulation, strong work is done to harmonise regulations for more cooperation efficiency and cross-sectoral implementation. Public transport as a service is becoming the norm in the transport sector, and transport companies are developing cooperative business models to facilitate the move to multimodal. Local and circular economy is being encouraged. At the same time, new and existing transport infrastructure have received public and private funding and benefited from real-time risk management that anticipates adaptations to climate change and the need to protect biodiversity. Synergies between nature-based solutions and ecological connectivity objectives are found in the design and adaptation of infrastructurerelated habitat.

By 2050, the transport infrastructure sector has achieved its "net biodiversity gain" target with stable maintenance costs and improved resilience indicators for adaptation to climate change. Investment banks have committed early on to sustainable infrastructure funding at a supranational level, defining key performance indicators (KPI) related to biodiversity. A common fund for biodiversity and climate change related to new and existing infrastructure has been effective since the beginning of the 2030s. Biodiversity has begun to recover.

EXPECTED IMPACT ON BIODIVERSITY

- **Defragmentation**
- **Natural habitats related to TI**
- **Rare species conservation**
- **Invasive species control**
- **Climate change impact**

Variability beetwen local areas

Policy recommendations from the scenarios

To achieve the transformative change envisioned in the best scenario (Scenario 4) for biodiversity and transport infrastructure, the BISON partners and external experts have formulated four strategic guidelines. These strategic guidelines are as follows:

FINANCING

Encourage all public players and businesses to allocate a portion of their budget towards financing actions in favour of biodiversity, similar to their efforts to reduce their carbon impact. Programmes such as the InvestEU offer opportunities to mobilise public and private funds to support the enhancement of nature and biodiversity through green infrastructure projects along road or rail verges and blue infrastructure projects such as canals or rivers, as part of new solutions for green business-model.

SOBRIETY PLANNING

Design actions and integrate them into comprehensive, large-scale, and long-term ecological strategies. This approach will help achieve the Goal A of the COP15 agreement, which means a significant increase in the quantity, quality and connectivity of green and blue spaces within urban and densely populated areas. By prioritizing biodiversity considerations in land planning, native biodiversity, ecological connectivity and integrity will be strengthened. Moreover, this approach also aligns with the Trans-European Transport Network (TEN-T) policy, which emphasises that, when planning infrastructure, Member States and other project promoters should pay particular attention to risk assessment and adaptation measures to adequately improve resilience to climate change and environmental disasters.

COOPERATION AND CAPACITY BUILDING

Organise training and skills development programmes for all private and public professionals, particularly in regional planning and development, who are involved in activities that affect species and ecosystems. As outlined in the EU's green infrastructure strategy, professionals working with green infrastructure must acquire adequate skills and competencies to adopt innovative approaches alongside technological advancements. It is imperative to address skills shortages through training initiatives and further education for skilled personnel. This approach will help establish a well equipped workforce in the medium term, capable of effectively addressing biodiversity concerns and implementing sustainable practices.

To ensure a successful implementation of the European Supply Chain law and Goal D of Kunming-Montreal Global Biodiversity Framework target 15, infrastructure companies should prioritize training their procurement and operational teams.
By providing comprehensive training, infrastructure companies can empower their teams to make informed decisions and take proactive measures to mitigate negative impacts on biodiversity throughout the supply chain. This includes raising awareness about the potential ecological consequences of sourcing practices, construction activities, and operational processes.

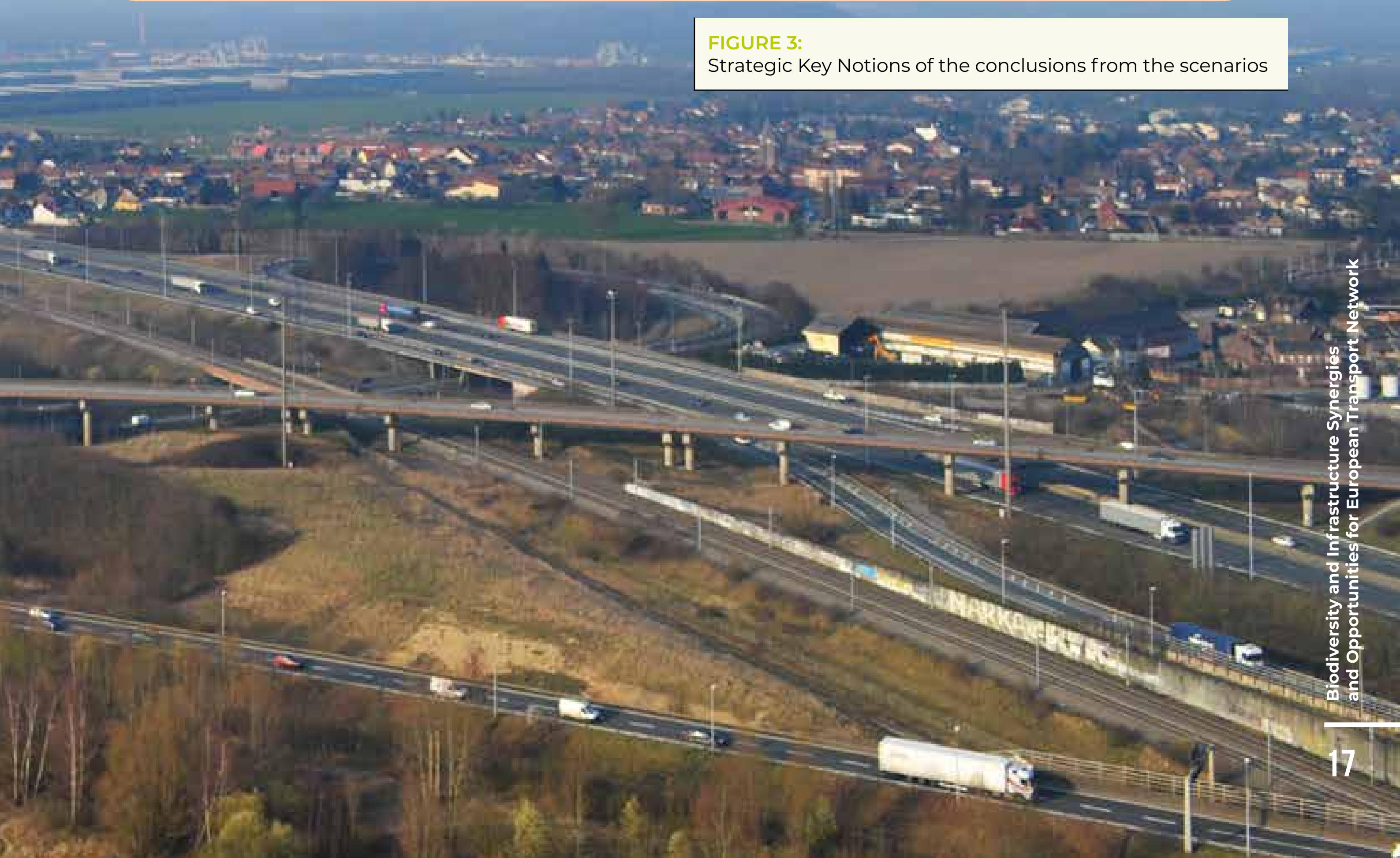


FIGURE 3:
Strategic Key Notions of the conclusions from the scenarios

1. SHORTCOMINGS OF CURRENT POLICIES AND PRACTICES: MAIN CHALLENGES

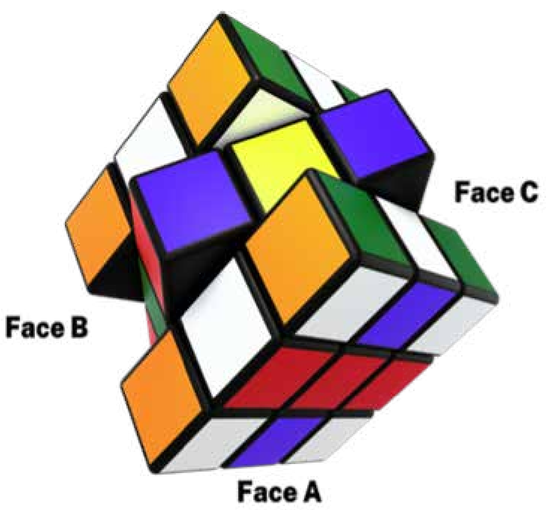
The relationship between infrastructure and biodiversity is often reduced to a narrow technical perspective, overlooking its fundamental multidimensional nature. The complexity of the systems involved and their constant interrelations and interactions present difficulties in understanding and addressing the possible solutions. In fact, the fear of unintended consequences severely limits the capacity for innovation. This situation calls for a strategic approach to overcome these challenges. Developing a holistic vision requires mobilising various interconnected factors, including governance, economic models, societal engagement, assessment of reversibility of impacts on biodiversity, and support for innovative operational approaches. Research and innovation play a vital role in connecting these elements.

This chapter aims to explore these challenges and propose potential solutions to establish a mutualistic beneficial relationship between transport infrastructure life cycle and biodiversity conservation. It delves into the challenges faced in the fields of transport infrastructure and biodiversity conservation, presenting potential solutions. By addressing these barriers, it aims to foster a symbiotic relationship between transport infrastructure development and biodiversity conservation, ultimately leading to more sustainable practices and positive outcomes for both ecosystems and society.

1.1. ALIGN NATIONAL, EUROPEAN, AND INTERNATIONAL POLICIES FOR A STRATEGIC APPROACH

1.1.1 TACKLE THE INTERTWINED CHALLENGES OF TRANSPORT INFRASTRUCTURE AND BIODIVERSITY EFFECTIVELY

European transport infrastructure faces challenges in adapting existing infrastructure to new climatic conditions and finding innovative and sustainable solutions to reduce its impacts on biodiversity, including ecosystem fragmentation. These challenges must be balanced with the need for economic development supported by new transport infrastructure while also considering the preservation of local biodiversity. However, the fragmented and compartmentalised nature of the funding framework further constrains the ability to effectively address these issues, impeding an optimal response to the joint issues of transport infrastructure and biodiversity conservation.



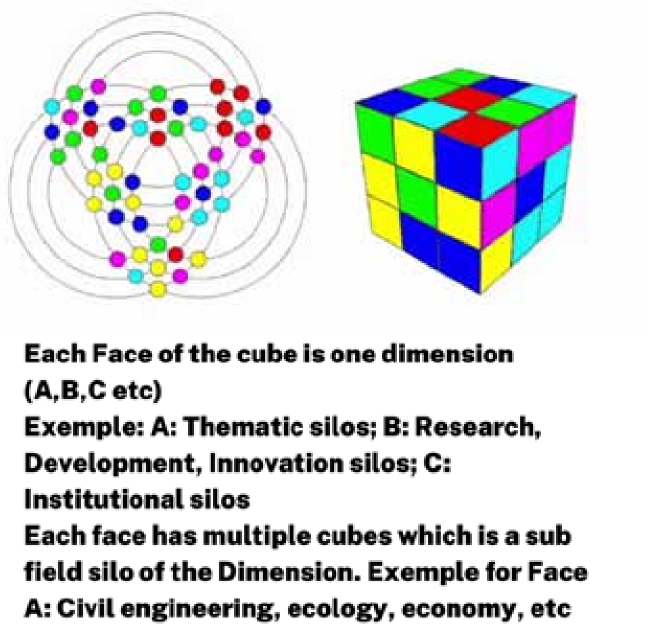


FIGURE 4:
Graphic depicting the intricate relationships between the transport sector and biodiversity

Biodiversity protection has been a central focus of European policies since their involvement in environmental matters began. To provide a more research-oriented perspective, it's worth noting that the European Union (EU) has implemented several key initiatives and regulations to address biodiversity conservation, including the Natura 2000 network of protected areas, the EU Biodiversity Strategy, and the Habitats Directive, among others. Moreover, it has been following and been in alignment with the international concerns and agreements like those of the UN and the Convention on Biological Diversity. It is worth noting that the Birds Directive (1979) and the Habitats Directive (1992) established frameworks for species conservation and the Natura 2000 protected areas network. In line with the European Green Deal, the EU's 2030 Biodiversity Strategy aims to strengthen the integration of biodiversity considerations across all relevant sectors. Despite numerous ecosystem protection policies, the "State of Europe's Nature 2020" report by the European Environment Agency highlights a strong and quick ongoing decline in biodiversity. Alarmingly, two-thirds of the species protected under the Habitats Directive in the EU face poor or deteriorating conservation statuses. The unmanaged infrastructure growth, such as highways and power plants, has contributed to this deterioration and poses significant threats to Europe's protected species.

To address some of the threats to biodiversity, several sector-specific policies have emerged, such as the Green Infrastructure Strategy, the Connecting Europe Facility, and the Strategic Transport Research and Innovation Agenda. Furthermore, Horizon Europe seeks to support the EU's Green Deal and Biodiversity Strategy by fostering research and innovation.

However, various challenges are hindering the effective implementation of these policies. The absence of binding obligations reduces their impact, as Member States have discretion in adoption and implementation. Inconsistent interpretations of strategies, like the European Green Infrastructure Strategy, create confusion and impede coordinated policy implementation. Divergent national priorities further complicate Member States policy coordination, affecting biodiversity and infrastructure initiatives. As a result, there is currently no dedicated European policy specifically addressing the intersection of transport infrastructure and biodiversity.

Consequently, a distinct European policy explicitly addressing the convergence of transport infrastructure and biodiversity remains absent. The incorporation of green infrastructure into European policy and legal frameworks remains a work in progress, leading to delays in fulfilling the environmental mandates set forth by the European Union for transport infrastructure. Moreover, numerous EU Member States encounter challenges in effectively enforcing green infrastructure legal frameworks, leading to notable disparities in their implementation across countries.

- **The Environmental Impact Assessment is, currently, the main instrument for integrating biodiversity criteria into transport infrastructure.**

Field action policies are a central pillar for success. Aligning legal mechanisms within the conventional legal framework of the European Union Member States' is essential. These legal tools are a first step towards integrating biodiversity considerations into transport infrastructure development.

Strategic Environmental Assessments (SEA), Environmental Impact Assessments (EIA), and Appropriate Assessment (AA) procedures are legal tools to address the complex interactions between linear transport and energy infrastructure and biodiversity. These tools enable the minimisation of negative impacts on biodiversity and facilitate informed and sustainable decision-making in the development of transportation infrastructure. Moreover, Environmental Impact Assessment (EIA) and Strategic Environmental Assessment (SEA) are two distinct instruments used in the field of environmental management, but they differ in their focus, timing, and scope. EIA is a technical instrument that evaluates and mitigates the specific environmental impacts of individual projects, focusing on minimising those impacts. It is reactive and conducted towards the end of the decision-making process. SEA is a systematic process used earlier in the decision-making process for strategic initiatives. It takes a proactive approach, addressing sustainable development issues and identifying potential cumulative effects of multiple projects. It aims to integrate environmental objectives and provide early warnings. As a result, the SEA is an instrument that intervenes much further upstream than the EIA and can therefore have more decision-making power in favour of biodiversity.

Article 11 of the Treaty on the Functioning of the European Union (TFEU) requires integrating environmental protection into all policies. While EU national transport policies do not explicitly mention biodiversity protection, this principle ensures that environmental requirements are incorporated into all actions and policies, including infrastructure projects. As the EU progresses towards implementing the Green Deal, it emphasises the need to avoid harming the environment. Therefore, the objectives of the

EU Biodiversity Strategy must be considered in all EU-level policies and actions. This general legal consideration allows transport infrastructure to fall within the scope of legislation imposing environmental impact assessment. According to Annex I (points 7 and 8) of the 2001/42/EC Directive on "plans and programs", specific transport infrastructure such as railway lines, airports, freeways, express roads, commercial ports, and loading/unloading areas are subject to environmental assessment. The criteria for assessment include thresholds based on the size, duration, and volume of the operation. This requirement ensures that large infrastructure projects undergo an environmental assessment. It should be also noted that the EIA focuses only on new projects, it does not cover environmental impacts of existing infrastructure.

Transport infrastructure projects are subject to environmental assessment due to the specific nature of their sector. This requirement is established under the EIA Directive, which governs the approval process for projects falling within the scope of the Habitats Directive and the Birds Directive, as outlined in Articles 6 and 7. Additionally, EU Member States are required to identify projects with significant environmental impacts. The Habitat Directive mandates the prior assessment of any project to have a significant effect on protected areas, including those where transport infrastructure projects are located. An immediate relation with the ecological connectivity and the transport networks is the article 10 of the Habitat Directive aiming to support the cohesion of the Natura 2000 Network as the largest network of protected areas globally.

However, environmental impact assessments often give limited consideration to biodiversity, even in areas designated as Natura 2000 sites. This deficiency can impede project authorisation. Furthermore, the strict transposition of norms without adequately considering economic and social realities in countries can also present challenges. **The sole reliance on the Environmental Impact Assessment as a legally binding instrument underscores the limited effectiveness of existing biodiversity policies in efficiently addressing the interconnected challenges of infrastructure and biodiversity.**

1.1.2. IMPROVE THE STRATEGIC ROLE OF TARGETED FUNDING

Europe has developed specialised funding mechanisms to meet various needs in sectors such as transport, agriculture and research. However, it is challenging to identify specific funding dedicated to infrastructure and biodiversity. To address this, it is crucial to capitalise on previous achievements.

Funding mechanisms play a crucial role in supporting environmental and biodiversity initiatives. The LIFE program, managed by the European Commission, has financed numerous projects focused on environmental and climate protection. However, it provides limited funding specifically aimed at integrating biodiversity with transport infrastructure. Interreg, funded by the European Regional Development Fund (ERDF), facilitates crossborder cooperation but may not sufficiently support on-the-ground actions for transport infrastructure and biodiversity. COST, an interdisciplinary research-funding agency, primarily emphasises networking activities rather than direct research, which may limit its effectiveness in driving tangible actions at the intersection of transport infrastructure and biodiversity.

While these funding mechanisms provide valuable support in their respective domains, it is necessary to address their limitations and develop more comprehensive and cross cutting approaches for integrating transport infrastructure and biodiversity conservation.

However, the implementation of national biodiversity strategies often faces challenges due to a lack of resources and influence to achieve ambitious goals. Moreover, the bureaucratic paperwork and fragmented manner of harnessing EU funds restrict their effective use at the national level, further impeding progress. In contrast to substantial funding systems established by public entities for climate transition, private financial support for biodiversity remains constrained. Insufficient structural funding for biodiversity makes it difficult to identify specific investments despite the existing commitment to addressing biodiversity loss.

The huge financial disparities between the transport and biodiversity sectors represent an additional challenge for joint research efforts. The significant difference in funding allocation between these sectors creates an imbalance, impeding collaboration. Limited private investments in biodiversity research are attributed to difficulties in comprehensively assessing biodiversity loss and the complex nature of financing. The concept of return on investment, essential in the transport sector, presents complexities in the biodiversity sector, further hindering coordinated investments in both domains. In this case the polluter pay principles is of great challenge to be implemented especially in the most transparent way.

At last, but not least, the random willingness of political actors and public awareness undermines interest in understanding the effects of transport infrastructure on biodiversity, resulting in insufficient funding for research and implementing biodiversity-friendly infrastructure. Prioritising economic development that does not integrate environmental protection exacerbates the situation, leading to resource shortages in addressing the issue. Typical obstacles encompass cost-related factors and the need for swift project execution. Additionally, private land ownership and prevailing economic trends can serve as hindrances to advancing towards infrastructure that is more aligned with biodiversity sustainability.

In conclusion, the current funding landscape for biodiversity research and innovation can be considered imbalanced, fragmented, and inadequate, while the interdisciplinary character of this field, coupled with the scarcity of intermediaries within the public sector, creates hurdles in securing funding that predominantly targets knowledge acquisition and the preservation of protected areas, with limited attention to innovation and experimentation. Moreover, the absence of comprehensive tools for evaluating biodiversity funding and the inadequacies in the funding sections within national biodiversity strategies underscore the imperative need for enhancements in this domain.

However, solutions exist, and to ensure adequate research and conservation efforts, the funding structure for biodiversity research in Europe needs to be addressed. Addressing these challenges requires increased investment in research and innovation, particularly in emerging areas like green technologies. Collaboration among academia, industry, infrastructure operators and government is crucial, along with international cooperation, to tackle global challenges and develop effective nature-based solutions. Public authorities must, therefore, prioritise biodiversity research funding, and the private sector should play a more active role in financing biodiversity research and conservation. The need to promote research and innovations that go beyond the limit of a single field, 'Biodiversity', and promote transdisciplinary research working together with experts on ecology and infrastructure is the real revolutionary change we need to overcome barriers and create disruptive science and action. New paradigms and new solutions require different disciplines to work together.

1.1.3. HOMOGENISE SOCIETAL AWARENESS

Achieving nature-based solutions and integrating social and ecological values into transport infrastructure planning and design is complex. It requires economic viability while striving for long-term sustainability, even if immediate financial returns may not be as attractive. Balancing economic interests with environmental and social considerations is essential for creating infrastructure that benefits both people and nature.

A significant challenge lies in ensuring public involvement in research and innovation priorities to align funding with societal needs. It is crucial to engage the public to understand their perspectives and incorporate them into decision-making processes. Additionally, assessing the cumulative effects of infrastructure development is essential, considering the future challenges of increased demand for mobility and the need for climate change adaptation. This assessment should encompass the long-term impacts of transportation projects on biodiversity and ecosystems.

Another challenge is the lack of consistent knowledge regarding the full range of impactsacross different project life cycle phases. Understanding the comprehensive effects, from construction to operation and maintenance, is crucial for effective decision-making and mitigating negative consequences.

Furthermore, the influence of industry lobbying and policies on ecologically sustainable and biodiversity-friendly transport can impede progress. It is important to address these influences and ensure that policies and practices align intending to promote sustainable transportation that protects and enhances biodiversity.

While revolutionary changes in transportation technology promise improved efficiency and resilience, they may not fully meet the needs of a growing global population and rising living standards. Therefore, it is necessary to approach the integration of biodiversity and transport infrastructure with a comprehensive and collaborative effort involving all stakeholders.

With a joint effort, it seems possible to overcome these challenges and create a more sustainable and inclusive transportation system that benefits both people and the environment.

1.1.4. INCREASE RESEARCH COLLABORATION IN TRANSPORTATION INFRASTRUCTURE AND BIODIVERSITY

→ DEVELOP INTERDISCIPLINARY APPROACHES

The absence of sufficient interdisciplinary approaches in infrastructure development has resulted in a fragmented and isolated understanding of the issue, where experts tend to focus solely on their specialised fields of study, often disregarding the broader ramifications of their work. This narrow focus frequently leads to a concentration on technical solutions that overlook the complex social, economic, and ecological systems affected by infrastructure development. To address this, interdisciplinary research involving disciplines such as ecology, engineering, social sciences, and economics becomes imperative. Such research provides a more holistic understanding of how infrastructure impacts biodiversity and other environmental factors, as well as the social and economic dimensions of infrastructure development. By collaborating across disciplines, researchers can adopt a more comprehensive approach to infrastructure development, considering long-term effects and devising sustainable solutions that strike a balance between economic and ecological considerations. Regrettably, opportunities for conducting these types of research activities within long-term observatories are infrequently planned and funded.

→ IMPROVE RISK TAKING IN RESEARCH

Risks and benefits in managing infrastructure habitats and employing Nature-based Solutions (NbS) must be carefully balanced. The current system primarily supports projects with predictable outcomes, limiting risk-taking and resulting in conservative investments. Initiatives supporting a riskier approach tend to focus on technically complex subjects with limited systemic scope[4]. Project performance indicators mainly rely on techno-economic objectives, neglecting to sufficiently consider results that cannot be easily quantified economically. Risk aversion and a low willingness to embrace the possibility of failure[5] also restrict transformative research, which involves ideas, discoveries, or tools that fundamentally change our understanding of existing scientific or technical concepts or create new paradigms.

Furthermore, the nature of the work undertaken in the field of biodiversity and infrastructure is inherently uncertain, leading to tensions, disruptions, and opposition. This uncertainty reflects the stochastic and dynamic nature of biodiversity, which contrasts with the desire for standardisation prevalent in the world of transport engineering. To overcome these challenges, it is necessary to consider how to adapt the system to allow for increased risktaking by mobilising the research framework. It is also important to develop tools and intermediaries, such as knowledge brokers, to effectively transfer the knowledge produced to non-scientific audiences.

→ THE SPREAD OF KNOWLEDGE: CAPACITY TRAINING AND KNOWLEDGE BROKERS

Building from high political level on decision-making to the local level of actual projects' implementation is essential for the long-term success and sustainability of biodiversity-friendly infrastructure initiatives. Involving local communities and stakeholders in the planning and execution of projects is vital for their effectiveness. To bridge the gap between scientific research and practical implementation, knowledge brokers are needed to play a crucial role in connecting research findings with on-the-ground applications.

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4. See deliverable 4.2 part 4.1 Strategic Action Research Programme

5. See deliverable 5.6 EU funding opportunities and proposals for cross-sectoral topics and final conference discussion *https://bison-transport.eu/2023/06/27/catch-up-the-international-seminar-transport-infrastructure-and-biodiversity-at-a-nexus-of-challenges/*

Facilitating knowledge sharing and dissemination among various actors, including researchers, practitioners, and policymakers, is key to achieving the goals of biodiversity friendly infrastructure. Ongoing efforts to raise awareness and build capacity for such projects should be integrated into broader education and training programs.

Addressing tensions and barriers in language and communication requires an intermediary who can facilitate connections between parties and ensure effective knowledge management. This intermediary should promote research outputs and enable operational actors to incorporate them into their work. Additionally, supporting the evolution of research communities to better understand the needs of research commissioning bodies is important.

To optimise resources and overcome language barriers, coordination is crucial. Collaborative efforts among stakeholders can help identify and implement effective communication and language translation strategies. This could involve the development of multilingual resources, training programs, and platforms that facilitate knowledge exchange and understanding among diverse actors involved in biodiversity-friendly infrastructure projects. For instance, fostering better communication between stakeholders at various levels is essential, and establishing a Glossary[6] in collaboration with relevant organisations is a significant step in this direction. Additionally, there is a need for interdisciplinary education and training for technical staff and establishing a centralised "Learning Hub[7]" can provide resources to enhance interdisciplinary skills. Such hubs provide the potential for nurturing Communities of Practice (CoP) where practitioners collaborate, share knowledge, and collectively solve problems alongside their peers and with the guidance of experts.

6. See annex 2

7. https://www.unep.org/resources/publication/international-good-practice-principles-sustainableinfrastructure

1.2. OVERCOME CHALLENGES IN CREATING SYMBIOSIS BEYOND SILOS

1.2.1. COMBINE SPATIAL AND TEMPORAL PLANNING

Integrating biodiversity into transport infrastructure poses various challenges that require a comprehensive approach to overcome. One significant challenge is the conflict between spatial and temporal planning. The prevailing focus on short-term planning and decision making often overshadows the long-term considerations related to ecological sustainability. To address this, spatial planning must encompass biodiversity considerations at all levels, from local to global, while also accounting for the cumulative impacts of multiple infrastructure projects, especially when aligned in a close distance leading on pairing of linear transport infrastructure in the same biodiversity key area.

The design and implementation of transport infrastructure must also take into account the socio-economic context of the local and regional communities. Balancing the community's needs while minimising negative impacts on biodiversity requires careful attention and consideration. Effective stakeholder engagement and collaboration across various levels and scales are necessary to reconcile conflicting objectives and ensure the integration of biodiversity considerations in transport infrastructure planning and implementation.

The adoption of green infrastructure measures varies across countries due to differences in governance structures, financial resources, and stakeholder involvement. Ambiguous national policies and regulations related to green infrastructure, coupled with a lack of coordination among different sectors and government agencies, can impede its effective implementation. Additionally, a lack of long-term political will to prioritise biodiversity concerns in transport infrastructure development can further hinder progress.

These challenges emphasise the importance of increased collaboration between national and local actors but also between cross-border authorities on transnational scale projects. It is crucial to ensure that biodiversity is adequately considered in transport infrastructure planning and decision-making processes. By fostering stronger partnerships and aligning efforts, it is possible to engage integrated approaches that prioritise biodiversity conservation while meeting the needs of transportation system improvement.

1.2.2. BRIDGE THE GAP BETWEEN THEORY, TOOLS, PRACTITIONERS, AND CIVIL SOCIETY

The current dialogue and knowledge sharing between different types of infrastructure are incomplete, creating a gap between theory, tools, and stakeholders. This challenge hinders the symbiosis between transport infrastructure and biodiversity, as they often operate in silos. The BISON project has identified and objectivised a significant gap in integrating digital technology across these sectors, resulting in limited collaboration and understanding of project impacts throughout their life cycle. Addressing these gaps is crucial to foster collaboration and ensure a holistic approach to the intersection of transport infrastructure and biodiversity management.

To mainstream biodiversity and drive change in the global economic system, four areas of transformation should be prioritised: increased funding, redirected incentives, enabling regulation, and transformed metrics. Traditional impact assessments do not adequately address the cumulative and long-term effects of infrastructure development and climate change. Moreover, there is a pressing need to bridge the gap in awareness and education. Stakeholders, including policymakers, employees in the transport sector, and citizens, often have limited knowledge and understanding of biodiversity issues. Bridging this gap requires highlighting the discrepancy between citizen expectations, scientific capabilities, and current policy proposals.

The existing regulatory framework sometimes demands actions beyond the current capabilities of science, leading to poor management and implementation by authorities. This mismatch between regulatory requirements and scientific feasibility poses a significant challenge in addressing biodiversity issues and managing transport infrastructure sustainably. In the context of the BISON project, a cross-cutting approach is employed to optimise existing infrastructure emphasising collaboration and synergy between stakeholders and sectors.

Active involvement and collaboration from all stakeholders are crucial to effectively bridge the awareness and education gap. It can align social expectations, scientific capabilities, and policymaking processes by raising awareness, improving knowledge dissemination, and promoting interdisciplinary cooperation. This concerted effort will enable us to address challenges, optimise biodiversity management within transport infrastructure, and contribute to sustainable development goals.

1.2.3. INTERCONNECT THE TECHNICAL, ORGANISATIONAL SIDES, AND GOVERNANCE

The absence of connections between the technical and organisational aspects, as well as governance considerations, represents also a significant obstacle to the seamless integration of biodiversity into the planning and development of transport infrastructure. There is a limited understanding of the impacts of transport infrastructure on various species, vegetation, and soil, which hampers accurate impact assessments. Coordination between national biodiversity strategies and transport plans is lacking, and the dynamic aspects of biodiversity are often not integrated into transport or energy policies. National transport plans primarily focus on reducing greenhouse gas emissions, neglecting biodiversity concerns. Weak cooperation and coordination also exist between regional governments and ministries. Mobilising private actors is difficult due to the challenge of assigning a monetary value to biodiversity, which is a common good with long-term benefits at the same time. Strategies for managing invasive species should be integrated with broader biodiversity management approaches for a more holistic approach.

While the transport sector has implemented some effective measures to mitigate its impacts on nature, such as wildlife mortality and habitat fragmentation, these measures are primarily very site specific - rather than universally applicable technical solutions. The BISON project aims to contribute to this challenge by developing an online handbook to disseminate best practices and facilitate their practical implementation. However, achieving widespread adoption of these best practices requires enhanced cooperation among stakeholders in the transport and environmental sectors to ensure their effective implementation.

The current assortment of legal, political, financial, and operational solutions falls short of effectively addressing transportation infrastructure and biodiversity issues. The BISON project is dedicated to addressing these challenges and identifying sustainable solutions aligned with the visionary BISON Scenario 4. To achieve this, a comprehensive exploration of existing practices in the legal, policy, financial, and operational domains is essential to guide effective actions in this interdisciplinary field.

1.2.4. REINFORCE EVIDENCE-BASED RESEARCH AND INNOVATION THROUGH DATA SHARING AND CAPITALISATION

The existing scientific publishing system places a premium on high precision, which can impede interdisciplinary research. Consequently, a substantial body of research on the intersection of infrastructure and biodiversity remains underutilised. To tackle this challenge, regulatory mandates should compel the sharing of essential data within the research community, treating biodiversity as a collective resource and facilitating environmental oversight. Nevertheless, addressing this matter continues to pose significant difficulties.

Among several priorities, managing the spatial and temporal heterogeneity of infrastructure and biodiversity data presents a significant challenge. This necessitates handling data at a large scale, utilising 2D Geographic Information Systems (GIS) and Building Information Modelling (BIM) for the development of Digital Twin (DT) tools. However, the lack of emphasis on expanding the application field of BIM hampers interoperability between biodiversity and transport infrastructure management. Resolving interoperability problems, particularly related to data structure and exchange file format compatibility between software, is essential. Standards play a crucial role in optimising knowledge for rapid deployment and reinforcing economic and industrial sectors. They offer methodological and organisational solutions to broad issues, like the ISO 14001 for environmental management. Drafting such standards is a collaborative process taking about three years, involving multiple contributors and consultations to achieve international consensus.

Everything remains to be done in terms of standardisation for NbS but it is important to note that standards constitute on the contrary a valuable tool to methodologically support the implementation of NbS. There are global visions, but there's a significant gap in comprehensive NbS standards. Moreover, inconsistencies and conflicts can arise concerning environmental standards, posing challenges in ensuring that the implementation of NbS[8] does not compromise existing environmental regulations. In the development and implementation of NbS, there is often an oversight of the explicit evaluation of biodiversity aspects, neglecting the potential impact of NbS on biodiversity. The application of green infrastructure standards faces significant challenges in adhering to environmental laws, particularly when implemented across countries with varying levels of environmental regulations. Additionally, there are gaps in the implementation of impact studies, often failing to fully consider the potential environmental damage caused by a project. Addressing these challenges is vital to effectively support biodiversity conservation by implementing green infrastructure standards.

8. https://knowledge4policy.ec.europa.eu/biodiversity/nature-based-solutions-biodiversity-climate_en

2. STRATEGIC AGENDA: A FRAMEWORK FOR ACTION

→ AIMS AND ORGANISATION

The realisation of the BISON project's Strategic Research and Deployment Agenda (SRDA) is the result of the contributions from various project deliverables. This agenda aims to bring together resources and actors across different areas to proactively develop a different way of addressing the issue. As the first of its kind on the subject, this agenda integrates research questions and operational issues. It is an important step laying the foundations for the active deployment of the contributions gathered throughout the project and to prepare for implementations. The SRDA is only an intermediate stage and its implementation will have to be the subject of future actions well beyond the end of the BISON project itself.

The agenda is divided into two main parts. The first part, for transversal issues, is dedicated to **Governance and strategy for transformative changes.** It defines the framework for cross-cutting actions. The second part addresses the operational and more specific implementation of sustainability objectives throughout the infrastructure's life cycle: **Sustainable infrastructure life cycle implementation.**

→ METHODOLOGY AND REPRESENTATION

The organisation of this section of the SRDA was also carried out progressively, starting with the BISON project deliverables themselves. An initial analysis of these deliverables, whether completed or in progress, identified several hundred entries. These entries were then processed during working sessions or workshops with members and contributors of the BISON project. The resulting list was supplemented by SRDA-specific topics that were not covered in the BISON deliverables. This agenda aims to bring together resources and actors across different areas to proactively develop a different way of addressing the issue. These topics include emerging themes that arose after the start of the project, such as One Health[9] approach.

In each section, thematic actions are introduced, followed by concise descriptions. These actions are further elaborated with specific attributes, including their thematic focus (1), level of progress (2 - Maturity level), geographical scope of implementation (3), and a timeline (4). Unless specifically indicated, the actions presented apply to all infrastructure and have a generic and cross-cutting dimension. The problems and solutions concern a wide range of modes and can be shared more widely, regardless of the vehicle or infrastructure type.

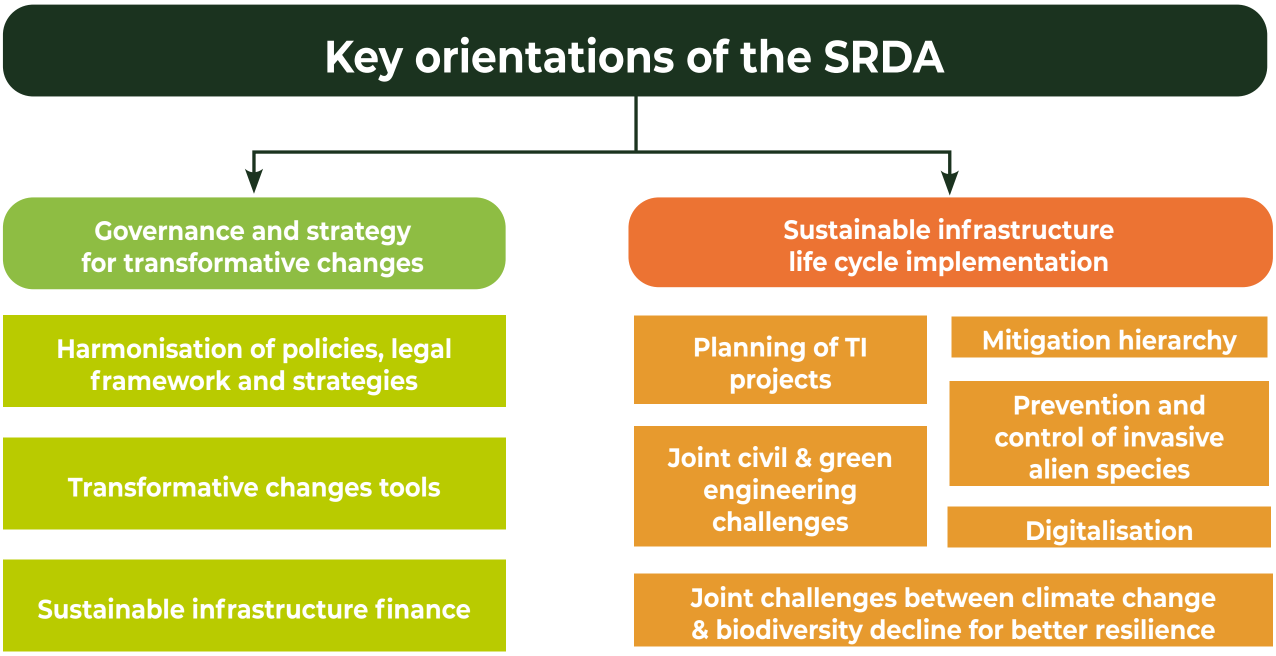


FIGURE 5:
General structure of the agenda

9. https://www.who.int/news-room/questions-and-answers/item/one-health

Actions	Description of actions	Thematic area*	Maturity by spatial level of implementation**				Timeline***		
			local	National	E.U.	Interna-tional	Short term	Medium term	Long term
1.1.2 Assessment	Consolidate a comprehensive monitoring and assessment framework for transport and environmental policies and strategies to allow for better environmental monitoring of national transport plans		-			-			

FIGURE 6:
Example of graphical illustration

1 Thematic area

a. Governance (policy, regulation, law, directives, taxes, incentives...)

b. Operational (standards, technical/ technological solutions, good practices, skills and competences, monitoring & reporting...)

c. Socio-economical (behaviour, business model, funding, awareness, training and capacity building...)

2 Maturity level

The recommendations expressed in this report are important as they aim to fill gaps and overcome barriers to mainstream biodiversity and transport. Some can be treated directly on the operational ground and deployment of actions. Some others may call some research or innovation.

a. Research
b. Innovation
c. Deployment

3 Spatial implementation level

The recommendations that have emerged have to be handled as a baseline framework to update international, national and local level policies or strategies on harmonisation of Green Infrastructure and Biodiversity with Transport Infrastructure development. International

a. European
b. National
c. Local level

4 Timeline

The implementation of the proposals varies over time. A short-term (5 years), medium-term (10 years), or long-term (20 years) projection is proposed, but it remains indicative because, as the COVID crisis reminded us, disruptive events can occur that may alter these timeframes.

a. Research
b. Innovation
c. Deployment

Short term (5 years)
Medium Term (10 years)
Long Term (20 years)

2.1. GOVERNANCE AND STRATEGY FOR TRANSFORMATIVE CHANGES

2.1.1. HARMONISE NATIONAL AND EUROPEAN LEGAL FRAMEWORKS FOR ENHANCED POLICIES AND STRATEGIES

→ RATIONALE

It is particularly difficult to ensure a perfect balance of public policies. It is common for strategies to have contradictory effects due to a constant accumulation of standards and regulations. The situation regarding the interrelations between transport and biodiversity protection policies is a particularly striking example of the difficulties encountered.

Several tools developed since the 1970s, such as Strategic or Environmental Impact Assessments, do try to mitigate these contradictions by reconciling economic development and environmental protection. However, the actual and coordinated application is very heterogeneous and remains compartmentalised, leading to major risks of litigation. In fact, the judiciary's role tends to grow regularly to settle disputes arising from the stacking of poorly adjusted or insufficiently integrated regulations. Therefore, the consequences for public authorities or developers are important both from a planning and cost control point of view.

However, there is a strong mismatch between the arguments used on the transport side, which benefits from significant resources, enabling it to develop profitability models explaining the monetisation of the expected benefits. On the other hand, the data from biodiversity are much more heterogeneous, far less standardised and are essentially linked to protected areas or species. However, in the decision-making process, the difficulty in presenting arguments often makes it difficult to take them into account in the final choice. Many ecological indicators such as those used for the "Fauna Passages efficiency" are used by practitioners but are not consistent enough: i.e., number of animal species crossing fauna passage. This indicator does not answer to the case of efficiency is for animals' species populations scales without the density of local fauna populations indicator. No scientific study for now really answers to this question. Standardisation is a long-term task concerning road transport ecology.

The legal framework plays a crucial role in supporting sustainable mobility policies. Within the SRDA framework, we propose four complementary approaches: (1) harmonisation and simplification of existing regulations and laws are necessary for better coordination and application. (2) conducting assessments will facilitate their evaluation. (3) there is a need to improve the active implementation of policies and strategies, as their current implementation shows significant disparities among stakeholders. (4) exploring new frameworks, particularly at the European level, holds great potential for enhancing a truly integrated approach to address these issues.

Actions	Description of actions	Thematic area*	Maturity by spatial level of implementation**				Timeline***		
			local	National	E.U.	Interna-tional	Short term	Medium term	Long term
1.1.1 Harmonisation and simplification	Enhance, standardise and implement the definition of "green infrastructure" in close link with European directives (landscapes, habitat, transport...)	Governance, Socio-Economical	Research, Innovation, Deployment	Research, Deployment	Research, Deployment	Research, Innovation, Deployment	Research, Innovation, Deployment		
	Align and harmonize Green and Grey Infrastructure Strategies and policies to reduce the risk of legal action	Operational, Governance	-	Research, Innovation, Deployment	Research, Innovation, Deployment	Innovation, Deployment		Research, Innovation, Deployment	
	Simplify and clarify planning legislation and policy while keeping environmental considerations as a high priority to reduce legal risks	Operational, Governance, Socio-Economical	-	Research, Innovation, Deployment	Research, Innovation, Deployment	Research, Deployment	Research, Innovation, Deployment		
1.1.2 Assessment	Consolidate a comprehensive monitoring and assessment framework for transport and environmental policies and strategies to allow for better environmental monitoring of national transport plans	Operational, Governance	-	Research, Innovation, Deployment	Research, Deployment	-	Innovation	Research, Deployment	
1.1.3 Improve active implementation of policies and strategies	Apply the “do not harm” principle under the Recovery and Resilience Facility Regulation	Governance	Research, Innovation, Deployment	Research, Innovation, Deployment	Deployment	-	Research, Innovation, Deployment		
	Establish internal and legal regulations about biodiversity in transport infrastructure project	Governance	Research, Innovation, Deployment	Research, Innovation, Deployment	Deployment	-		Research, Innovation, Deployment	
	Reduce legal risks by encouraging early collaboration between infrastructure, biodiversity and third parties actors to overcome conflicts	Governance, Socio-Economical	Deployment	Research, Innovation, Deployment	-	-	Research, Innovation, Deployment		
1.1.4 Development of new framework	Create a spatial planning Directive considering the need of coordination between national level and regions	Operational, Governance	Deployment	Research, Innovation, Deployment	Research, Innovation, Deployment	Research, Innovation, Deployment		Research, Innovation, Deployment	
	Development and Adoption of a European Defragmentation Program prioritising TEN-T and TEN-N conflicts reduction but also the whole European transport and ecology networks aligned with EU Green Deal	Governance	-	Research, Innovation, Deployment	Research, Innovation, Deployment	-		Research, Innovation, Deployment	

*** THEMATIC AREA :** Operational Governance Socio-Economical

**** MATURITY BY SPATIAL LEVEL OF IMPLEMENTATION :** Research Innovation Deployment

***** TIMELINE :** Research Innovation Deployment
Short term Medium Term Long Term

2.1.2. TRANSFORMATIVE CHANGES TOOLS

➔ RATIONALE

The pursuit of transformative change stems from a profound realisation: the conventional approach to conducting actions can no longer guarantee the long-term sustainability of our way of life. Siloed, thematic approaches are no longer efficient. The globalisation of the issues at stake complicates the identification of each actor's role within a coherent overall strategy. The IPBES describes transformative change as "a fundamental, system-wide reorganisation across technological, economic and social factors (2019, IPBES Global Assessment).

As the various BISON deliverables have shown through the tensions and problems identified, the subject of the interrelationships between infrastructures and biodiversity, therefore, corresponds very strongly to the ambitions of this definition. As such, the research and innovation to be undertaken on the subject is a real opportunity to tackle the root causes of the problem.

Change cannot be achieved by "miracle" solutions. Multiple efforts will be needed through various routes of developing transport networks compatible with biodiversity objectives. The proposals outlined in the SRDA encompass a comprehensive systemic approach that spans various domains, including technical, economic, and societal aspects. These diverse elements must be systematically addressed in a coordinated manner to mitigate significant areas of conflict and dispute. To achieve long-term sustainability, it is crucial to adopt an iterative and dynamic approach that embraces risk-taking and avoids remaining stagnant in an unsustainable status quo.

To achieve these objectives, it is necessary to combine four key elements: (1) Strengthening the research and innovation framework through evidence-based reinforcement and interdisciplinary approaches, promoting risk-taking and improved project evaluation systems; (2) Enhancing coordination and incorporating research findings into the science/society dialogue, while considering national specificities; (3) Improving knowledge transfer processes and supporting the role of knowledge brokers; and (4) Engaging stakeholders, including the general public and operational players, to facilitate significant improvements in the environmental integration of infrastructures.

Actions	Description of actions	Thematic area*	Maturity by spatial level of implementation**				Timeline***
			local	National	E.U.	Interna-tional	Short term / Medium term / Long term
1.2.1 Evidence based reinforcement and organisation of R&I framework	Promote independent, innovative, sound and open evidence-based R&I&D sustainable solutions addressing the integration of green and grey infrastructure	Operational, Governance, Socio-Economical	Deployment	Deployment	Deployment	Deployment	Research, Innovation, Deployment (short to medium term)
	Create transversal funding schemes: "mission projects" (Life, HE, Interreg, COST, etc.) based on the Horizon Europe Missions to enhance consistency	Governance, Socio-Economical	-	Innovation, Deployment	Innovation, Deployment	-	Research, Innovation, Deployment (short term)
	Support the creation or strengthening of research organisations to increase the mobilisation of private actors	Operational, Governance, Socio-Economical	-	Research, Innovation, Deployment	-	-	Research, Deployment (short term)
	Simplify evaluation procedures for cross-cutting topics inspired by COalition for Advanced Research Assesment	Governance	Research, Deployment	Research, Deployment	Research, Deployment	Research, Deployment	Research, Deployment (short term)
	Increase fundings support for high-risk high-reward projects addressing simultaneously infrastructure and biodiversity	Governance, Socio-Economical	-	Research, Innovation, Deployment	Research, Innovation, Deployment	-	Research, Innovation, Deployment (short to medium term)
	Foster cooperative, multidisciplinary and multiscale living labs	Operational, Governance	Research, Innovation, Deployment	Research, Innovation, Deployment	-	-	Research, Innovation, Deployment (short term)
	Develop cross sectoral and interdisciplinary collaboration to maximize (the synergies) and impact of both green and grey (infrastructure) projects	Operational, Governance, Socio-Economical	-	Research, Innovation, Deployment	Research, Innovation, Deployment	-	Research, Innovation, Deployment (short term)
1.2.2 Coordination enhancement	Emphasize and foster a long-term relationship between all stakeholders (including citizens) in the decision-making process / infrastructure life cycle and allocate clear role and responsibilities for the different actors	Socio-Economical	Deployment	Deployment	Deployment	Deployment	Deployment (short to medium term)
	Strengthen multi language-based cooperation	Socio-Economical	-	Deployment	Deployment	Deployment	Deployment (short to medium term)

*** THEMATIC AREA :** Operational Governance Socio-Economical

**** MATURITY BY SPATIAL LEVEL OF IMPLEMENTATION :** Research Innovation Deployment

***** TIMELINE :** Research Innovation Deployment
Short term Medium Term Long Term

Actions	Description of actions	Thematic area*	Maturity by spatial level of implementation**				Timeline***		
			local	National	E.U.	Interna-tional	Short term	Medium term	Long term
1.2.3 Knowledge transfer	Promote a culture of learning to develop continuous evaluation and exchange of knowledge and experience.	Socio-Economical	Deployment	Deployment	Deployment	Deployment	Deployment	Deployment	
	Develop knowledge hubs integrating guidelines for best practices and the use of a standardised / shared between the different actors' glossary	Operational	Research	Research	Research	-	Research		
	Support a "knowledge broke" role of national resource centres (e.g. DIH – Digital Innovation Hubs)	Socio-Economical	-	Research, Deployment	-	-	Research, Deployment	Deployment	
	Foster coordinated capacity building supports	Socio-Economical	Research, Deployment	Research, Deployment	Research, Deployment	Research, Deployment	Research, Deployment		
	Enhance awareness of all types of stakeholders about the shared social value, translations and language of biodiversity and mobility by identifying and understanding the cultural barriers and potential catalysts that exist	Socio-Economical	Deployment	Deployment	Deployment	Deployment	Deployment	Deployment	Deployment
1.2.4 Stakeholder engagement	Facilitate societal engagement and mobilize citizen science efforts.	Socio-Economical	Deployment	Deployment	-	-	Deployment	Deployment	
	Encourage corporate culture engagement through biodiversity labels or policies for voluntary assessment of biodiversity protection beyond regulatory requirements	Socio-Economical	Deployment	Deployment	-	-	Deployment	Deployment	
	Reduce legal and reputational risks faced by companies by endorsing the incorporation of biodiversity into their social and environmental responsibility policies.	Governance	Deployment	Deployment	Deployment	-	Deployment	Deployment	
	Use behavioural science to engage the public as actor of societal and political changes.	Socio-Economical	Research, Deployment	Research, Deployment	Deployment	Deployment	Research, Deployment	Research, Deployment	Research, Deployment

*** THEMATIC AREA :** Operational Governance Socio-Economical

**** MATURITY BY SPATIAL LEVEL OF IMPLEMENTATION :** Research Innovation Deployment

***** TIMELINE :** Research Innovation Deployment
Short term Medium Term Long Term

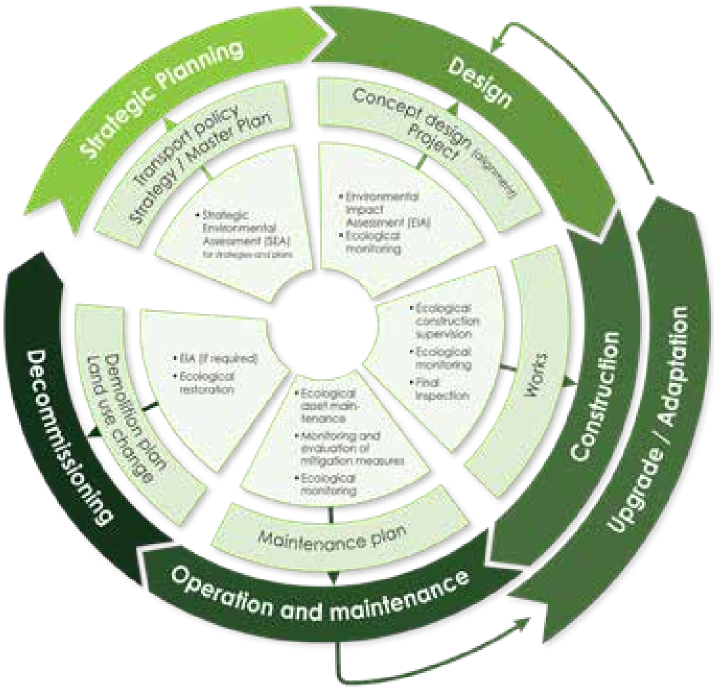
2.1.3. SUSTAINABLE FINANCE INFRASTRUCTURE IMPROVEMENT

➔ RATIONALE

Biodiversity must be taken into account in infrastructure throughout the project life cycle, including in the earliest phases. In this respect, the commitment to sustainable finance is an essential and major prerequisite before any project is undertaken. Controlling the monetary and non-monetary costs borne by biodiversity in infrastructure projects still raises questions about methods and acceptability. The non-monetisation of certain impacts also poses problems of recognition - and therefore consideration - in the decision-making process. Both of these issues need to be clarified and resolved because, ultimately, all the effects of a single project, whether or not they are monetisable, must be considered fairly, consistently, and transparently. Progress in this direction will lay the foundations for the necessary concrete initiatives in the field of financial compensation for biodiversity impacts in the transport sector.

Furthermore, the entry into force in 2024 of the European taxonomy for qualifying the impacts of economic activities on biodiversity will require organising and systematising the reporting and communication of the biodiversity impacts of financial portfolios and products, building on the recommendations from the Taskforce on Nature-related Financial Disclosures to develop regulation and standardisation in this area.

The combination of four key inputs is vital to address the challenges at hand. (1) fiscal innovation supported by public authorities should establish an investment and management framework that aligns environmental criteria (climate, biodiversity) and employs control tools to ensure effective measures. (2) strengthening this foundation requires joint mobilisation of public and private stakeholders, integrating biodiversity dynamically within non-financial reporting while providing flexibility for the private sector and security for the public sector. (3) the ability to measure and compare progress and improvement potential is essential, achieved through standardised performance indicators and metrics applied at all scales with a focus on longer-term dynamics aligned with biodiversity concerns. (4) these actions collectively facilitate the emergence of an industrial sector capable of developing truly sustainable infrastructures on a large scale and effectively implementing stated political ambitions.



Infrastructure and biodiversity Life Cycle relation (Vaclav Hlavac, NCA)

Actions	Description of actions	Thematic area*	Maturity by spatial level of implementation**				Timeline***		
			local	National	E.U.	Interna-tional	Short term	Medium term	Long term
1.3.1. Budgetary innovations.	Mainstream biodiversity in transport/mobility budgets	Governance	-	Deployment	Deployment	-	Deployment	Deployment	Deployment
	Align investors' monitoring criteria with the ones from the European recommendations and set up a specific monitoring of transport expenditures for the benefit of biodiversity	Operational, Governance, Socio-Economical	-	-	Research, Deployment	-	Research, Deployment	Research, Deployment	Deployment
	Develop infrastructure investments optimisation by reducing biodiversity-damaging subsidies and mobilisation of funds for the development of sustainable infrastructures that fully integrate biodiversity	Governance, Socio-Economical	-	Research, Deployment	Research, Deployment	Research, Deployment	Research, Deployment	Research, Deployment	Deployment
	Co-finance biodiversity actions and infrastructure overarching investments optimization framework	Governance, Socio-Economical	Deployment	Deployment	Deployment	Deployment	Deployment		
	Creation of guarantee funds to ensure the capacity to maintain and improve the mitigation measures to reduce impacts and benefit biodiversity during the whole operation phase	Operational, Governance	Deployment	Deployment	Deployment	-	Deployment	Deployment	
	Enhance biodiversity through low-carbon labels by elevating co-benefit requirements between climate action and biodiversity conservation	Operational, Governance, Socio-Economical	Deployment	Research, Innovation, Deployment	Research, Innovation, Deployment	Deployment	Research, Innovation, Deployment	Research, Innovation, Deployment	
1.3.2. Public-Private dialogue	Enforce public procurement with an emphasis on performance based and innovative solutions developed by public-private partnerships under concessionary agreements	Operational, Governance	Research, Innovation, Deployment	Research, Innovation, Deployment	Research, Innovation, Deployment	Research, Innovation, Deployment	Research, Innovation, Deployment	Innovation, Deployment	
	Initiate and support the development of incentive initiatives for the development of public and private accounts integrating the natural heritage in partnership with voluntary business organisations	Governance, Socio-Economical	-	-	Research, Innovation, Deployment	Research, Innovation, Deployment	Research, Innovation, Deployment	Research, Innovation, Deployment	
	Revision of the accounting standard to integrate ecological accounting and natural capital into public and private accounting	Governance, Socio-Economical	Research, Innovation	-	-	-	Research, Innovation	Research, Innovation	

*** THEMATIC AREA :** Operational Governance Socio-Economical

**** MATURITY BY SPATIAL LEVEL OF IMPLEMENTATION :** Research Innovation Deployment

***** TIMELINE :** Research Innovation Deployment
Short term Medium Term Long Term

Actions	Description of actions	Thematic area*	Maturity by spatial level of implementation**				Timeline***		
			local	National	E.U.	Interna-tional	Short term	Medium term	Long term
1.3.3. Key Performance Indicators (KPI's)	Develop a set of shared indicators on biodiversity impacts and risks, refined according to sectors and pressures, and promote an ambitious non-financial reporting framework	Operational	Research, Innovation	-	-	-	Research, Innovation	Research, Innovation	
	Develop specific environmental reporting requirements for infrastructure investors to include biodiversity in their investment decisions. This includes demonstrating compliance with long-term biodiversity targets, assessing contributions to pressure reduction, and providing a biodiversity footprint indicator alongside its calculation and correlation to measuring biodiversity target achievements	Operational, Governance, Socio-Economical	Innovation, Deployment	Innovation, Deployment	-	-	Innovation, Deployment		
	To support the implementation of the European taxonomy reference document to assess the impacts of transport activities on biodiversity understandable for all actors of the territory	Governance	Deployment	Deployment	Deployment	-	Deployment		
	Create a comprehensive framework of environmental indicators, assigning appropriate weight values to each factor, in order to prevent unwarranted conflicts or competition between issues to take care of like climate change and biodiversity	Operational, Governance	Deployment	Deployment	Deployment	-	Deployment	Deployment	
	Improve the process for assessing the effects of transport infrastructure under operation on biodiversity and ensure effective and long-term monitoring of compliance with biodiversity commitments	Governance	Research, Deployment	Research, Deployment	Research, Deployment	Research, Deployment	Research, Deployment	Deployment	Deployment
	Assessment of the feasibility of implementing target densities for transport networks that align with national or European ecological corridors	Operational	-	Research, Deployment	Research, Deployment	-	Research, Deployment		

* THEMATIC AREA : Operational Governance Socio-Economical

** MATURITY BY SPATIAL LEVEL OF IMPLEMENTATION : Research Innovation Deployment

*** TIMELINE : Research Innovation Deployment
Short term Medium Term Long Term

Actions	Description of actions	Thematic area*	Maturity by spatial level of implementation**				Timeline***		
			local	National	E.U.	Interna-tional	Short term	Medium term	Long term
1.3.4. Industrialisation	Support the implementation in the field of infrastructure demonstrators that fully integrate biodiversity according to clearly defined protocols and objectives and aiming widespread deployment	Operational, Governance	Research, Innovation, Deployment	Research, Innovation, Deployment	Research, Innovation, Deployment	-	Research, Innovation, Deployment	Research, Innovation, Deployment	Research, Deployment
	Support the development of companies or networks of companies pooling their resources to better integrate biodiversity-related issues	Socio-Economical	-	Deployment	Deployment	-	Deployment	Deployment	Deployment
	Development of industrial standards that fully integrate biodiversity while promoting development of Nature Based Solutions	Operational, Governance	Research, Innovation, Deployment	Research, Innovation, Deployment	-	-	Research, Innovation, Deployment	Research, Innovation, Deployment	
	Initiate research into standard and cost-effective construction processes for wildlife passages and other mitigation measures, utilising prefabricated or standardised durable and with low carbon footprint elements.	Operational	Research, Innovation, Deployment	Research, Innovation, Deployment	Research, Innovation, Deployment	-	Research, Innovation, Deployment		
	Support the creation of a European industrial sector for construction and exploitation tools or equipment integrating biodiversity issues	Operational, Governance	-	-	Innovation, Deployment	-	Innovation, Deployment	Innovation, Deployment	

*** THEMATIC AREA :** Operational   Governance   Socio-Economical

**** MATURITY BY SPATIAL LEVEL OF IMPLEMENTATION :** Research   Innovation   Deployment

***** TIMELINE :** Research   Innovation   Deployment
Short term   Medium Term   Long Term

2.2. SUSTAINABLE INFRASTRUCTURE LIFE CYCLE IMPLEMENTATION

2.2.1. PLANNING OF TRANSPORT INFRASTRUCTURE PROJECTS

→ RATIONALE

Infrastructure planning is a key issue for ensuring the real sustainability of mobility. Transport infrastructure (TI) projects affect biodiversity directly (e.g. vehicle collisions, habitat destruction, noise pollution), but also indirectly through the various land use changes that they modify in the areas crossed (urbanisation, agriculture, natural areas, etc.). The planning and designing of new infrastructures must be undertaken using a systemic approach at the landscape scale. Landscape and biodiversity must be considered in the very beginning of the TI projects. It must also be developed within a timeframe consistent with biodiversity issues. This **integrated planning** opens up the opportunities of peaceful synergies with local stakeholders for sustained, long-term actions.

As regards transport, the integration of environmental considerations is mainly based on strategic environmental assessments and environmental impact assessment for plans and projects. The consideration of biodiversity is limited or mixed with a heterogeneous set of other environmental factors. However, social and ecological values need to be considered together in the planning and design of transport infrastructure, alongside technical, economic and environmental concerns. The aim is to achieve a consensus among the actors involved, but this is currently limited and de facto limits the scope of impact assessments. It is, therefore essential to create a clear legal, financial and regulatory framework at the landscape level. It should facilitate the integration of green infrastructure, biodiversity and ecological connectivity into the environmental supervision of the entire life cycle of transport infrastructure projects. Improving the infrastructure planning process requires developing tools to better measure the effectiveness of mitigation and compensation measures undertaken.

Although Directive 2001/42/EC currently states that environmental assessments "should include secondary, cumulative, synergistic, permanent and temporary effects in the short, medium and long term, both positive and negative", to date, this standard has rarely been applied. A key issue will be the ability to take into account the cumulative effects of ALL the infrastructures present in a territory and not separately from each other in order to respond effectively to future challenges such as the increase in demand for mobility and new transport infrastructures or adaptation to climate change and resilience to invasive species. It is also essential to think about infrastructure not only at the time of its creation but throughout its operation in order to strengthen synergies with other policies.

In this context, the SRDA proposes the combination of four inputs. (1) enhancing the planning process requires designing a legal framework that aligns with the actions aimed at improving national or European planning strategies. (2) improving the tools and implementation of the planning process is crucial, focusing on enhancing the quality of impact studies and utilising reliable data to facilitate objective discussions. (3) addressing the cumulative or bundling effects is paramount, particularly in relation to the assessment of infrastructure's cumulative impact on a territory, which is currently underestimated and requires priority attention, especially with the ongoing expansion of renewable energy infrastructure networks. (4) achieving a spatial mesh and integrated planning entails creating a better-structured spatial network that aligns with a coherent planning policy, preserving areas that are still free from transport networks and optimising existing areas that are already heavily equipped enhancing a truly integrated approach to address these issues.

Actions	Description of actions	Thematic area*	Maturity by spatial level of implementation**				Timeline***		
			local	National	E.U.	Interna-tional	Short term	Medium term	Long term
2.1.1 Improved planning process - Legal framework	Ensure that the status of biodiversity and its protection objectives are properly taken into account during the infrastructure Life Cycle process	Governance	Deployment	Deployment	-	-	Deployment	Deployment	
	Amend infrastructure planning legislation to mandate the inclusion of measures to mitigate damage and to achieve a net gain of biodiversity in the technical feasibility studies, costs assessments, and revenue forecasts during the project planning phase	Operational, Governance	Deployment	Research, Innovation, Deployment	Research, Innovation, Deployment	Deployment	Research, Innovation, Deployment	Research, Deployment	Deployment
	Establish a clear legal framework on environmental evaluation of Transport Master Plans and monitoring their impacts on biodiversity	Operational, Governance	Deployment	Research, Innovation, Deployment	Research, Innovation, Deployment	Deployment	Research, Innovation, Deployment	Research, Innovation, Deployment	Deployment
	Ensure robust enforcement of existing laws to incorporate biodiversity and habitats conservation and restoration in environmental impact assessment studies (SEA or EIA), regardless of whether the transport infrastructure is connected or not with the Natura 2000 network or a wildlife corridor	Governance	Deployment	Deployment	Deployment	-	Deployment	Deployment	Deployment
	Create a clear legal, funding and regulatory framework with integrating green infrastructure, biodiversity and ecological connectivity in environmental monitoring and management of the whole life cycle of transport infrastructure projects and the effectiveness of the mitigation and compensation measures	Governance	Deployment	Deployment	Deployment	-	Deployment		
2.1.2 Improved planning process tools and implementation	Mobilise data and objectivation of concertation on the assessment of the environmental impacts by developing participatory science and digitalisation tools	Operational	Innovation, Deployment	-	-	-	Innovation, Deployment		
	Develop and implement standardized evidence-based tools to follow the projects' results implementation and environmental monitoring and management (guidelines, Standards, national–regional data tools and bases)	Operational	Research, Innovation	Research, Innovation	Research, Innovation	-	Research, Innovation	Research	

*** THEMATIC AREA :** Operational Governance Socio-Economical

**** MATURITY BY SPATIAL LEVEL OF IMPLEMENTATION :** Research Innovation Deployment

***** TIMELINE :** Research Innovation Deployment

Short term Medium Term Long Term

Actions	Description of actions	Thematic area*	Maturity by spatial level of implementation**				Timeline***		
			local	National	E.U.	Interna-tional	Short term	Medium term	Long term
2.1.3 Cumulative or bundling effects	Definition of critical thresholds for cumulative infrastructure that include spatial and temporal impact and are adaptable to local context	Operational	Research	Research	Research	Research	Research	Research	
	Development or use of pre-defined methodologies and tools (guidelines, standards, indicators) to refine the cumulative impact analysis and measuring the impacts on biodiversity and landscape.	Operational	-	Research, Innovation, Deployment	Research, Innovation, Deployment	Deployment	Research, Innovation, Deployment	Research, Deployment	Deployment
	Develop pilot studies to get comprehensive ecological and economic assessments for bundling projects in comparison to alternatives	Operational	Deployment	Deployment	Deployment	Deployment	Deployment	Deployment	
	Conducting research on ecological function of buffer areas or the minimum required distance between bundled transport infrastructure and/or technical facilities accompanying transport infrastructure.	Operational	Research	-	-	-	Research	Research	
	Promote agencies, independent of multiple project developers, to assess the cumulative effects of infrastructure on the environment and have a holistic analysis	Governance	Deployment	-	-	-	Deployment	Deployment	Deployment
2.1.4 Spatial mesh and integrated planning	Analyse of the spatial Infrastructure mesh within the urban-rural balance and its contributions for urban green infrastructure.	Operational, Governance	Research	Research	Research	Research	Research		
	Evaluate the effects of developing multimodal platforms on reducing free land usage	Operational	Research	Research	-	-	Research		
	Understand the effects of transport network density and use intensity of infrastructures on wildlife population dynamic and ecological functions and ecosystem services at landscape scale	Operational	Research	Research	Research	-	Research		
	Ensure effective protection of large, unfragmented, roadless areas (or areas free from roads and other infrastructure) inside and outside protected areas	Operational, Governance	Research, Innovation, Deployment	Research, Innovation, Deployment	Research, Innovation, Deployment	-	Research, Innovation, Deployment	Innovation, Deployment	Deployment

* THEMATIC AREA : Operational Governance Socio-Economical

** MATURITY BY SPATIAL LEVEL OF IMPLEMENTATION : Research Innovation Deployment

*** TIMELINE : Research Innovation Deployment
Short term Medium Term Long Term

2.2.2 MITIGATION HIERARCHY

➔ RATIONALE

The mitigation hierarchy is a conceptual framework designed to manage impacts on biodiversity. Applied to any impact assessment, it is described as a 3-step iterative sequence: Avoidance-Reduction-Compensation (ARC mitigation sequence). If applied to direct, indirect and cumulative impacts, the mitigation hierarchy can greatly reduce impacts and is key to pursuing No Net Loss (NNL) or Net Gain of Biodiversity (NG) in projects, programmes, and plans. NNL or NG implies that no biodiversity has been lost or some biodiversity has been gained at the end of the project life cycle compared to a previously established baseline condition. This hierarchy is present in Strategic Environmental Assessment and Environmental Impact Assessment EU directives, and has been translated to the EU biodiversity strategy, although the way they are interpreted and implemented varies greatly between member states. In close link with the previous SRDA part, a wider landscape-level approach, including a strong cumulative impact assessment to identify impacts on the ecosystem and not only on protected species or areas, is required within the SEA and EIA processes. Interactions between mitigation measures must also be considered in strategic landscape planning to achieve the goals of NNL or NG.

It is also important for science to take into account avoidance, i.e. areas that absolutely deserve to be protected because of their high biodiversity value as well as roadless areas which are rare and diminish constantly. To ensure that decisions in this area are rational, the ecological arguments used to decide between on-site treatment (reduction) or remote treatment (translocation, compensation) must be made explicit by science (common rules). With regard to compensation, which from a strictly ecological point of view is particularly delicate to achieve, it is necessary to establish the ecological and economic balance of all the experiments conducted to date in Europe. This knowledge would shed light on the prospects for the development of the concept, a question that cannot be ignored in a European context of increased competition for the use of space.

Within this context, the SRDA presents proposals in two key domains. (1) emphasising the importance of effective implementation, the SRDA underscores the need for a comprehensive and impartial evaluation of the mitigation hierarchy, which is currently inadequately assessed and often a subject of disputes. (2) In order to achieve this, the SRDA advocates for capitalising on existing measures and evaluating them through scientifically objective criteria that are standardized at the European level. By doing so, a precise and tangible understanding of the impacts of transport infrastructures can be obtained.

Actions	Description of actions	Thematic area*	Maturity by spatial level of implementation**				Timeline***		
			local	National	E.U.	Interna-tional	Short term	Medium term	Long term
2.2.1 Implementation	Ensure that the mitigation hierarchy approach is applied and fully respected during strategic planning on selection of transport infrastructure alignments	Governance	Deployment	Research	-	-	Research, Deployment	Deployment	
2.2.2 Public-Private dialogue	Assessment and improvement of mitigation hierarchy measures of transport infrastructure effects on biodiversity and develop better solutions for biodiversity in this field	Operational	Research, Innovation	Research, Innovation	Deployment	-	Research, Innovation, Deployment	Research, Deployment	
	Define standardised international/ national guidelines for the appropriate mitigation hierarchy application and the cost-benefit analysis of transport masterplans which fully reflect environmental costs and benefits	Operational, Governance, Socio-Economical	-	Innovation, Deployment	Innovation, Deployment	Innovation, Deployment	Innovation, Deployment	Deployment	

*** THEMATIC AREA :** Operational Governance Socio-Economical

**** MATURITY BY SPATIAL LEVEL OF IMPLEMENTATION :** Research Innovation Deployment

***** TIMELINE :** Research Innovation Deployment
Short term Medium Term Long Term

2.2.3. CIVIL AND GREEN ENGINEERING COMMON CHALLENGES

→ RATIONALE

Civil and environmental engineering is a key cornerstone in ensuring that biodiversity cooperation is better integrated into the life cycle of infrastructure. This close collaboration is the oldest sign that transport has taken account of the specific characteristics of biodiversity, with the first wildlife crossings created in the late 1950s. But today's challenges and the scale of future investment mean that we need to move on from working on a project-by-project basis to a structured, holistic approach, as developed in the section 2.1.3 Sustainable Finance Infrastructure Improvement.

This move to a larger scale must be accompanied by the development of European or even international standards, based on scientific evidence, accelerating the operational implementation of developments and easily adaptable to specific local characteristics. Taking greater account of the areas affected is a key issue, because the ecological connectivity disrupted by infrastructure often goes beyond the traditional scope of impact studies and takes little account of the cumulative effects of other infrastructure and the very low reversibility of the environmental impacts. It is also necessary to assess the relationship between infrastructure rights-of-way and adjacent agricultural or urban areas, because in some conditions of highly artificialised land, this areas may be the only ecological corridors that can still be used.

In order to address these objectives, five major approaches have been identified in the following table, each closely interlinked. (1) The analysis of new mobility modes' impacts on biodiversity is crucial, considering the intersection of ecological and civil engineering and exploring how emerging technologies can better account for these multidimensional concerns. Additionally, the examination of the broader implications of new mobility forms on engineering developments, including the potential impact on vehicles themselves due to rare earth supplies, is necessary to mitigate the loss of biodiversity in Europe and beyond its borders. (2) Wildlife passages serve as important connections between wildlife and ecosystems at both sides of linear infrastructure and deserve increasing attention in the context of climate change requiring many species the possibility to adapt its distribution areas. (3) Ensuring ecological permeability of existing transport infrastructures is crucial, requiring defragmentation plans including effective measures. (4) Understanding and controlling disturbances caused by transport infrastructure on biodiversity is essential due to notable impacts that light, noise and other sources of pollution cause in species and ecosystems. (5) The management of habitats related to infrastructure under operation, particularly in the green and blue areas located in the infrastructure rights of way holds significant potential for biodiversity.

Actions	Description of actions	Thematic area*	Maturity by spatial level of implementation**				Timeline***		
			local	National	E.U.	Interna-tional	Short term	Medium term	Long term
2.3.1 New mobility modes impact on biodiversity	Improve the evaluation of effects of transport infrastructure operation (traffic speed and intensity and other) on wildlife	Operational	Research	-	-	-	Research		
	Expand the application of automated techniques to identify and mitigate hazards to wildlife and traffic safety of automated or electrical vehicles	Operational	Research, Innovation	-	-	-	Research, Innovation		
	Study the effects of the whole life cycle related to e-mobility on ecosystems – analysis of imported biodiversity loss	Operational	Research	-	-	-	Research		
	Analysis of the evolution and reconversion of infrastructure networks linked to new mobilities and their impact on biodiversity	Operational	Research	Research	Research	-	Research		
2.3.2 Wildlife passages	Promote the application of compulsory evidence-based standards for wildlife passages dimensions and density to ensure an effective permeabilisation of infrastructure	Operational	Research, Innovation, Deployment	-	-	-	Research, Innovation, Deployment		
	Establishment of harmonised conventions for rating fauna passages effects on the population levels	Operational, Governance	-	-	Research, Innovation, Deployment	Research, Innovation, Deployment	Research, Innovation, Deployment	Deployment	
	Development of innovative designs for wildlife passages, fencing and other mitigation measures combining goals of increase infrastructure resilience, reduce biodiversity loss and restore ecological connectivity	Operational	-	Research, Innovation, Deployment	Research, Innovation, Deployment	-	Research, Innovation, Deployment	Research, Deployment	Deployment
	Assessment of eco-regional differences of wildlife passages use to guarantee optimal deployment and adaptation to local conditions	Operational	-	Research	Research	-	Research		

*** THEMATIC AREA :** Operational Governance Socio-Economical

**** MATURITY BY SPATIAL LEVEL OF IMPLEMENTATION :** Research Innovation Deployment

***** TIMELINE :** Research Innovation Deployment
Short term Medium Term Long Term

Actions	Description of actions	Thematic area*	Maturity by spatial level of implementation** – local	National	E.U.	Interna-tional	Timeline*** (Short term / Medium term / Long term)
2.3.3 Achieving ecological permeability of TIs	Identify and understand the consequences of barrier effects caused by infrastructure on wildlife populations and develop solutions to restore ecological permeability and facilitate climate change adaptation	Operational	Research, Innovation	Research, Innovation	-	-	Research: Medium term; Innovation: Medium term
	Plan and apply adaptive management to Habitats related to Transport Infrastructure (HTI) to fulfil their potential as positive biodiversity refuges and ecological corridors but avoiding functioning as traps for wildlife and dispersal corridors for alien species	Operational, Governance	Research, Innovation	Research, Innovation	-	-	Research: Long term; Innovation: Medium term
	Understand and improve the ecological potential of transport infrastructures and their associated source material production sites to make them contribute to restore blue and green infrastructure and enhance their ecological functioning	Operational	Research, Innovation, Deployment	-	-	-	Research: Long term; Innovation: Long term

Actions	Description of actions	Thematic area*	Maturity by spatial level of implementation** – local	National	E.U.	Interna-tional	Timeline*** (Short term / Medium term / Long term)
2.3.4 Disturbances and pollutions from TI on biodiversity	Pollution evaluation (light, noise, chemical, electromagnetism) and assessment of their impact on ecosystem health	Operational	Research, Innovation	Deployment	-	-	Research: Medium term; Innovation: Medium term; Deployment: Long term
	Assessment of implementation of the "responsible polluter pays" principle in the infrastructure framework taking into consideration the impacts on biodiversity and ecological connectivity	Operational, Governance, Socio-Economical	-	Deployment	-	-	Deployment: Medium term
	Develop alternative solutions to minimise light, sound, chemical, pesticides, mechanical, etc. disturbances	Operational	Research, Innovation	Deployment	-	-	Research: Short term; Innovation: Medium term; Deployment: Medium term

*** THEMATIC AREA :** Operational Governance Socio-Economical

**** MATURITY BY SPATIAL LEVEL OF IMPLEMENTATION :** Research Innovation Deployment

***** TIMELINE :** Research Innovation Deployment
Short term Medium Term Long Term

Actions	Description of actions	Thematic area*	Maturity by spatial level of implementation**				Timeline***		
			local	National	E.U.	Interna-tional	Short term	Medium term	Long term
2.3.5 Management of habitats related to existing infrastructure	Development of innovative methods to avoid and reduce wildlife mortality caused by different types of infrastructure (airports, waterways, power lines...) and their use	Operational	Research	-	-	-	Research		
	Evaluate the effects of different verge design and soil management for connectivity and people well-being in different eco-regions	Operational	Research	-	-	-	Research	Research	Research
	Assess effects of rewilding on traffic safety and develop solutions to enhance infrastructure permeability and reduce hazards	Operational	Research	Research	-	-	Research, Innovation	Research, Innovation	Research, Innovation
	Evaluation of non-concrete grounds within infrastructures by conducting research on the resistance of dense herb and grass strips on small animal movement and thresholds for verge vegetation or green strip vegetation densities	Operational	Research	Research	-	-	Research		
	Design and apply nature-based solutions (NBS) and innovative practices in HTI management allowing to benefit biodiversity and increase infrastructure resilience	Operational	Research, Innovation, Deployment	-	-	-	Research, Innovation, Deployment	Research, Innovation, Deployment	Innovation, Deployment
	Analysis of the impact of green verges and vegetation structure on the effectivity of right-of-ways as supra local corridors for migration and dispersal distances	Operational	Research	-	-	-	Research	Research	Research
	Development of tools and indicators to assess the ecological and economic potential of enhancing biodiversity and nature-based solutions in the infrastructure rights-of-way	Operational	Research	Research	Research	-	Research	Research	
	Assessing the time factor in the process of ecological management of infrastructure rights-of-way	Operational	Research	Research	-	-	Research		
	Support of adaptive maintenance plans that contribute to manage and monitor the specific impacts of transport infrastructure on biodiversity	Operational	Research, Deployment	Research, Deployment	-	-	Research, Deployment	Research, Deployment	Deployment
	Promote innovative design of drainage systems to benefit biodiversity and reduce risks associated to extreme weather events	Operational	Innovation, Deployment	Innovation, Deployment	-	-	Innovation, Deployment	Innovation, Deployment	

*** THEMATIC AREA :** Operational, Governance, Socio-Economical

**** MATURITY BY SPATIAL LEVEL OF IMPLEMENTATION :** Research, Innovation, Deployment

***** TIMELINE :** Research, Innovation, Deployment; Short term, Medium Term, Long Term

2.2.4. PREVENTION AND CONTROL OF INVASIVE ALIEN SPECIES

➔ RATIONALE

Transport and infrastructure facilitate the spread of species around the globe that can be harmful to ecosystems, cause damage to infrastructure or impose a risk to human health. Transported by traffic, these species reach places that they could not have reached on their own. Increasing human mobility and growing trade worldwide, now aided by a changing climate, will accelerate the introduction of invasive species and other species of concern and thus require intensified counteraction by the transport sector.

Although for some of the most invasive species, regulatory frameworks are already in place and efforts are made to control their spread, the legal situation regarding control liability is inconsistent among the EU Member States. Furthermore, due to differences in e.g., climatic conditions, land use and biodiversity management, national lists of invasive species vary between countries. However, the number of species of concern listed as invasive or not, is growing in most countries. It is indispensable to further develop the knowledge base about these species so that colonisation of new areas can be prevented, and already invaded areas can be better controlled. As the transport sector is an important pathway for the introduction and spread of species that are invasive or of other concern, the risks must be considered in the management of transport infrastructure and balanced by the benefits of enhancing infrastructure habitats to support native fauna and flora. This requires more holistic and internationally aligned management plans for all biodiversity.

Within this context, the SRDA presents proposals in three key areas. (1) Focusing on strategies and policies, highlights the importance of aligning and coordinating control strategies, particularly from a regulatory standpoint. (2) To effectively achieve this objective, sufficient resources for comprehensive evaluation are necessary to enable impactful actions. (3) Emphasising the significance of tools and procedures, the SRDA advocates for the utilisation of nature-based solutions and the development of action standards based on relevant data, which should be incorporated into a dynamic process.

Actions	Description of actions	Thematic area*	Maturity by spatial level of implementation** local	National	E.U.	Interna-tional	Timeline*** Short term	Medium term	Long term
2.4.1 Strategies and policies	Deployment of shared Invasive Alien Species and biodiversity-friendly control and management strategies in a territorialised and multi-infrastructure approach	Governance	-	Deployment	Deployment	Deployment	Deployment	Deployment	
	Harmonisation and coordination of policy and legal frameworks among countries, while considering biogeographic differences among countries and ecosystems	Operational, Governance	-	-	-	Deployment	Deployment	Deployment	
2.4.2 Evaluation	Evaluate transport-specific problems impacts exceeding the EU-legislation for challenges in controlling Invasive Alien Species (safety, health, dissemination, regulation of herbicides, human resources management...)	Operational, Governance	Research, Deployment	Research, Deployment	Research, Deployment	-	Research, Deployment	Research, Deployment	
	Identify and understand all the phenomena bound to spread of Invasive Alien Species in infrastructure, their foreseeable effects and develop mitigation solutions, as well as, if possible, nature-based solutions against dispersal of invasive species	Operational	Research, Deployment	Research, Deployment	Research, Deployment	Research, Deployment	Research, Deployment	Research, Deployment	Deployment
2.4.3 Tools and procedures	Development of standardised procedures for prevention or action against Invasive Alien Species along transport infrastructure to mainstream biodiversity and capitalize in terms of knowledge and skills among actors and residents of the territory	Operational, Governance	Research, Innovation	Research, Innovation, Deployment	Research, Innovation, Deployment	-	Research, Innovation, Deployment	Research, Innovation, Deployment	
	Develop and standardise at European/international scale monitoring system as early warning systems in order to engage a fast onset of control programs by utilising multiple approaches (e.g., citizen sciences)	Operational, Governance	-	-	Research, Innovation, Deployment	Research, Innovation, Deployment	Research, Innovation, Deployment	Research, Innovation, Deployment	
	Evaluation of nature-based solutions and traditional chemical potential solutions to control Invasive Alien Species	Operational	Research	Research	-	-	Research	Research	

*** THEMATIC AREA :** Operational Governance Socio-Economical

**** MATURITY BY SPATIAL LEVEL OF IMPLEMENTATION :** Research Innovation Deployment

***** TIMELINE :** Research Innovation Deployment
Short term Medium Term Long Term

2.2.5. DIGITALISATION

RATIONALE

Transport infrastructure and biodiversity are two complex interacting systems in which building the resilience of each can be antagonistic or synergetic. Therefore, relevant decision-making can hardly be performed if a strong imbalance in their relative and interacting resilience evaluation ability does exist. There is an urgent need to integrate biodiversity themes into the digital environment of transport infrastructure to ensure this balance and, subsequently, improve transport infrastructure's sustainability.

In this context, the generalisation of BIM-like approaches associated with the development of tools able to manage at the same time GIS, BIM and DT models in the biodiversity management sector would strongly contribute to mainstreaming biodiversity in transport infrastructure. However, such a convergence would require the development of a common working culture.

Future research, innovation and deployment offer very interesting opportunities for both sectors, namely biodiversity conservation and transport infrastructure management. This research would also pave the way for future RDI and expected co-benefits in other major sectors, such as the development of smart, sustainable cities, urban facility management, computer science, etc. To ensure an efficient transition and proportional deployment of digital technologies to mainstream biodiversity in transport infrastructure, joint low and high-tech approaches should be developed in a close relation. In addition to mainstream biodiversity in transport would be considered a part of the project's externalities.

To ensure the success of digitalisation efforts within the SRDA framework, four types of actions need to be undertaken. (1) There should be a focus on data production and improvement, with an emphasis on collecting high-quality data while considering associated risks. This serves as the foundational element for this entire domain of work. (2) The issue of data heterogeneity in biodiversity must be addressed to facilitate their effective use in performance indicators. Standardisation efforts are crucial in this regard. (3) The availability of reliable data becomes a valuable resource for enhancing environmental impact assessments, allowing for dynamic and iterative approaches. (4) Strengthening the digital component in various tools, such as those utilised in pan-European TEN-T planning, can contribute to making the complex and conflicting issues more tangible and comprehensible.

*** THEMATIC AREA :** Operational Governance Socio-Economical

**** MATURITY BY SPATIAL LEVEL OF IMPLEMENTATION :** Research Innovation Deployment

***** TIMELINE :** Research Innovation Deployment

Short term Medium Term Long Term

Actions	Description of actions	Thematic area*	Maturity by spatial level of implementation**				Timeline***		
			local	National	E.U.	Interna-tional	Short term	Medium term	Long term
2.5.1 Data production and improvement	Create and maintain reliable databases that provide up-to-date information on biodiversity and ecosystem services, including ecological connectivity and wildlife mortality. Develop and mobilise long-term observatories	yellow, grey	-	green, orange	green, orange	green, orange	green, orange	green, orange	
	Acquisition of new technologies such as Internet of Things (IoT) and remote sensing for infrastructure and biodiversity monitoring, while managing risks associated with data privacy (RGPD) or illegal trade of protected species for instance	yellow	-	green	green	green	green	green	
2.5.2 Standards	Development of effective standardized Key performance indicators (KPI) for assessment procedures regarding fragmentation and defragmentation effects at different scales	yellow	green	green	green	green	green		
2.5.3 Impact assessment improvement	Development of digital standardized methods for the integration of supra-regional migration corridors of larger mammals into impact assessment	yellow	green	green, blue	green, blue	green, blue	green, blue	green, blue	
2.5.4 Tools	Development and regular update of a standardized European defragmentation map joining TEN-T corridors and a Pan European natural Habitat network currently being developed within TEN-N	yellow, grey	-	orange, blue	orange, blue	-	orange, blue	orange, blue	blue
	Establishment of a detailed mapping of Green and Grey Infrastructure conflict points at national and regional level, including current and future infrastructure for transport and energy	yellow, grey	-	green, blue	green, blue	-	green, blue	blue	blue
	Use of new data technologies for infrastructure development and maintenance (digital twins, Big data, IA)	yellow, grey	blue	blue	blue	-	blue	blue	blue
	Creation of scientifically robust and shared BIM models, that will include a Common Data Environment (CDE) fed by environmental data to properly integrate biodiversity management into the complete life-cycle of transport infrastructures to ensure their sustainability	yellow, grey	green, orange, blue	green, orange, blue	green, orange, blue	-	green, orange, blue	green, orange, blue	green, orange, blue
	Based on the evaluation of long-term monitoring data of green infrastructure, to establish standardized follow-up processes to support the improvement of Transport Master Plans and the functionality of ecological corridors	yellow, grey	-	green, orange, blue	-	-	green, orange, blue	green, orange, blue	blue

2.2.6. JOINT CHALLENGES BETWEEN CLIMATE CHANGE AND BIODIVERSITY DECLINE FOR BETTER RESILIENCE

→ RATIONALE

The development of a combined vision integrating both climate change and biodiversity in the analysis of the environmental impacts of transport is only very recent and still very limited. Both are recognised as being among the main threats to our near future, but it is paradoxical to note that, despite efforts, the links between the two aspects are ultimately very limited and their treatment by science remains confined. Complex connections are being made, but there are significant gaps. There is, however, a major common entry marked by the need to avoid a Manichean view of possible solutions. It is indeed common that biodiversity or climate solutions proposed by one side may be harmful to the other and lead to systemic consequences that are difficult to assess.

The 2019 joint IPCC/IPBES workshop had a clear objective: "Limiting global warming to ensure a habitable climate and protecting biodiversity are mutually supporting goals, and their achievement is essential for sustainably and equitably providing benefits to people". It laid the groundwork for dialogue for the first time but remained confidential and was not included in any European or national calls for projects. Or, when it was, few researchers were able to respond to the proposed questions. However, this subject must be strongly reinforced in the very short term in the joint field of transport and energy, which must not be treated separately.

Limiting greenhouses gases (GHG) emissions in the transportation sector will not only help to contain the rising temperature but also reduce pollution, which is one of the main drivers of biodiversity loss and ecosystem degradation. At the same time, these ecosystems can then assist in the mitigation of climate change as "sinks" that accumulate and store carbon. Meanwhile, adaptation of transport infrastructure to climate change involves a two-pronged approach: nature-based solutions and engineered and technological solutions. Even though global warming causes this inevitable transportation turmoil, it also gives new opportunities for biodiversity to be better included in every transport project.

Actually, both ecological connectivity and climate change adaptation with short but strong storms need larger culverts and bridges. Still, these adaptations can be pricey, and countries' leaders need to prioritise the primary areas of concern in their territory. Thereby, decision support-tools shall be created and shared with decision-makers to give them an overview of the vulnerabilities, risks and exposure to climate change hazards.

Within the framework of the SRDA, we propose the development of three inputs. (1) The mobilisation of both technical and nature-based solutions is crucial to enhance resilience. (2) In the context of strengthening the circular economy and bio-sourced energies, it is essential to assess the impact of mobility evolution on biodiversity. (3) This analysis should be conducted within a comprehensive One Health approach, which, despite being relatively underrepresented in the transport sector, has become imperative in light of the significant COVID crisis. Indeed, the integrated "One Health" approach recognises human, animal, and environmental health interconnection. The animal-human-environment interface poses risks that require a collaborative, multisectoral, and transdisciplinary approach similar to BISON.

Actions	Description of actions	Thematic area*	Maturity by spatial level of implementation**				Timeline***		
			local	National	E.U.	Interna-tional	Short term	Medium term	Long term
2.6.1 Nature Based Solutions	Analysis of the potential of NbS to enhance invasive species control and adaptation to extreme weather events along transport infrastructures	Operational	Research	Research, Innovation	Research, Innovation	-	Research, Innovation	Innovation	
2.6.1 Nature Based Solutions	Assessment of the coherence between NbS deployment along infrastructure and conservation strategies such as the Natura 2000 network development or the rewilding initiatives	Operational, Governance	-	-	Deployment	Deployment	Deployment	Deployment	
2.6.2 Circular economy et bio-resources	Evaluate the joint potential of infrastructure rights-of-ways as a carbon sink and green corridor	Operational, Governance	Innovation, Deployment	Research, Innovation	Research, Innovation	-	Research, Innovation, Deployment	Research, Innovation, Deployment	Deployment
2.6.2 Circular economy et bio-resources	Analysis of the impact of biofuels and alternative fuels on biodiversity	Operational	Research	-	Research	-	Research	Research	
2.6.3 One Health	Use a One Health approach to assess the biodiversity risks associated with infrastructure development, particularly in terms of public health and resilience to the effects of climate change	Operational, Governance	-	Research, Innovation	Research, Innovation	-	Research, Innovation	Research, Innovation	Research, Innovation

*** THEMATIC AREA :** Operational Governance Socio-Economical

**** MATURITY BY SPATIAL LEVEL OF IMPLEMENTATION :** Research Innovation Deployment

***** TIMELINE :** Research Innovation Deployment
Short term Medium Term Long Term

3. OPERATIONNAL TOOLS

3.1. BIODIVERSITY AND INFRASTRUCTURE: A HANDBOOK FOR ACTION

→ CONCEPT AND OBJECTIVES

Sustainable transport and energy infrastructures are essential to economic and social progress. In addition to improving their resilience and safety, considering the environment in managing existing infrastructures and developing new networks must go beyond decarbonisation and digitalisation and seek to restore nature, safeguard biodiversity and produce positive results for human societies. To achieve this, adopting innovative solutions on a large scale is necessary while developing best practices that benefit nature.

Such an objective requires sharing technical and scientific knowledge and close collaboration between practitioners and researchers in the transport and ecology sectors. The fragmentation of actors and knowledge means that resources need to be pooled to master the best practices currently available while keeping costs and timescales under control.

By integrating biodiversity considerations into all phases of the infrastructure lifecycle and drawing on the latest research, it is possible to identify synergies that conserve nature and benefit society. For example, incorporating wildlife-friendly designs the risk of collisions between wildlife and vehicles can be reduced the damage caused to wildlife and people. In addition, adapting to climate change through ecological approaches contributes to both resilience and ecological restoration.

Biodiversity and infrastructure: A handbook for action is essential for achieving these objectives and improving knowledge transfer and capacity building, enabling the transport and ecology sectors to work together to achieve sustainable infrastructure development. As a result of a global collaboration between public and private practitioners and scientists, the handbook is intended to be used in all the steps of the life cycle infrastructure from planning to maintenance. It gives access to concise, up-to-date and evidence-based information, providing clear technical instructions for planning, designing and maintaining effective biodiversity mitigation measures in infrastructure development.

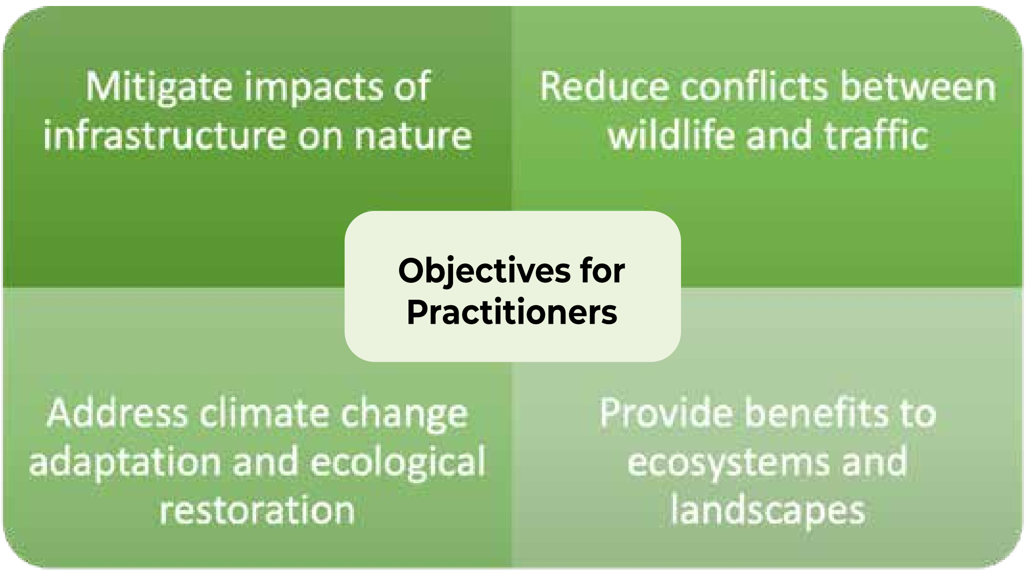
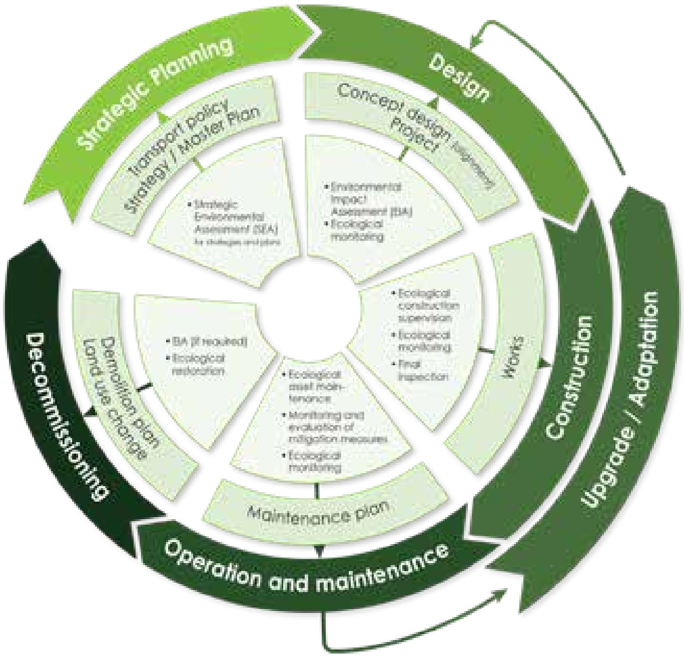


FIGURE 7:
Objectives of the Handbook

→ ORGANISATION AND POSSIBLE USES

Cooperation between transport and biodiversity professionals is essential to achieve effective large-scale change. This requires an interdisciplinary platform where engineers, planners and ecologists can collaborate, share resources, provide workable evidence-based solutions and draw on a common glossary of terms.



The new online handbook "Biodiversity and Infrastructure. A handbook for action" provides this common space, building on the best practice developed in recent years since the first publication in 2003 of "Wildlife and Traffic. A European Handbook for identifying conflicts and designing solutions". The new handbook includes up-to-date information, recommendations and standards to be applied throughout the life cycle of transport and energy infrastructure development and operation.

A simplified search entry allows to navigate through the entire lifecycle, quickly refining searches according to purpose, taxon, infrastructure or lifecycle phase, with criteria that can be mixed and keywords searched.

The website also includes a **"Guidelines Portal"**, which provides easy access to guidelines published in different countries and languages.

A reference **"Glossary"** is also included. Specifically developed in cooperation with IENE, PIARC, CEDR and other organisations, it is essential for mutual understanding between experts in the fields of ecology and infrastructure. It provides a basis for cooperation between the two disciplines, helping to identify current and emerging conflicts, understand their driving forces and causes, and accelerate the application of appropriate, evidence-based solutions to reduce biodiversity loss and increase infrastructure resilience and safety.

The online manual can also be used for teaching and training in engineering or ecology schools, as well as for training staff and field personnel working in the field of infrastructure management. At the same time, succinct overviews of different topics provide accessible, cutting-edge information for decision-makers and the public.

It is a living document, based on the latest knowledge, and will be regularly updated in the future with the cooperation of the Infrastructure and Ecology Network Europe (IENE).

http://www.biodiversityinfrastructure.org

3.2. EUROPEAN DEFRAGMENTATION MAP (EDM)

➔ CONCEPT AND OBJECTIVES

The European Defragmentation Map (EDM) is a decision-support planning tool covering almost the entire continent, focusing on the TEN-T networks. Flexible and easy to use, this dynamic online map makes it possible for the first time to coherently combine the management of existing infrastructures and biodiversity issues, including ecological connectivity. The EDM aims to facilitate exchanges between the transport and biodiversity sectors by identifying the interactions between the various planning processes. This tool, which is the first of its kind and will be updated in the future, is a major step that has identified several theoretical, technical and regulatory needs for further study to improve the coordination of objectives and resources mobilised to promote ecological reconnection.

The EDM is mainly a compilation of the current situation:

- Networks of ecological habitats on European land,
- Natura 2000 Habitats Directive sites designated by EU Member States,
- The selection of strictly protected areas against a backdrop of nationally designated areas
- The overlapping sections of the three ecological zones mentioned with the TEN-T relate to barriers.

Ready to use for existing infrastructures, the EDM provides an initial preliminary indication of the defragmentation measures that should be considered from regional to European level, considering the applicable planning rules and principles to be implemented at the different scales.

The European defragmentation map is a prototype that meets the basic requirements for operational use. It is strongly recommended to use the numerous development possibilities offered by the ArcGIS online platform with its applications (dashboard, experience builder, history maps) to optimise performance and presentation quality. In addition, the future management, maintenance and updating of data beyond the BISON project must be regulated and organised.

➔ ORGANISATION AND USES

The EDM web application is an interactive map created with ArcGIS Online. This map allows users to interact with the data, zoom in and out and search the map. Using intuitive analysis tools, selected information can be accessed, displayed, and partially downloaded (depending on individual data rights). Using the map requires no special GIS knowledge, skills, or GIS software. The EDM is displayed and used via a standard web browser.

Several grouped contents can be displayed by selecting the corresponding layers. Each layer has descriptive attributes, which can be displayed as a legend on the right-hand side of the map. A wide variety of base maps are available for creating individual backgrounds, e.g. Open Street map, Imagery, Topographic.

All the information presented in the EDM can be evaluated according to various aspects and criteria stored in the spatial data attributes. EDM users can create graphics, filter content, perform analyses, modify map style, and content, and configure pop-up windows and labels.

→ WARNING POINTS

The sections identified may be of European importance for defragmentation measures and should be taken into account in future TEN-T planning and implementation. Particular attention should be paid to areas of overlap

between ecological networks and the TEN-T affected by barriers, as they represent habitats of national importance (core areas) AND habitat connections (corridors). In addition, areas where Natura 2000 sites designated under the Habitats Directive and strictly protected areas overlap with the barrier-relevant TEN-T have been identified.

All the areas of overlap identified have been initially prioritised and are presented in detail in the spatial analyses of the EDM. If we look at the map in the figure opposite, we can see certain major rivers (e.g. the Rhine, Elbe, Meuse and Lek) appear as overlapping sections. These rivers are both central corridors in the ecological network and TEN-T waterways. Depending on their ecological status and level of use, watercourses are more or less well managed. The assessment of the barrier effect and the need for defragmentation depends on the ecological status and the level of use. These overlapping sections should be noted and checked separately.

In addition, the small scale chosen for the map (approximately 1:18,500,000) in this figure shows the overall superimposition, which makes the superimposed sections appear massive and contiguous, but this is only due to the scale of presentation.

The larger-scale map views, on the other hand, clearly show the actual dimensions of the overlays.

All areas of overlap between the ecological networks and the TEN-T relevant to the barrier were checked and assessed to see whether strictly protected areas were also affected. The close grouping of transport infrastructures was considered a priority in the three ecological reference zones. This results from an initial attempt at prioritisation, which will be finalised in consultation with experts and project partners.

A range of information is stored in the explanatory attributes (tables) for all the overlap areas identified. This includes, for example, information on the ecological network element/protected area concerned, the TEN-T infrastructure relevant to the dissection and the results of spatial analyses on the presence of an existing defragmentation measure in the section (checked within a radius of 500 m) or an airport, port or rail terminal (checked within a radius of 5,000 m). The presence or absence of defragmentation measures or transport infrastructure is

additional information that can be used to increase or decrease the priority of the defragmentation section.

The EDM will be accessible in a near future directly from :

www.bfn.de

WAYS FORWARD

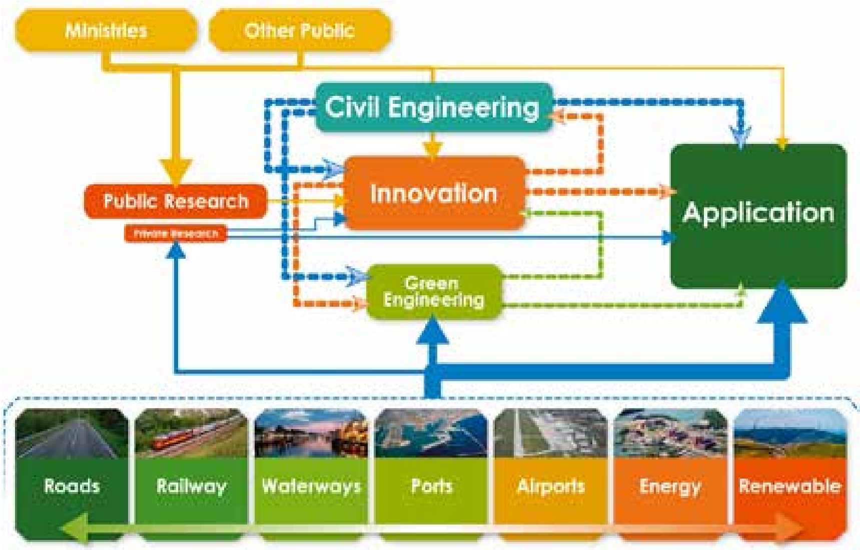
The BISON project, the first of its kind on this subject, has opened up and stabilised a number of areas. Far more than initially imagined. This result is all the more remarkable given that no fewer than 45 partners, including 16 transport ministries, contributed to the project, many of them during the Covid period. All of this on a subject with a very high potential for conflict and is very difficult to characterise in terms of research or innovation priorities.

The results produced have already demonstrated the extent of their potential. Global players' appropriation of the results is a major marker of the quality of the work carried out and the importance of the subject, with the United Nations Environment Programme taking the lead through the Sustainable Infrastructure Partnership. But it is also possible to mention PIARC, which contributes to its global research agenda, and the UIC, not forgetting ISO for TC 331 Biodiversity and the IUCN, as part of its working group on Large Landscape Conservation.

In less than two and a half years, this conceptually risky project, supported by Europe, has met with a very broad national, European and international response. The suddenness, diversity and scale of the players who have joined in and supported the action shows the extent to which BISON has acted as a catalyst for needs and gaps. The period 2021 - 2023 was marked by a major paradigm shift brought about by Covid, which showed that environmental issues could not be limited to climate, but that climate AND biodiversity were the obverses and reverse sides of the same global issue and that both had to be addressed in the same way to try and meet the challenges facing us.

But BISON is just one project, one stage, and it's reasonable to say that the hardest part is still to come: translating the results into action on a subject that transcends traditional boundaries and silos. This objective has been a constant thread running through all the partners. However, as has been emphasised on several occasions in the various deliverables and this SRDA, success will not come from a traditional approach. Analysis of the interactions between biodiversity and infrastructure goes beyond the simple limits of transport networks, and it is indeed all networks: transport, energy and renewable energies that must jointly address the issue in order to optimise synergies. In this respect, Cluster 5 (EC, Horizon Europe), which coordinates transport and energy in relation to global climate issues, is the crucible for a potential major change if it succeeds, in conjunction with the other clusters and partnerships involved, in fully addressing this issue in the same way as climate change.

BISON was the first step in a process that must continue, and for which it will be important to focus on four major inputs.



Research and innovation on transport and biodiversity - schematic organisation of the investment disequilibrium

1°) The development of a biodiversity-friendly approach for different types of transport infrastructure has been included in the actions of national, European and international authorities in various forms for several years. However, the principles of long-term monitoring and provision of sustainable services using state-of-the-art technologies within a single ressource center have not yet been developed, and efforts at each national level have remained isolated and independent of each other. Given the demand and needs of the transport and energy sectors, it is not yet clear how the carbon debt of infrastructure projects and the loss of carbon sinks will be calculated and covered, and the impacts on biodiversity and habitat should therefore be considered in a broader context with a joint climate/biodiversity approach closely linking transport networks, energy and renewable energies.

2°) The technical objectives to be further developed should fully integrate the synergies between the transport and energy sectors and ensure the development of an inclusive framework for assessing the impacts of infrastructure on biodiversity, enabling improvements in procurement through the generation of harmonised, transparent, and robust data.

3°) The economic aspects of the project, including the use of the SOURCE tool, the multilateral platform for the preparation of sustainable infrastructure projects, should enable the commitment of green bonds, with criteria and a rating to be established. Such an action would contribute to its support and dissemination as capacity building in developing countries, in relation with the EU Global Gateway. BISON and the SRDA were developed for the European context, but countries from other continents can find material adaptable to their reality. It would help to identify tools to help players in the sector to better integrate biodiversity into their strategic and operational plans.

4°) Finally, it is essential to take account of the societal perspective. Promoting a holistic approach to integrating the environment into infrastructure must produce comparable results to demonstrate the benefits and impacts of infrastructure projects on public health and well-being, as well as better integration into policy-making processes. But this will also require capacity building through the development of an initial and ongoing training programme.

All these actions should aim to support the emergence in a near future of a European centre of knowledge on infrastructures and biodiversity.

FIGURE 8:
Ways forward for the post BISON project

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APPENDICES

Detailed list of deliverables
https://bison-transport.eu/deliverables/

Deliverable 1.7, the Strategic and deployment Agenda:

The document aims to harmonize national and European legal frameworks, offering recommendations and practical tools to enhance sustainable infrastructure development and biodiversity conservation by fostering collaboration among stakeholders and adopting an integrated territorial approach.

Deliverable 2.1, Communication and dissemination strategy

Deliverable 2.2, Project website:

https://bison-transport.eu/

Deliverable 2.6, Policy briefs:

The policy briefs are developed by relevant participants to the project, based on the needs identified as part of the Exploitation plan, under the lead of WP2. They are build on content developed by WP3, WP4 and WP5.

Deliverable 2.7, Capacity-building platform:

The on-line platform for sharing knowledge and information with stakeholders and the wider public is embedded on the project's website.

Deliverable 3.1, Report on principles and criteria to select good practice:

The report is provide comprehensive recommendations of principles and criteria to identify good practice and recommended practice for each transport mode is included. Information compiled on the surveys and particularly

Deliverable 3.2, Report on identification of Gaps and Barriers to expand replicability and application of good practice to mainstream biodiversity and transport:

A report resuming the list of gaps to be fulfilled and barriers to be overcome for improving practice on mainstreaming biodiversity in transport sector is produced.

Deliverable 3.3, Online handbook 'Biodiversity and Infrastructure: A handbook for action':

Online platform providing guidelines and examples of good practice to be applied by practitioners in planning, design and operation of transport infrastructure. Technical drawings, infographics and other resources are included in the online handbook that is also be an interactive platform to enhance users' participation and future stakeholder cooperation. http://www.biodiversityinfrastructure.org/

Deliverable 3.4, Report on future trends and emerging topics.

The report describes both, challenges and future opportunities linked to emergent topics that are playing a major role in development of future transport such as climate change effects, future transportation, nature-based solutions and emerging synergies and cumulative effects as well as new social and economic implications.

Deliverable 3.5, Report on application of BIM and other tools to standardise data record and management.

The report identifies current and future needs to integrate and standardize data analyse and the potential to use digital automatic and semi-automatic data record and analyses coming from infrastructure and biodiversity facts. It also evaluate the potential to adapt BIM model approach to all life-cycle management for developing and operating infrastructure.

Deliverable 4.2, Strategic research action programme:

This document will provide a series of research initiatives that should be taken and achieved in the short (5 years), medium (10 years) and long (20 years) term, to support the development and implementation of innovative solutions for more-biodiversity-friendly transport infrastructure in Europe. Consideration for short to long-term societal and environmental challenges, along with the size of knowledge gaps today, will be the main factors of the agenda. D4.1 will have received a significant first level of endorsement from stakeholders. It will include a pan-European value section, but also possible regional-specific parts.

Deliverable 5.1, Status of national policy, legislation and implementation tools and recommendations for the integration of the EU SGI into transport infrastructure development:

The report is going to include the results of the gap analysis, the status and needs of the legislative framework in support of the integration of the EU SGI into national transport infrastructure development and will provide relevant recommendation for legislative harmonization.

Deliverable 5.2, Recommendations for policy/strategy harmonisation:

The report will explore the policy/strategy alignment and implementation maturity in reconciliation with the EU SGI for ensuring ecological connectivity in infrastructure development; and derive recommendations for addressing the different levels of maturity (M23). This report will feed into the SRDA.

Deliverable 5.3, Development and use of the European Defragmentation Map

along with planning methods and standards developed for efficient avoidance of fragmentation and for integrative mitigation and compensation.
www.bfn.de

Deliverable 5.4: Effective transport infrastructure life cycle tools, processes, and implementation barriers

for Green and Grey Infrastructure and recommendations for adaptations and deployment to other transport modes and/or regional clusters

Deliverable 5.5, Allocation of innovative solutions to future scenarios:

The report analyse the development of scenarios and the innovative solution allocation.

Deliverable 5.6, EU funding opportunities and proposals for cross-sectoral topics:

The report present the mapping of funding sources and proposals for future cross-thematic funding.

GLOSSARY 'BIODIVERSITY AND INFRASTRUCTURE'

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https://www.biodiversityinfrastructure.org/

Accompaniment measure
An intervention intended to be positive for biodiversity and ecosystem services, but not providing measurable gains that can be set against residual impacts. Accompaniment measures may or may not target the BES features significantly impacted by a project. Synonym: 'Addtional Conservation Actions'.

Adapted culverts
Modified pipe or box culvert that allows a watercourse and/or drainage to flow underneath transport infrastructure and includes adaptations to facilitate terrestrial wildlife crossing. These often include dry ledges or shelves to provide dry passage, which are connected to adjacent habitat. The design and landscaping at the entrances is particularly designed for the needs of wildlife, not only erosion control.

Adapted viaduct
Large structure, usually supported by pillars or arches, which carries transport infrastructure and enables the preservation of valuable ecosystems and ecological corridors below the structure. Preservation and restoration of continuous terrestrial, riparian and aquatic habitats below viaducts facilitate movement of multiple vertebrate and invertebrate species. Land uses and activities under the structure must be compatible with fauna movements and preservation of ecological connectivity. Viaducts must not be considered as wildlife passages when human disturbance or infrastructure with high traffic volume is beneath.. Synonym: 'Landscape underpass'.

Additional Conservation Actions
See 'Accompaniment measure'.

Additionality
A property of a biodiversity offset, where the conservation outcomes it delivers are demonstrably new and additional and would not have resulted without the offset. See also 'Offset'.

Agricultural (underpass or overpass)
Passageway across transport infrastructure to provide access to agricultural or forestry land, which may also be used by wildlife. See also 'Forestry road'; 'Cattle passage'

Alien species
Animals and plants introduced accidentally or deliberately into a natural environment where they are not normally found. Such species can become invasive in their new environment if they start spreading and causing serious damage to native species and ecosystems. See also 'Invasive Alien Species'.

Amphibian crossing
See 'Amphibian passage'

Amphibian fencing
A continuous structure erected alongside infrastructure, designed to prevent amphibians from crossing and directing them to a specific crossing point. See also 'Amphibian passage'.

Amphibian passage
Small structures built under transport infrastructure designed specifically to provide a safe crossing point for amphibians. Often consisting of multiple underpasses in close proximity to each other. Requires effective opaque fencing to intercept the amphibians and funnel them to the crossing structures. Synonym: 'Amphibian crossing'; 'Amphibian tunnel'."

Amphibian tunnel
See 'Amphibian passage'.

Animal Detection System (ADS)
Mitigation measure to alert drivers that a large animal is approaching the road and prevent animal vehicle collisions. The system involves signs that emit flashing warnings, activated by large animal detection sensors. When an animal is detected, signs are activated warning drivers that animals may be on or near the road at that time.

Animal Vehicle Collision (AVC)
When an animal is hit by a moving vehicle. If the animal is a wildlife species also called 'Wildlife Vehicle Collision' (WVC). Synonym: Roadkill.

Anthropogenic
Generated and maintained, or at least strongly influenced by human activities.

Arboreal crossing structure
See 'Tree top overpass'.

At Grade Passage
See 'Level crossing'.

Avoidance
Measures taken to anticipate and prevent adverse impacts on biodiversity before actions or decisions are taken that could lead to such impacts. See also: 'Mitigation Hierarchy'.

Avoidance measures
See 'Avoidance'., See also 'Mitigation'.

Balancing pond
Artificial water body fed by storm drains and surface runoff, where pollutants from the road can settle out or filter through reeds before being released into the wider drainage system.

Barrier
Any structure that restricts or prevents the movement of flora or fauna.

Barrier effect
The extent to which linear infrastructure features prevent, or filter animal movement. It is a combined effect of traffic mortality, physical barriers and avoidance, which together reduce the likelihood and success of species crossing infrastructure.

Before-After-Control-Impact (BACI)
Study concept design in which data is gathered before and after infrastructure or infrastructure mitigation measures are constructed. This data from areas with infrastructure or mitigation measures (impact) is compared with data obtained from areas without infrastructure or mitigation measures (control).

Berm
Horizontal ledge in an earth bank or cutting constructed to ensure the stability of a steep slope. See also 'Earth berm'.

Best practice (BP)
A superior or innovative method, process or technique that contributes to the improved performance of an asset, activity or organization and is usually recognised as 'best' by peer organizations. See also 'Good Practice'.

Biodiversity
The richness among living organisms including terrestrial, marine and freshwater ecosystems and the ecological complexes of which they are a part. It includes diversity within and between species and within and between ecosystems as well as the processes linking ecosystems and species. Synonym: 'Biological diversity'.

Biodiversity baseline
Specific species, habitats or ecosystems, and ecosystem services occurring at a project site, their current condition, and trends before a project commences.

Biodiversity targets
Measurable, actionable, and time-bound objectives, based on the best available science, that allow actors to align with Earth's limits and societal sustainability goals.

Biological diversity
See 'Biodiversity'.

Biota
All organisms in a community or area.

Biotope
Area which has a characteristic set of environmental conditions and is inhabited by a specific community of living organisms.

Bottleneck
Defined area (e.g. habitat corridor or patch) which, due to the presence of linear transport infrastructure or other land use, has become a limiting factor to animal migration or dispersal.

Brash
Cuttings of woody vegetation (often left in a pile, or randomly scattered across infrastructure verges).

Buffer zone
Vegetated strip of land intended to protect sensitive habitats, e.g. protected sites, from impacts such as pollution or disturbance from infrastructure.

Building Information Modelling (BIM)
A digital form of construction and asset operations. It brings together technology, process improvements and digital information to radically improve client and project outcomes and asset operations. BIM is a strategic enabler for improving decision-making for both buildings and public infrastructure assets across the whole life-cycle.

Business Processing Modelling
Consists in modelling the workflow which have to be managed during the project life-cycle. In particular, these models can describe actor interactions, data life-cycle and interoperability management.

By-pass
Highway route that passes around a congested town, village or other sensitive/vulnerable area.

Canopy bridge
See 'Tree-top overpass'.

Carriageway
One of the two sides of a motorway or other large road, used by traffic moving in the same direction.

Catchment area
Geographical area from which all precipitation flows to a single stream or set of streams (may also be termed as drainage basin, or watershed). In this handbook this may also refer to the area from which animals come to use a particular fauna passage.

Catenary
Overhead wires which support the contact wire on overhead electrification line equipment in a railway.

Cattle grid
Ditch transversal to the road covered by metal bars which allows cars to pass over but prevent cattle and also some other species of wildlife to cross it. Usually installed when roads create openings in fences to avoid animal access into the fenced area.

Cattle passage
See 'Drove road'.

Central reservation
See 'Median'.

Clippings
Cuttings from herbaceous vegetation.

Cluster (roadkill cluster)
Road stretches with aggregations of animal vehicle collisions or road kills, stretches with a greater number of occurrences than would be expected by chance. Synonym: 'Hotspot'. See also 'Animal vehicle collisions'.

Community (biotic)
Assemblage of interacting species living in a given location at a given time.

Compensation
In terms of biodiversity, compensation involves measures to recompense, make good or pay damages for loss of biodiversity caused by a project. It differs from offsets in that compensation can involve reparation that falls short of achieving no net loss. See also 'Offsets' and 'Accompaniment measures'.

Compensatory measure
Measure or action taken to compensate for a residual adverse ecological effect which cannot be satisfactorily mitigated. See also 'Mitigation'.

Connectivity
See 'Ecological connectivity'.

Conservation banking
A market where the credits from actions with beneficial biodiversity outcomes can be purchased to offset the debit from environmental damage. Credits can be produced in advance of, and without ex-ante links to, the debits they compensate for, and stored over time.

Construction
Third phase of the infrastructure life cycle. It is when the infrastructure is physically built in line with the requirement of the design document. It is the time when the effects of infrastructure development begin to show a real impact on nature. Strict adherence to all measures set to reduce environmental impacts is therefore a key consideration of this phase. See also 'Strategic Planning', 'Design', 'Operation and Maintenance', Decommissioning'.

Corridor
See 'Ecological corridor'.

Crossing
Designated or recognised place for people or fauna to cross from one side of a linear infrastructure to the other. The crossing site could be provided by an structure (overpass or underpass) or take place directly over the carriageway or railway. See also 'Wildlife Crossing' 'Wildlife Passage'

Crossroads
The intersection of two or more roads. Synonym: 'Junction'.

Culvert
Buried pipe, box or channel structure, that allows a watercourse and/or a transport infrastructure drainage feature to pass under infrastructure.

Cumulative effects
The increasing impacts resulting from the combination of effects from several projects or activities over a period of time. Their assessment is called cumulative effect assessment (CEA).

Curb
See 'Kerb'.

Currency
Unitary measures of biodiversity lost, gained or exchanged. This varies from very basic measures such as area, to sophisticated quantitative indices of multiple biodiversity components which may be variously weighted.

Cutting
V-shaped excavation of the land enabling transport infrastructure to be placed below the surrounding land surface.

Dark corridors
En ecological corridor that integrates mitigation of artificial light at night as an additional criterion to calculations of resistances to wildlife movement. See also 'Ecological corridor'.

Decommissioning
The final stage in the life cycle of transport infrastructure in which the infrastructure is no longer required -or has come to the end of its useful life-, and all its components can be removed and recycled, repurposed or disposed in appropriate sites, according to decommissioning plans. Few transport infrastructure projects reach this stage and most of them are maintained and upgraded. See also 'Strategic Planning', 'Design', 'Construction', Operation and Maintenance'.

Deer fence
See 'Fencing'.

Defragmentation
Actions aimed at recovering or increasing ecological connectivity in territories affected by existing transport infrastructure. It is also used to refer to actions to mitigate any of the effects that cause habitat fragmentation (road mortality, habitats disturbances, etc.).

Design
Second phase of the infrastructure life cycle which includes the 'Concept design' in which the route/site selection (alignment) is defined, followed by the definition of the project ('Detailed design') in which key features of the infrastructure are defined. Key deliverables include design and construction documents. During this phase, parameters determining the potential impact of the project development on the environment, including effects on biodiversity, and other sustainability considerations such a reduction of the carbon footprint must be assessed. See also 'Strategic Planning', 'Construction', 'Operation and Maintenance', Decommissioning'.

Digital Twin
A virtual representation that serves as the real-time digital counterpart of a physical object or process in the real world. DT can be developed for geographic areas (e.g. in urban spatial planning) or for build assets (e.g. in infrastructure development). See also 'Building Information Modelling'.

Dike
A wall built to prevent the sea or a river from flooding an area, or a channel dug to take water away from an area. Synonym: 'Dyke'

Direct effects
See 'Primary effects'.

Direct impacts
See 'Primary effects'.

Dispersal
Ecological process that involves the movement of an individual or multiple individuals away from the population in which they were born to another location, or population, where they will settle and reproduce.

Drainage
The system of drains, pipes and channels devised to remove excess water (surface or subsurface) from an infrastructure surface.

Drover road
Traditional path for the movement of livestock that form reticular networks across regions. In some countries (i.e., Spain, Italy) they are legally regulated and protected. Synonym: 'Stock route'; 'Drover track'.

Dual carriageway
Road with two lanes of traffic moving in opposite directions on either side of a central reservation (median).

Dyke
See 'Dike'.

Earth berm
A constructed mound of earth, usually along a road or railway, to provide a visual screen or absorb sound. See also 'Berm'.

Ecoduct
See 'Landscape overpass'.

Ecological asset
Items of the infrastructure that have an ecological value. It includes wildlife mitigation measures preventing impacts on wildlife and enhancing traffic safety such as fencing, wildlife passages, screens, adapted illumination and wildlife traffic signs. Drainage systems, road verges and other green areas associated with the infrastructure, managed in a way that supports wildlife conservation are also included.

Ecological connectivity
Parameter of landscape function that describes the processes by which sub-populations or organisms are interconnected into a functional demographic unit. More generally, the Convention on Migratory Species defines it as the unimpeded movement of species and the flow of natural processes that sustain life on Earth which means it can also encompass other processes such as flow of water or nutrients. Synonym: 'Connectivity'.

Ecological corridor
A geographically defined area which allows species to move between landscapes, ecosystems and habitats, natural or modified, and is intended to ensure the maintenance of biodiversity and ecological and evolutionary processes. Synonym: 'Corridor'.

Ecological equivalence
In the context of biodiversity offsets, the term is synonymous with the concept of 'like-for-like' and refers to areas with highly comparable biodiversity components. This similarity can be observed in terms of species diversity, functional diversity and composition, ecological integrity or condition, landscape context (e.g., connectivity, landscape position, adjacent land uses or condition, patch size, etc.), and ecosystem services (including people's use and cultural values).

Ecological network
A system of core habitats (protected areas, other conservation areas, and non managed intact natural areas), connected by ecological corridors, specifically designed, implemented and managed to ensure that ecological connectivity is maintained and enhanced where it is present, or restored where it has been lost. See 'Ecological Connectivity'.

Ecological Trap
Habitats that attract wildlife but pose hidden risks to the survival of animals. For example, attractive herbaceous vegetation near roads and railroads can increase road mortality risk for foraging animals.

Ecosystem
Dynamic complex of plant, animal and micro-organism communities and their non-living environment, interacting as a functional unit.

Ecosystem functioning
Involves the ecological and evolutionary processes, including gene flow, disturbance, pollination and nutrient cycling

Ecosystem services
Benefits provided to society by ecosystems. They are usually classified as provisioning (for example the production of food and water), regulation or maintenance (such as the control of climate, nutrient cycles…), and cultural, which includes the non-material characteristics of ecosystems that affect the physical and mental states of people.

Ecotone
Transitional zone between two habitats.

Ecotope
Distinct area with a recognisable set of characteristics relating to the soil, vegetation or water conditions. It represents the smallest land unit that makes up the landscape mosaic. See also 'Biotope'.

Edge
The portion of an ecosystem near its perimeter, where influences of the surroundings prevent the development of interior environmental conditions.

Effect
See 'Impact'.

Effect Zone
Strip of land both sides of an infrastructure where landscape conditions are modified by the effects of the infrastructure. The distance over which disturbances affect nature depends on topography, wind direction, vegetation, and the type of agent. The width of the affected zone is likely a magnitude larger than the physical width of the infrastructure itself. Synonym 'Road effect zone'.

Effective mesh density
Metrics for quantifying the effective number of meshes per square kilometre, that is the density of the meshes. The effective mesh density value rises when fragmentation increases. See also 'Effective mesh size'

Effective mesh size
Metrics for quantifying the degree of landscape fragmentation, based on the probability that two randomly located points (or animals) in an area are connected and are not separated by a barrier (e.g. roads, urban area). The smaller the effective mesh size, the more fragmented the landscape. See also 'Effective mesh density'.

Effective population size
The number of interbreeding adults in a population (smaller than the total population because it excludes juveniles, non-reproductive and post-reproductive individuals).

Embankment
Artificial bank (made of packed earth or gravel) such as a mound or dike, constructed above the natural ground surface in a linear form and designed to carry a roadway or railway across a lower lying area.

Emerald Network
A network of areas of special conservation interest (ASCIs), which is to be established in the territory of the contracting parties and observer States to the Bern Convention, including, among others, central and east European countries and the EU Member States. For EU Member States, Emerald network sites are those of the Natura 2000 network. See also 'Natura 2000 Network'.

Endemic species
A species only found in a particular region and thought to have originated there.

Environmental assessment
Procedure that ensures that the environmental implications of transport infrastructure development are taken into account before the decisions are made. Environmental assessment can be undertaken for public plans or programmes ('Strategic Environmental Assessment', SEA) or for individual projects, such as a motorway, an airport or a channel ('Environmental Impact Assessment' EIA).

Environmental Impact Assessment (EIA)
A process, applied mainly at project level, to improve decision making and to ensure that development options under consideration are environmental and socially sound and sustainable. EIA identifies, predicts and evaluates foreseeable impacts, both beneficial and adverse, of public and private development activities, alternatives and mitigating measures, and aims to eliminate or minimise negative impacts and optimise positive impacts. A subset of tools has emerged from EIA, including social impact assessment, cumulative effects assessment, environmental health impact assessment, risk assessment, biodiversity impact assessment and SEA. See also 'Strategic Environmental Assessment'.

Escape-device
Measure installed to prevent animals from becoming trapped by fences along infrastructure, e.g. badger gate, or built in the edge of a canal to enable animals to exit, e.g. escape-ramps. Synonym: 'Fauna exit'.

Evaluation
A process that critically assesses, test and measure the design, implementation and results of a plan or project, in relation to its objectives. It can be conducted both qualitatively and quantitatively, to determine the difference between actual and desired outcome. In transport ecology, the aim is to check whether a project and the mitigation measures applied have met their objectives in terms of reduction of and compensation for impacts.

FAIR data
Data which are Findable (metadata and data are expected to be easy to find by a human or machine); Accessible (once the data are found, the user easily know how to access them); Interoperable (metadata is sufficiently detailed to render the data set understandable in order to be integrated with others); Reusable (metadata is rich enough to allow for multiple reutilisation of the data set for various purposes).

Fauna
Animal species.

Fauna passage
See 'Wildlife passage'.

Fauna underpass
See 'Wildlife underpass'.

Fauna-exit
See 'Escape-device'.

Fencing
A structure made of wire or other materials supported with posts that is put along linear transport infrastructure to keep animals out and eventually guide them to crossing structures. It is also installed on areas of land as a boundary to keep animals in.

Filter effect
Referred to the effect caused by the infrastructure which inhibits the movement of certain species or individuals. The scale of the effect varies between species and may even vary between sexes or age categories.

Fish passage
Modified pipe or box culvert that allows a watercourse and/ or drainage to flow underneath transport infrastructure and includes adaptations to provide particular conditions that enable fish to swim through. When possible, adaptations for use by wildlife may also include dry ledges or shelves to provide passage for other terrestrial species, and which are connected to adjacent habitats.

Flora
Plant or bacterial life.

Forestry road
(Narrow) road built mainly for forestry purposes which may or may not have public access.

Fragmentation
The breaking up of a habitat, ecosystem or land use unit into smaller parcels.

Functional connectivity
A description or measure of how well genes, gametes, propagules or individuals move through land, freshwater and seascape. It is function of both the landscape structure and the behavioural response of organisms to this structure. Thus, functional connectivity is both specific to the species and the landscape where it occurs. See also 'Structural connectivity'

Game
Animals hunted for sport and food.

Game fencing
Fencing specifically for game species such as wild boar and deer. See also 'Fencing'.

Gene flow
The transfer of alleles or genes from one population to another.

Genetic diversity
The level of variability of genetic data within a sample or population, commonly measured through metrics such as heterozygosity and allelic richness.

Geographic Information System
A conceptualised framework that provides the ability to capture and analyse spatial and geographic data. GIS applications (or GIS app) are computer-based tools that allow the user to create interactive queries (user-created searches), store and edit spatial and non-spatial data, analyse spatial information output, and visually share the results of these operations by presenting them as maps.

Good practice
A methodology, process or technique that represents an effective way of achieving a specific objective, one that has been proven to work well and produce expected results, and is therefore recommended as a model or as a useful example. See also 'Best Practice'.

Gradient
The (rate of) change of a parameter between one area or region and another.

Green bridge
See 'Landscape overpass'.

Green Infrastructure (GI)
A strategically planned network of natural and semi-natural areas with other environmental features designed and managed to deliver a wide range of ecosystem services. It incorporates green spaces (or blue if aquatic ecosystems are concerned) and other physical features in terrestrial (including coastal) and marine areas. It is also defined as 'an interconnected network of protected land and water that supports native species, maintains natural ecological processes, sustains air and water resources and contributes to the health and quality of life for communities and people'.

Grey infrastructure
Engineered assets that aim to provide one or multiple services required by society, such as road, railways, urban areas, resource extraction, and other infrastructure.

Guard-rail
See 'Safety fence'.

Guide fencing
Fencing built to lead wild animals to a dedicated crossing point. See also 'Amphibian fencing'; 'Fencing'.

Gutter
Paved channel designed to carry runoff from the edge of infrastructure into the drainage system.

Habitat
The type of site (vegetation, soils, etc.) where an organism or population naturally occurs - including a mosaic of components required for the survival of a species.

Habitat attrition
Habitat destruction due to progressive damage, loss or decline in quality.

Habitat fragmentation
Dissection and reduction of the habitat area available to a given species - caused directly by habitat loss (e.g. land-take) and/or indirectly by habitat isolation (e.g. by barriers preventing movement between neighbouring habitat patches), habitat disturbance and other effects induced by infrastructure and other humanised land uses.

Habitat translocation
The relocation of a habitat from one place to another usually to avoid destruction of the habitat by infrastructure development.

Habitats related to Transport Infrastructure (HTI)
Green areas associated with transport infrastructure and usually managed by transport authorities and stakeholders. These areas include verges, resting sites, water retention ponds and other drainage elements, as well as fauna passages. These areas are inhabited by many animals, plants and other organisms which find refuge, food or other resources andcan potentially have either negative or positive effects on natural ecosystems and landscape surrounding the infrastructure.

Hard shoulder
See 'Shoulder'.

Hedgerow
A close row of woody species (bushes or trees) serving as a boundary feature between open areas (often used in combination with or as an alternative to a fence).

Herbicide
A chemical application which kills weeds.

Highway
Major road, usually with two or more lanes in each direction. See also 'Road'.

Hotspot (AVC hotspot/Roadkill hotspot)
See 'Cluster'.

Impact
The effect of an external factor on an organism, species or community which may result in wider consequences at the population level. Synonyms: 'Effect'.

Indicator
Measures of simple environmental variables used to denote some aspect of the state of the environment, e.g. the degree of habitat fragmentation.

Indicator species
Species indicative of (a) some current or historical environmental or historical influence (e.g. lichens can be atmospheric pollution indicators, and woodland ground-flora can be indicative of ancient woodland), or (b) a community or habitat type (e.g. some species can be used to classify invertebrate communities, or are indicative of particular habitats).

Indirect effects
See 'Secondary effects'.

Indirect impacts
See 'Secondary effects'.

Infrastructure
The basic systems and services that allow humans to fulfil the need for transport (e.g.,roads, railways, water channels, airports and ports), energy (e.g., coal, wind, gas, solar, hydropower, waves, power lines, oil and gas pipelines), water (e.g., canals, dams), and telecommunications (e.g., internet cables).

Infrastructure life cycle
The stages that an infrastructure asset passes through during its life cycle. These phases are: 1) Strategic Planning, including Transport Policy; Strategic Transport Plan and Project Plan (Transport Area or Corridor Delimitation); 2) Design, including Area or Route Selection, Concept Design; Procurement and Detailed design (also called Constructive Project); 3) Construction; 4) Operation and Maintenance including adaptation and mitigation measures and; 5) Decommissioning.

Invasive Alien Species (IAS)
Animals and plants that are introduced accidentally or deliberately into a natural environment where they are not normally found, with serious negative consequences for their new environment. These species are subject to common action at a European Union level under the European regulation and included on the 'List of invasive alien species of Union concern'. See also 'Alien Species'.

Junction
See 'Crossroads'.

Kerb
Edging (usually concrete) built along linear transport infrastructure to form part of the gutter. Synonym: 'Curb'.

Keystone species
A species that plays a pivotal role in an ecosystem and upon which a large part of the community depends for survival

Land cover
Combination of land use and vegetation cover.

Land unit
The smallest functional element of the landscape.

Land use planning
Activity aimed at predetermining the future spatial usage of land and water by society. Synonym: 'Spatial planning'.

Landform
Natural feature on the surface of the earth.

Landscape
The total spatial and visual entity of human living space integrating the geological, biological and human-made environment. It is an heterogeneous land area composed of a cluster of interacting ecosystems that create a specific, recognisable pattern. According to the European Landscape Convention, a landscape is perceived differently by local people or visitors, and evolves through time as a result of being acted upon by natural forces and humans.

Landscape diversity
The variation and richness of landscapes in a region.

Landscape element
Each of the relatively homogeneous units, or spatial elements, recognised at the scale of a landscape mosaic.

Landscape overpass
Large structure over transport infrastructure to provide continuity of habitats from both sides. Due to their width, a diversity of habitat types (e.g. vegetation or soil types, stone rows or piles, ponds, etc.) could be included. Combined with perimeter fencing that funnels the animals to the structure and with light/noise screens to reduce disturbance by traffic when required. The main difference to wildlife overpasses is their width and possibilities for vegetation cover and diversity of habitats being created which facilitate better ecosystem connection. Synonyms: 'Ecoduct'; 'Green bridge'. See also 'Wildlife overpass'.

Landscape underpass
See 'Adapted viaduct'.

Landscaping
To modify the original landscape by altering the topography and/or plant cover. This may include building earthworks to form new landscape structures.

Level crossing
A place designated for large mammals to cross a road at the same level than traffic combining fences to guide fauna to an open section equipped with Animal Detection Systems which detect the fauna and trigger driver warnings'. Synonym ' At grade passage'.

Like-for-like
Conservation (through the biodiversity offset) of the same type of biodiversity as that affected by the project. Sometimes referred to as 'in-kind'. 'Like-for-like' requires conservation of the same type of biodiversity as that affected by the project. This is sometimes modified to 'like-for-like or better', in which the offset conserves components of biodiversity that are a higher conservation priority than those affected by the development project for which the offset is envisaged. This is also known as 'trading up'.

Linear transport infrastructure
Road, railway or navigable inland waterway. Powerlines and pipelines are also included as they are designed for the transport of materials.

Major road
Road which is assigned permanent traffic priority over other roads.

Matrix
In landscape ecology, the background habitat or land use type in a mosaic, characterised by extensive cover and high connectivity. See also 'Mosaic'.

Median
The strip of land separating the lanes of a dual carriageway road or a motorway, which separates traffic flowing in opposite directions. Often vegetated with grass, shrubs and/or trees. Synonym: 'Central reservation'

Metapopulation
A set of local populations within an area, where typically migration from one local population to at least some others is necessary to sustain local population numbers. The metapopulation may have a higher persistence than the single local populations.

Metric
A set of measurements that quantifies results.

Microhabitat
Small-scale differences in habitat.

Migration
The regular, usually seasonal, movement of all or part of an animal population to and from a given area. Usually undertaken by some species in response to changing seasons or climatic events, such as rainfall.

Minimise
See 'Reduction'.

Mitigation
Action to reduce the severity of, or eliminate, an adverse impact.

Mitigation hierarchy
A framework for managing risks and potential impacts related to biodiversity and ecosystem services. It includes the following hierarchical but iterative actions to manage impacts: Avoid, Reduce or Minimise, Restore, and Compensate. These are often described as the four steps on the mitigation hierarchy which can also be summarised in 3 steps: Avoid, Reduce, and Compensate, when restoration actions are included as part of reduction or compensation measures.

Mobile Remote Sensing (MRS)
Any kind of sensor mounted on a mobile vector. Mobile vectors can therefore be satellites, vehicles, aeroplanes, UAVs, etc. In practice, MRS is generally deployed for specific reasons and with a specific purpose.

Mode (of transport)
Different ways of transporting people and goods (e.g. air, road, rail, maritime, inland waters, cycling, walking, etc.).

Monitoring
A process driven by the evaluation goals that combines repeated observations and measurements taken over time, usually to assess the temporal change in a parameter or in response to a disturbance/intervention or to quantify the performance of a plan/project, measure or action against a set of predetermined indicators, criteria or objectives. In the framework of transport ecology, monitoring is a key tool which begins with the design of the monitoring programme.

Mosaic
The pattern of patches and corridors embedded in a matrix (in this case, within a landscape). See also 'Matrix'.

Motorway
Road with dual carriageways and at least two lanes each way separated by a central reservation called 'median'. All entrances and exits are signposted and all interchanges are grade separated.

Multimodal
Pertaining to more than one 'mode' of transport.

Multiuse overpass
Structure built over transport infrastructure with multiple functions including the movement of fauna. It combines wildlife and human uses such as small forestry roads, cattle passages or pedestrian paths. Modifications are included to encourage use by wildlife such as addition of strips covered by natural materials and vegetation, and screens to reduce traffic disturbance when required. Combined with perimeter fencing that funnels the animals to the structure.

Multiuse underpass
Structure built under transport infrastructure with multiple functions including the movement of fauna. It combines wildlife and human uses such as small forestry roads, cattle or pedestrian passages. A drainage function including streams or other small waterways inside the structure is also compatible and may even lead fauna through the passage. They may include modifications to increase wildlife use such as fencing to funnel the animals, adaptation of vegetation at the entrances and measures to avoid excessive pooling of water. Combined with perimeter fencing that funnels the animals to the structure.

Natura 2000 network
Network of sites designated by Member States considered to have Community importance under the Habitats Directive 92/43/EEC or classified as special protection areas (SPAs) under the Birds Directive 79/409/EEC. Together, the SPAs make up the European network of protected sites, Natura 2000. See also 'Emerald network'.

Nature-based Solutions (NbS)
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.

Net Gain (NG)
The point at which project-related impacts on biodiversity and ecosystem services are outweighed by measures taken according to the mitigation hierarchy, so that a net gain results. May also be referred to as net positive impact. See 'Biodiversity' and 'Ecosystem Services'.

No Net Loss (NNL)
A goal for a development project, policy, plan or activity in which the impacts on biodiversity it causes are balanced or outweighed by measures taken to avoid and minimise the impacts, to restore affected areas and finally to offset the residual impacts, so that no loss remains. NNL must be defined relative to an appropriate reference scenario. See also 'Net Gain'.

Noise barrier
Measure installed to reduce the dispersal of traffic noise in a certain sensitive area (e.g. wall, fence, screen).

Offset
Measurable conservation outcomes resulting from actions designed to compensate for significant residual adverse biodiversity impacts arising from development plans or projects after appropriate prevention and mitigation measures have been taken. The goal of biodiversity offsets is to achieve no net loss and preferably a net gain of biodiversity on the ground with respect to species composition, habitat structure, ecosystem function and people's use and cultural values associated with biodiversity.

Operation and Maintenance
Fourth phase of the infrastructure life cycle, after the process of construction. It usually lasts for decades. During this phase, the infrastructure is used and maintained and induce effects in its surroundings due to pollution and disturbance and it creates barriers to movement and splits species populations. See also 'Strategic Planning', 'Design', 'Construction', Decommissioning'.

Overpass
Structure, mainly roads or railways or other type of linear transport infrastructure (including its accesses) which allows vehicles, people or fauna, to cross above another transport infrastructure. See also 'Wildlife overpass'.

Paved road
A road which surface is made with asphalt, bitumen, concrete or tarmac. See also 'Unpaved road'.

Pedestrian underpass
Structure under an infrastructure designed for use by pedestrians.

Pesticide
Any chemical application used to kill insects, rodents, weeds, fungi or other living organisms, which are harmful to plants, animals or foodstuffs.

Pipe
Cylindrical water tight structure sunk into the ground to provide a passage (from one side of the infrastructure to another).

Plan
A forward looking strategy or design, often with co-ordinated priorities, targets, options and measures that elaborate and implement policy. Synonym 'Plan'.

Policy
A general course of action/ direction guiding ongoing decision making towards a desired goal or outcome.

Population
Functional group of individuals that interbreed within a given, often arbitrarily chosen, area.

Precautionary principle
A principle to guide decision-making in the absence of scientific certainty which states that precautionary measures should be taken when an activity may harm human health or the environment and that the proponent for an activity must prove that the action will not cause harm.

Primary effects
An outcome directly attributable to a defined action or project activity. They are produced by the physical presence of infrastructure, its structural design, maintenance, and use. Synonyms: 'Direct impacts', 'Direct effects'. See also: 'Secondary effects'.

Programme
A coherent, organised agenda or commitments that implements policy. Could encapsulate many projects.

Project
See 'Design'.

Protected Areas
See 'Protection Zone'.

Protection Zone
An area of land and / or sea especially dedicated to the protection and maintenance of biological diversity, and of natural and associated cultural resources, and managed through legal or other effective means.

Public-Private Partnership (PPP)
A cooperative system made up of two or more public and private organizations, typically involved in a long-term agreement.

Red list
The IUCN Red List of Threatened Species provides taxonomic, conservation status and distribution information on taxa that have been evaluated using a system designed to determine the relative risk of extinction. The main purpose of the IUCN Red List is to catalogue and highlight those taxa that are facing a higher risk of global extinction (i.e. those listed as Critically Endangered, Endangered and Vulnerable). Red lists of species also exist at the national level.

Reduction
Measures taken to reduce the duration, intensity, significance and/or extent of impacts (including direct, indirect and cumulative effects, as appropriate) that cannot be completely avoided, as far as is practically feasible. Synonym: 'Minimise'. See also: 'Mitigation hierarchy'.

Reforestation
Re-establishment of forest by the planting of trees (may have commercial or ecological functions).

Region
A geographical area (usually larger than 100 km^2) embracing several landscapes or ecosystems that share some features, e.g. topography, fauna, vegetation, climate, etc. Examples include bio-geographic and socio-economic regions.

Regrading
The process of converting an existing landscape surface into a designed form by undertaking earthworks, e.g. cutting, filling or smoothing operations.

Remediate
See 'Restore'.

Remote Sensing
Methods for gathering data from a distance. In environmental studies and in monitoring, it usually refers to the use of satellite or airborne sensors to examine conditions and changes over large regions or landscape scale analysis; often used in conjunction with Geographic Information Systems and often involves validation through on-the-ground activities.

Resilience
The ability of an ecosystem to respond to a perturbation or disturbance by resisting damage and recovering quickly.

Restoration
Process of actively or passively assisting the recovery of an ecosystem towards or to good condition, of a habitat type to the highest level of condition attainable and to its favourable reference area, of a habitat of a species to a sufficient quality and quantity, or of species populations to satisfactory levels, as a means of conserving or enhancing biodiversity and ecosystem resilience.

Restore
In the context of ecological corridors, the recovery of ecological connectivity that has been diminished, impaired or destroyed. For a generic definition of restoration as an action within the Mitigation Hierarchy see 'Restoration'.

Rewilding
The process of rebuilding, following major human disturbance, a natural ecosystem by restoring natural processes and the complete or near complete food web at all trophic levels, as a self-sustaining and resilient ecosystem with biota that would have been present had the disturbance not occurred. The ultimate goal of rewilding is the restoration of functioning native ecosystems containing the full range of species at all trophic levels whiles reducing human control and pressures.

Right of Way (ROW)
Strip of land over which is built a public road, rail or other infrastructure where the infrastructure operators have legal rights. Often used to refer road sides. See also 'Habitats related to transport infrastructure', 'Roadside' Road verge'

Riparian forest
Forest situated by a riverbank or other body of water.

Road
Concrete or tarmac public way for vehicles, humans and animals.

Road corridor
Linear surface used by vehicles plus any associated verges (usually vegetated). Includes the area of land immediately influenced by the road in terms of noise, visual, hydrological and atmospheric impact (normally within 50 to 100 m of the edge of the infrastructure).

Road ecology
See 'Transport Ecology'.

Road network
The interconnected system of roads serving an area.

Road verge
Area adjacent to roads generally located outside the road shoulder and vegetated.

Roadkill
Animals that have died as a result of collisions with vehicles on roads. See also 'Animal vehicle collision'.

Roadside
Area adjacent to the carriageway, generally includes the road shoulder and the road verge.

Roundabout
Junction where three or more roads join and traffic flows in one direction around a central island of land which is often vegetated.

Safety barrier
A vehicle-resistant barrier installed alongside or on the central reserve of infrastructure, intended to prevent errant vehicles from leaving the designated corridor and thus limit consequential damage. See also 'Safety fence' 'Guard-rail'.

Safety fence
Continuous structure (of varied material) erected alongside infrastructure designed to prevent errant vehicles from leaving the designated corridor and limit consequential damage. Synonym: 'Guard-rail'.

Scale
In landscape ecology, the spatial and temporal dimensions of patterns and processes.

Scoping
Process for identifying content and extent of the information to be submitted to the competent authority under the EIA process. Scoping is mandatory for the SEA process. See also 'Strategic Environmental Assessment'.

Secondary effects
Impacts triggered in response to the presence of the project, rather than being directly caused by the project's own operations. They are derived from interactions among primary effects, and the interplay with environmental conditions and other driving factors at a landscape or regional level Synonym: 'Indirect effects', 'Indirect impacts'. See also: 'Primary effects'.

Service road
Subsidiary road connecting a more major road with adjacent buildings or facing properties. Normally not a thoroughfare.

Sheet piling
Waterway bank erosion protection (wooden, iron or concrete planks sunk vertically between the edge of the water and the embankment).

Shoulder
The linear paved strip at the side of a motorway which vehicles are allowed to use during emergencies, and which is used by maintenance vehicles to access works. Synonym: 'Hard shoulder'.

Single carriageway
Road in which a single lane of traffic is flowing in each direction, with no barrier or median strip dividing them.

Single track road
Road that is only as wide as a single vehicle, and thus does not permit the flow of two-way traffic.

Site
A defined place, point or locality in the landscape.

Slope protection
Activity or measure aimed at preventing soil erosion on slopes (e.g. by covering the ground with vegetation, stones, concrete or asphalt).

Small fauna underpass
Structure built under transport infrastructure designed specifically to provide a safe crossing point for small fauna such as reptiles, small mammals or invertebrates which are used to dark, humid habitats. Construction types are predominantly box or vault structures. Combined with perimeter fencing that funnels the animals to the structure and with light/noise screens to reduce disturbance when required. See also 'Amphibian passages'.

Source - sink habitats and populations
Source habitats are areas where populations of a given species can reach a positive balance between births and deaths and thus act as a source of emigrating individuals. Sink habitats, on the other hand, have a non-sustaining birth-death ratio and are dependent on immigration from source populations.

Spatial planning
See 'Land use planning'.

Stepping stone
Ecologically suitable habitat patch where an organism temporarily stops while moving along a heterogeneous route.

Stock route
See 'Drover route'.

Strategic Environmental Assessment (SEA)
A range of analytical and participatory approaches that aim to integrate environmental considerations into policies, plans and programmes and evaluate the inter linkages with economic and social considerations. See also 'Environmental Impact Assessment.

Strategic Planning
First phase of the infrastructure life cycle. It starts with the definition of general goals and vision for transport corridors, identifying the needs for transport infrastructure in a region or country, and providing specifications about priorities, location and planned schedule. This phase includes the definition of the transport Policy and Strategy . See also 'Design', 'Construction', 'Operation and Maintenance', Decommissioning'.

Strategy
See 'Plan'.

Structural connectivity
A description or measure of habitat permeability (how well a given habitat allows movement) based on the physical features and arrangements of habitat patches, disturbances and other land, freshwater or seascape elements presumed to be important for organisms to move through their environment. Structural connectivity is used in efforts to restore or estimate functional connectivity where measures of it are lacking. See also 'Functional connectivity'.

Surface-water drainage
System devised to remove water from the surface of the ground (or infrastructure) (see also 'Drainage').

Target species
A species or group of species that is the subject of a conservation or mitigation action or the focus of a study.

Taxon
Category in the Linnean classification of living organisms, e.g. species. The plural from is 'Taxa'.

Terrestrial
Pertaining to land or earth.

Top soil
The top layer of soil that supports vegetation.

Transport corridor
Areas which concentrate linear transport infrastructure, such as roads, railways, waterways or powerlines, and which may impede or facilitate movement across the landscape. See also 'Ecological corridor'.

Transport ecology
Science that seeks an understanding of the interactions between roads/railways/utility easements etc. and the natural environment, including wildlife, natural resources, land use and climate change. Synonym 'Road Ecology'.

Tree-top overpass
Rope, net or pole suspended above transport infrastructure from vertical poles or trees, for arboreal and scansorial species. While fencing would improve rates of use, fence designs are yet to be developed due to the climbing ability of the target species. Similar structures have been proposed for bats, the success of which has yet to be demonstrated. Synonyms: 'Canopy bridge'; 'Arboreal crossing structure'.

Underpass
Structure (including its access points) which allows one linear transport infrastructure to pass under another. See also 'Wildlife underpass'.

Unpaved road
A road not covered by any artificial material such as asphalt or concrete. See also 'Paved road'.

Upgrading
Structure, mainly roads or railways or other type of linear transport infrastructure (including its accesses) which allows vehicles, people or fauna, to cross under another transport infrastructure. See also 'Wildlife underpass'.

Verge
The strip of land (often vegetated) beyond the infrastructure surface itself, but within the infrastructure corridor.

Viaduct
Long elevated bridge, typically supported on pillars, which carries a transport infrastructure over a valley or other similar low-level landscape area. The landscape below these structures can be designed to conserve or maintain continuous riparian and aquatic habitats, thereby facilitating wildlife movement. See also 'Adapted viaduct'.

Waterway
A navigable body of water.

Weir
Construction in a river or canal designed to hold the water upstream at a certain level.

Wetland
Land or area containing high levels of soil moisture or completely submerged in water for either part or the whole of the year.

Wildlife
All wild animals, plants, fungi and bacteria collectively.

Wildlife corridor
Linear-shaped area or feature of value in facilitating wildlife movement across a landscape. See also 'Ecological corridor'.

Wildlife crossing structure
See 'Wildlife passage'.

Wildlife fencing
Fencing designed and erected specifically to prevent animals from gaining access onto infrastructure and to lead them to safe crossing points.

Wildlife overpass
Structure built over transport infrastructure specifically to provide a safe crossing point for wildlife and to connect habitats from both sides. The surface is covered with natural materials and soil allowing the growth of different species of vegetation. Other refuges for fauna such as stone or wood rows can also be installed. Combined with perimeter fencing that funnels the animals to the structure and with light/noise screens to reduce disturbance when required. While similar to landscape overpasses, they are narrower, limiting the extent to which different habitats and vegetation can be included on the structure. Synonym: 'Fauna overpass'. See also: 'Landscape overpass'.

Wildlife passage
Structure designed to facilitate the safe movement of wildlife across linear transport infrastructure, located over or under the infrastructure. It can be specifically designed for wildlife use or modified to combine wildlife crossing with other uses such as drainage and other. Synonym: 'Wildlife crossing structure', 'Fauna passage'.

Wildlife underpass
Structure built under transport infrastructure specifically to provide a safe crossing point for wildlife, typically large and medium-sized mammals, such as ungulates and large carnivores, but also for other vertebrates and invertebrates. Construction types are predominantly box, vault or beam platform structures. The substrate is covered with natural materials and soil allowing different species of vegetation growth where there is enough light and humidity. Elements such as stone rows may provide wildlife refuges inside. Combined with perimeter fencing that funnels the animals to the structure and with light/noise screens to reduce disturbance when required. Synonyms: 'Fauna underpass'.

Wildlife Vehicle Collisions (WVC)
See 'Animal Vehicle Collision'.

Willingness-to-pay (WTP)
A term used in economics to quantify the maximum amount of consumption possibilities that an individual is prepared to sacrifice in order to consume a particular good. In many research projects, such as valuation of various environmental assets, the purpose is to estimate WTP in terms of money.

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TABLE OF ACRONYMS

AI
Artificial Intelligence

AR
Augmented Reality

BD
Big Data

BIM
Building Information Model(ling)

BPMN
Business Process Model and Note

CDE
Common Data Environment

DL
Deep Learning

DT
Digital Twin

EIA
Environmental Impact Assessment

EU
European Union

GIS
Geographic Information System

IoT
Internet of Things

IT
Information Technology

LCA
Life-Cycle Analysis

MBSE
Model-Based System Engineering

NNL
No Net Loss

OGC
Open Geospatial Consortium

RDI
Research Development & Innovation

SEA
Strategic Environmental impact Assessment

SDG
Sustainable Development Goal

SRDA
Strategic Research & Development Agenda

TI
Transport Infrastructure

TRL
Technology Readiness Level

UNEP
United Nations Environment Program

WP
Work Package

TABLE OF FIGURES

PHOTO CREDIT

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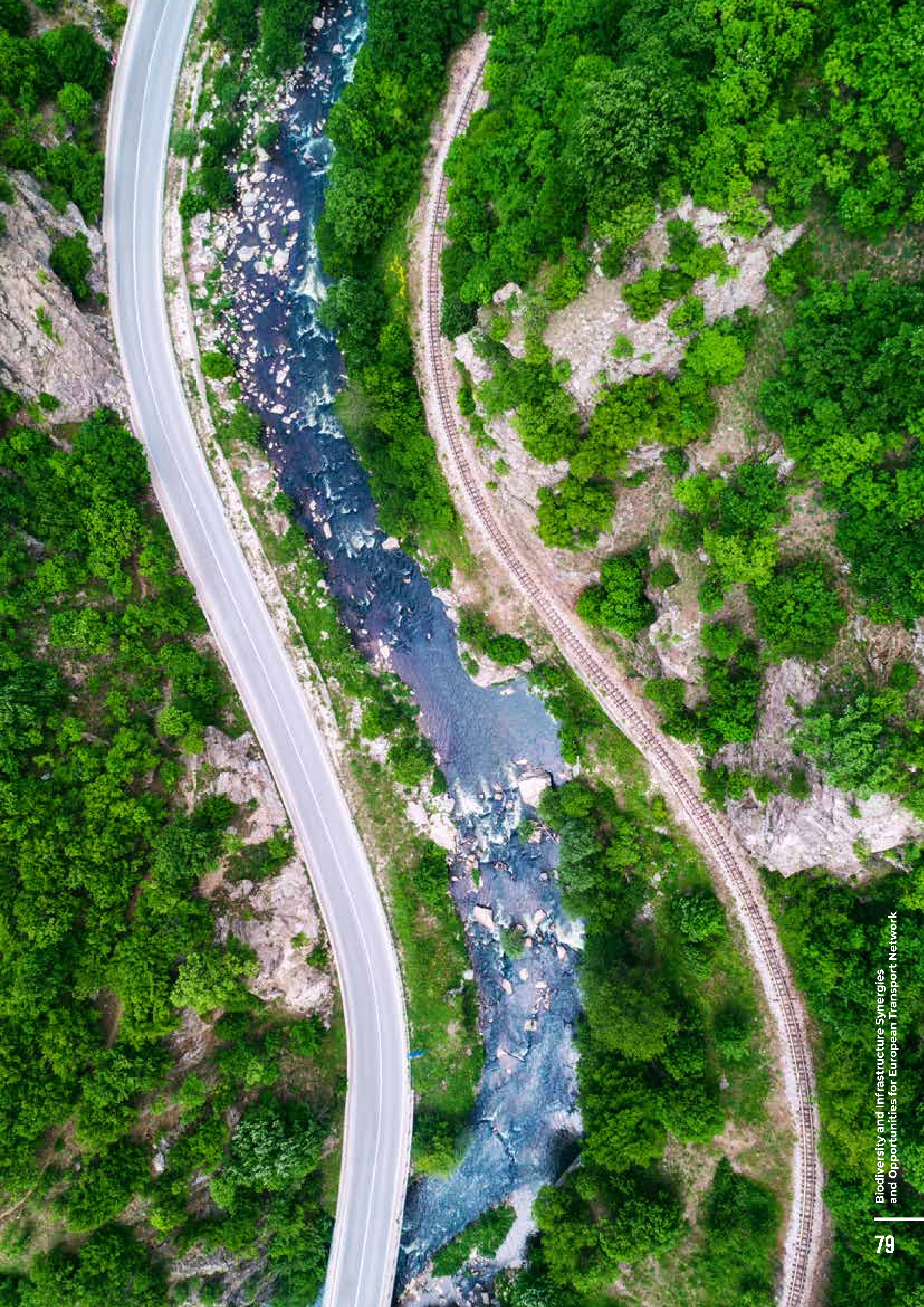

BISON

Transport infrastructure and related mobility are key drivers of global economic development. However, their negative impacts on climate change and biodiversity are significant and deserve consideration as they impact global economic development.

Analysis of the interactions between biodiversity and infrastructure goes beyond the simple limits of transport networks, and it is indeed all networks: transport, energy and renewable energies that must jointly address the issue in order to optimise synergies.

In less than two and a half years, this conceptually daring project, supported by the European Commission, has garnered broad national, European, and international resonance. The suddenness, diversity, and magnitude of actors that joined and supported the action highlight how BISON catalysed needs and gaps.

The Strategic Research and Deployment Agenda is not a ready-made solution for achieving full environmental integration in transport infrastructure. Rather, it serves as an essential step to initiate dialogue and cooperation with stakeholders who often work in isolated silos. It endeavours to catalyse transformative change and pave the way for a harmonious coexistence between biodiversity and infrastructure.

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