UIC SUSTAINABILITY

UIC Guidelines on Managing Railway Assets for Biodiversity

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ECOLOGICAL EFFECTS OF RAILWAYS ON WILDLIFE
REVERSE

INTERNATIONAL UNION
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1. INTRODUCTION

The word “biodiversity” stems from a contraction of “biological diversity” which refers to the multiplicity of life on Earth at all its levels, from gene variation within a population, to the number of plant, animal and fungi species and other living organisms within a habitat, and the range of ecosystems in a region. International organisations and agreements, including the United Nations Convention on Biological Diversity (CBD) and the European Union Biodiversity Strategy, emphasise the importance of biodiversity for maintaining healthy, balanced ecosystems which in turn provide our society with “ecosystem services”. These ecosystem services improve our daily lives, including access to green spaces, nutrient cycling and soil fertility, crop pollination, and clean air and water. Moreover, they directly improve our ability to reduce and mitigate climate change, as plants and soils capture and store carbon dioxide and reduce the likelihood and impact of flooding and landslides. Considering ecosystem services when managing railway assets on existing lines and considering environmental assets in conjunction with other asset management plans is of growing importance for UIC and its members. Investors and railway infrastructure managers must consider their environmental footprint, including biodiversity, in their construction and maintenance projects. This document compiles information from the REVERSE project members on the steps that should be taken and how they should be implemented for the best practice management of railway assets on existing and upgraded lines. The purpose of the guidelines is to enable railway infrastructure managers to incorporate biodiversity conservation into all levels of their business, and to help them make informed decisions on how to manage railway assets in order to have the least negative impact on biodiversity.

As outlined in the UIC’s report on *European Railways: Strategy and Actions for Biodiversity* [1], UIC, together with its members, promotes the integration of a mitigation hierarchy into all areas of railway asset management, and the open and high quality, nature-related monitoring and reporting of these assets (e.g., annual reports of the infrastructure companies for their financial years - e.g. ÖBB [2], and DB [3]). The objective to protect and restore biodiversity and ecosystems is fundamental to future environmentally sustainable investment in European railway infrastructure through the EU Taxonomy [4] and similar financial regulations in other countries. As well as UIC’s *Strategy and Actions for Biodiversity* [1], we recommend that users of this guide consult the *Swedish Ecological and Cultural Heritage Standards for Road and Rail* document [5], the *Wildlife and Traffic in the Carpathians* report [6], *Wildlife and Traffic: A European Handbook for Identifying Conflicts and Designing Solutions* [7] [8] for further general guidance on the issues around biodiversity and the rail network.

1.1. WHO ARE THESE GUIDELINES FOR?

The target audience for this guide is technical railway managers (rather than railway engineers and professional ecologists working in the field) who have the technical knowledge to make strategic decisions about the management of their assets and associated biodiversity, and the competence to develop internal management plans by reviewing international documents written in English in line with national policies. Individuals working for national authorities who are responsible for revising technical guides and regulations for operators are also expected to take note of these guidelines, and finally, the document will also support those involved in preparing general recommendations on asset management, those responsible for training employees, and subcontractors whose work on building and maintaining railway assets may impact biodiversity.

2. SCOPE, DEFINITIONS AND LIMITATIONS OF THIS GUIDANCE

The European railway network extends for almost 230,000km across the continent and covers an estimated 315,000 to 420,000 ha of land. It covers an enormous range of different ecosystems (Figure 1), including mountains, woodlands, shrublands, grasslands, wetlands, and coastal and urban landscapes. Therefore, it is unlikely that any one of these habitats is not in some way influenced or connected by the European rail network. It is therefore vitally important that railway infrastructure and assets are managed sensitively conserve and enhance biodiversity.

When planning construction projects to match rising mobility demands, infrastructure managers need to meet various conditions to provide a reliable and resilient service, including the environmental management requirements of railway assets. The different categories of railway network maintenance and construction are listed below (Table 1) to outline the scope and limitations of the report.

Table 1: Guidelines structure and coverage

Included in the Guidelines:	
Maintaining existing lines	↗ Railway lines in service
Upgrading existing lines	↗ Construction work on existing lines, to carry out modernisation and improvement projects. It is important to note that planning legislation varies between countries, and in some circumstances major upgrading projects may be referred to as the 'construction of new railway lines.
Excluded from the Guidelines:	
Constructing new lines	↗ The construction of new lines where there is no pre-existing line (including the decision process, from land purchasing to project completion).
Decommissioned lines	↗ Lines that were formerly in service, but which are indefinitely excluded from operation.

This guide has been assembled in consultation with railway infrastructure managers and ecological experts by looking at best practices across the sector. The authors have drawn on published examples and case studies, some of which were contributions in the *Strategy and Actions for Biodiversity* report [1]. The guidelines cover in-service railway assets on existing and upgraded lines, such as track beds, catenaries, overhead power lines, fencing, and lineside buildings which are routinely managed or upgraded (see the description of the railway corridor and associated habitats in Figure 1).

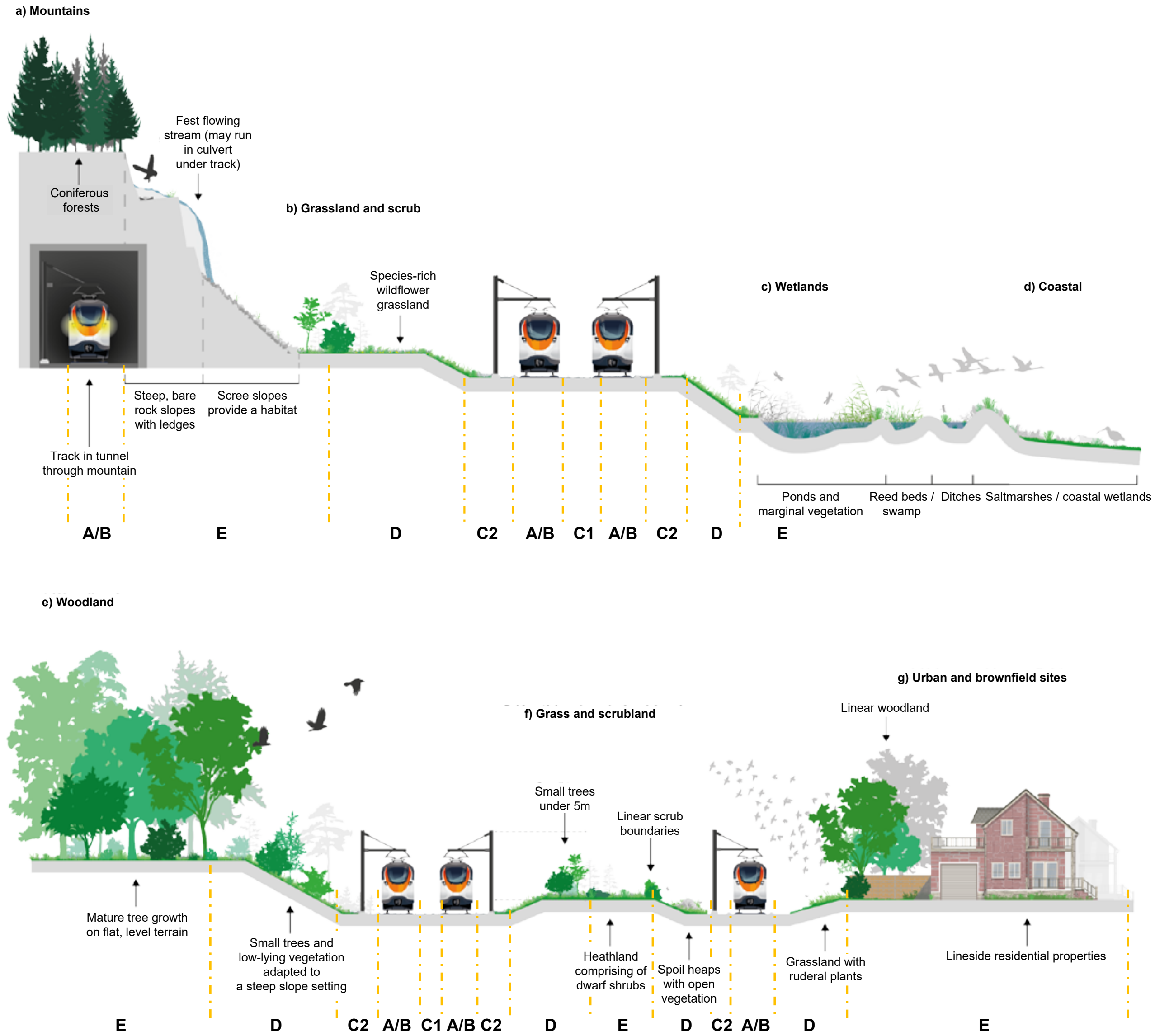


Figure 1: The main habitats associated with the European rail network together with their key benefits to biodiversity.

Table 2: Description of the railway corridor and description for associated habitats

Zone	Terminology			Description
A	Ballast bed			Part of the track bed made of ballast or gravel, including embedded sleepers and rails
	Slab track			Concrete track bed structure
B	Ballast shoulder			Part of the track bed covering the slope on both sides of the ballast bed
	Slab track			Different concrete track bed structure types are possible and, in some cases, may include a ballast shoulder
C	Transition area	C1	Spacing area	Part of the track bed abutting the slope on both sides of the ballast bed and including a footpath for maintenance / inspections, as well as walkways and spacing areas between tracks in the case of double or multiple tracks.
		C2	Side walkways	In some cases, drainage ditches are also constructed in area C
D	Lineside (cuttings or embankments)			Slopes alongside the track adjoining Area C, in which vegetation may affect the operational envelope ((A/B + C)
E	Unsealed area outside of the tracks			Power stations, service facilities, unsealed paths, areas around substations, unsealed areas around railway stations, forest land, meadows and unsealed fallow land
A/B + C	Operational envelope			The area within which the railway infrastructure sits
A/B + C + D	Railway corridor			Operational envelope and lineside

The planning and construction of new infrastructure is beyond the scope of this document. However, we do make reference to technical specifications relevant to the management of biodiversity assets on new and existing lines from the UK's high-speed line (HS) project carried out by HS2 [9] [10]. When constructing new rail routes, strategic environmental impact assessments on programmes and plans have to be followed, together with appropriate national planning regulations and the EU's Habitats Directive [9], with the 'avoidance' of habitat destruction being at the top of the Mitigation Hierarchy (Figure 2).

Moreover, this guide does not cover the management of decommissioned assets, such as sections of the rail network that are no longer in use. However, it is important to recognise that these areas, which fall under the general category of "brown field sites" (shown in (g) in Figure 1), can have considerable ecological value [11]. They may require the removal of redundant infrastructure and pollution risks, and active management, such as invasive species removal, to maintain or enhance their biodiversity value.

It should also be emphasised that the principles of good biodiversity management on railways can be applied to other modes of transport and there are considerable opportunities for knowledge sharing and collaborative working between rail and road [12] [13].

3. THE MITIGATION HIERARCHY AS A FRAMEWORK

One of the thirteen Strategic Goals and Actions presented in the *Biodiversity Strategy and Action Guide* [1] is to "Implement the biodiversity mitigation hierarchy" and therefore "limit the negative impacts of railway development activities by following the principles of avoiding, minimising, restoring, or offsetting impacts on biodiversity". The mitigation hierarchy [14] (Figure 2) is a widely used approach to consider how to best protect biodiversity with the aim of preventing, minimising or alleviating negative ecosystem impacts.[1]

When planning any railway asset construction or management work, the each of the mitigation hierarchy's four levels must be considered:

Avoid impacts by carefully choosing sites that are not ecologically sensitive habitats or do not contain rare and protected species, and plan disruptive work outside of the wildlife's breeding season. Essentially, the goal is to correctly design the project from the beginning to avoid creating a negative impact on biodiversity.

Reduce and lessen the impact by using additional infrastructure or strategies, such as physical barriers for animals or carefully planning access routes. Again, the goal is to build these principles into the very design of the project and not as an afterthought.

Restore habitats that are unavoidably damaged by construction, maintenance, and upgrade activities, so that they return to their previous state. This restoration focuses on affected areas and is therefore done onsite.

Offset unavoidable damage done onsite, or close to it, by creating or restoring equivalent habitats off-site, via mitigation banking or by translocating habitats. Following the 'no net loss' principle, the new habitat should, at a minimum, cover the same area and have the equivalent quality as the site which was destroyed. A net gain of biodiversity is the most preferable outcome to offset the ongoing decline in biodiversity.

Figure 2 shows that the initial predicted consequences on biodiversity can be incrementally diminished by first avoiding the negative impacts where possible, then reducing those that cannot be avoided, and finally restoring the habitats that have been damaged. Furthermore, these impacts can be turned into a "net gain" for biodiversity via appropriate offsetting measures that create new habitats [15].

[1] The terminology used by different authors and organisations varies, for example "repair" versus "restore" and "biodiversity offsetting" versus "ecological compensation", but the underlying principles are the same.

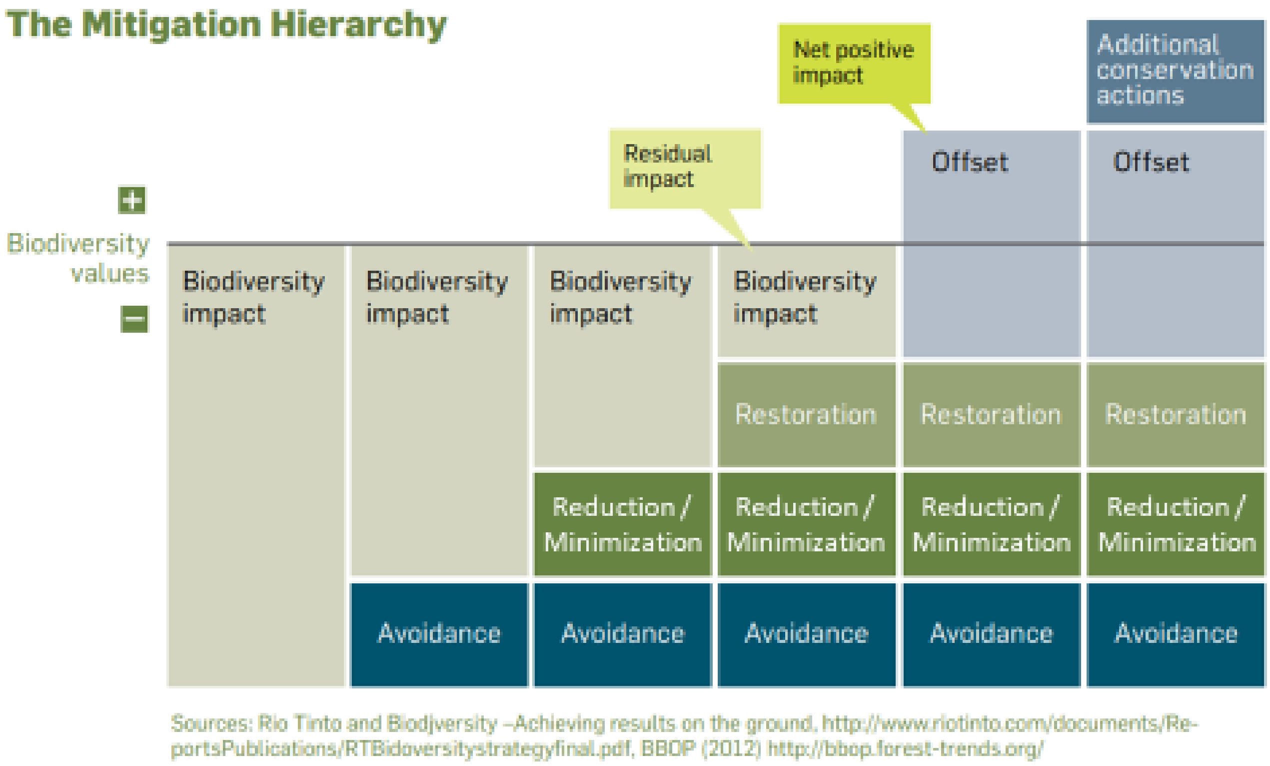


Figure 2: Mitigation hierarchy to manage biodiversity risk – adapted from © IUCN [15]

4. GUIDELINES FOR DIFFERENT ASSETS

4.1. HOW THIS GUIDANCE IS STRUCTURED

Each section begins with a brief introduction describing the asset in question, followed by an overview of the positive effects and negative impacts (to use the terminology of the *European Railways: Strategy and Actions for Biodiversity* report [1]) that a particular asset has on biodiversity. Following this, the majority of the section discusses how the biodiversity linked to the asset can be protected in relation to the mitigation hierarchy. After that, suggestions are put forward on how to monitor and evaluate any measures that are implemented.

As there are many different national and international pieces of legislation relating to biodiversity and how it should be managed and protected, any references that the guidance makes are numbered and listed with the relevant documents and websites in the bibliography. For ease of use and completeness, the principles of the mitigation hierarchy are applied regardless of the infrastructure type, and although some of the advice provided is very similar for different assets, it is repeated avoid the reader having to cross-reference between sections.

4.2. TRACK BEDS WITH SLEEPERS AND RAILS

Characterisation

The tracks of a railway line usually consist of a gravel ballast (or a ballastless slab-track) with embedded wooden, concrete, or composite sleepers, which the rails are fixed onto [16] [17] (Figure 1). The ballast stabilises the sleepers and rails when temperatures fluctuate and provides the strength needed for the heavy loads carried by trains. At the same time the ballast is permeable to water and also functions as a drainage system for the track. Therefore, the track and track bed of a rail system are fundamentally important assets that physically support and guide the engines, carriages, and other rolling stock. The track bed is often exposed to different temperature extremes, such as track buckling in hot weather, which causes asset management problems and requires urgent attention [17] (Figure 3).

Figure 3: Left: A ballasted track with concrete sleepers. © Deutsche Bahn AG Daniel Saarbourg, Right: A record-breaking forecast in the UK 53ºC track temperature © Network Rail

Furthermore, uncontrolled, or unmanaged vegetation growth on the track bed can jeopardise the stability of the infrastructure and, if not prevented, will significantly increase maintenance costs. In this regard, rail companies have differing local policies on whether the track bed should be partially or completely vegetation-free [18] [19] (see Figure 4).

Figure 4: Different rail companies allow different amounts of vegetation on and near the tracks. © Adobe Stock

The effect and impact on biodiversity

The design and structural characteristics of the track area result in a dry and hot habitat in summer that can be inhospitable for many plants and animals. However, the track bed mimics some extreme natural habitats, such as scree slopes and shingle beaches, and may support plants (along with the relevant insects) that have adapted to these conditions, meaning that ballasted track beds can support unique communities of annual plants that depend on hot, dry and low-nutrient conditions that are otherwise rare in the surrounding countryside. On the other hand, these environmental conditions and this railway maintenance can also promote invasive non-native and aggressive flora that may be resistant to herbicides or re-grow faster than non-invasive species after being cut down.

The management of vegetation on or near the track bed can have a major impact not only on plants, but on the species associated with them, including pollinating and herbivorous insects and the species feeding on them, such as reptiles and birds. If there is a requirement to keep the track bed vegetation-free, this can be achieved through the use of [20] manual removal, or the use of radiative or thermal methods as described by the UIC Herbie and TRISTRAM [21] and IRS 70723 [22].

Reptiles may also use these areas as temporary sunny spots for basking on. At the same time the space between the rails and ballast surface (Figure 5) may become a barrier for smaller animals like amphibians because they are unable to pass over the rails and may equally get trapped between them [23]. On a larger scale, depending on the number of rail lines and traffic density, the network might also act as a physical and sensory barrier to larger wildlife like roe deer, wild boar, and bears, as well as some bird and amphibian species. This can especially affect fauna that is sensitive to noise and vibration, or whose behaviour makes it vulnerable to collisions with rolling stock.

Figure 5: Left: two wild deer crossing the railway track at the South of Spain in Malaga © Adobe Stock, Right: female green lizard on railway © Adobe Stock

Large burrowing animals, such as badgers, may undermine the track bed or supporting embankments causing them to collapse [24]. In the Netherlands, it was reported that beavers had dug tunnels under the track between Assen and Groningen [25] and in certain areas where there are small rivers close to the railway line beavers have erected dams, causing the water levels to rise and weakening the substructure of the railway line. Therefore, in these cases, animals should be discouraged from colonising the rail network through the installation of physical barriers such as ground mesh or specialist fencing. If this has already happened, then then translocating them to a suitable habitat away from the railway line should be considered, even though this may require special permits from the regulatory authorities.

Some of these potential impacts on wildlife are outlined in Figure 6 together with possible mitigation measures in Figure 7. However, it is important to note that opportunities to enhance biodiversity on track-beds are limited by the requirements for the safe and efficient operation of the railway.

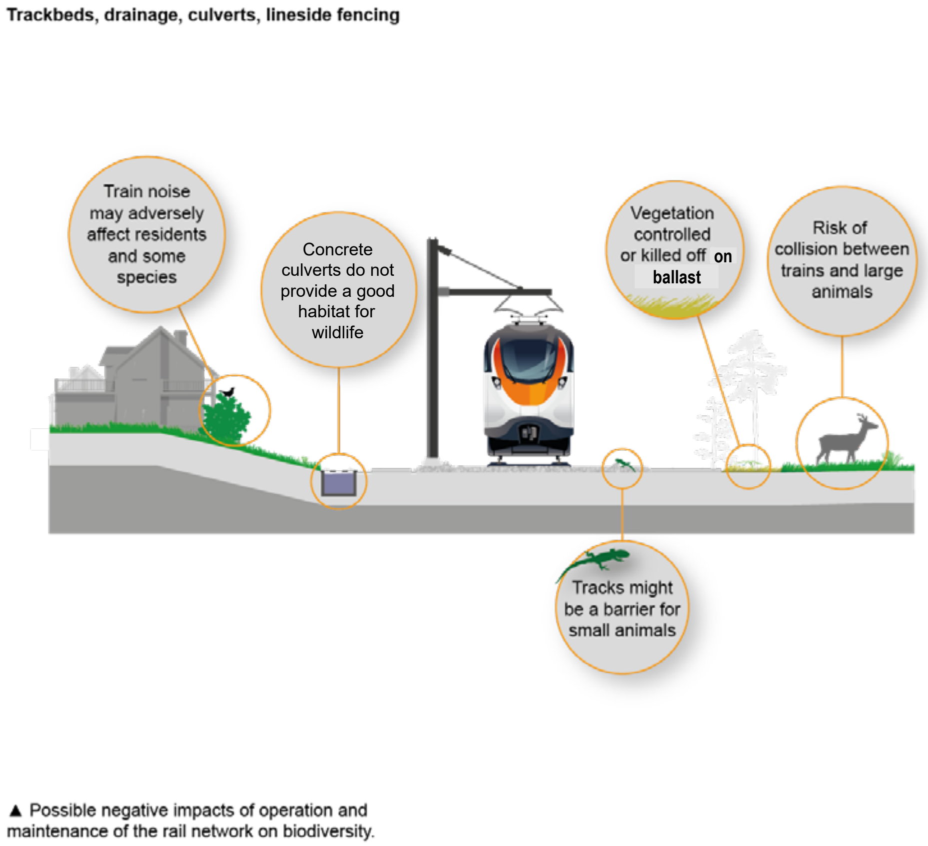


Figure 6: Possible impacts on biodiversity due to maintenance works and operation of a railway line.

Measures to protect biodiversity

This section focuses on measures linked to track beds with sleepers and rails. Any other suggested measures for lineside areas are described in section 4.9.

From an ecological point of view, a number of ideal biodiversity-friendly measures to manage the track bed environment are shown in Figure 7 and described in detail below. However, although these measures may provide mitigation for some biodiversity impacts, they may not always comply with the requirements prepared for the safe and effective maintenance and operation of the railway infrastructure. For these reasons it is vitally important to consult experts in the management of the track bed when planning any biodiversity enhancement.

Selected key design features

- Reduce the barrier effect by creating gaps under the rails and noise barriers, as well as tunnels and culverts under the railway-infrastructure to allow safe passage for animals.
- Construction of noise barriers to reduce disturbance of sensitive wildlife (and the general public) from passing trains.
- Green fences to provide wildlife habitats (although these need to comply with maintenance and safety requirements).
- Provide food resources for pollinating insects by allowing native flowering plants to establish themselves on unmanaged ballast outside of the immediate track area.
- Provide nesting and hibernation habitats for animals with spoil heaps and log piles outside of the immediate track area (although these need to comply with safety and waste management-regulations).

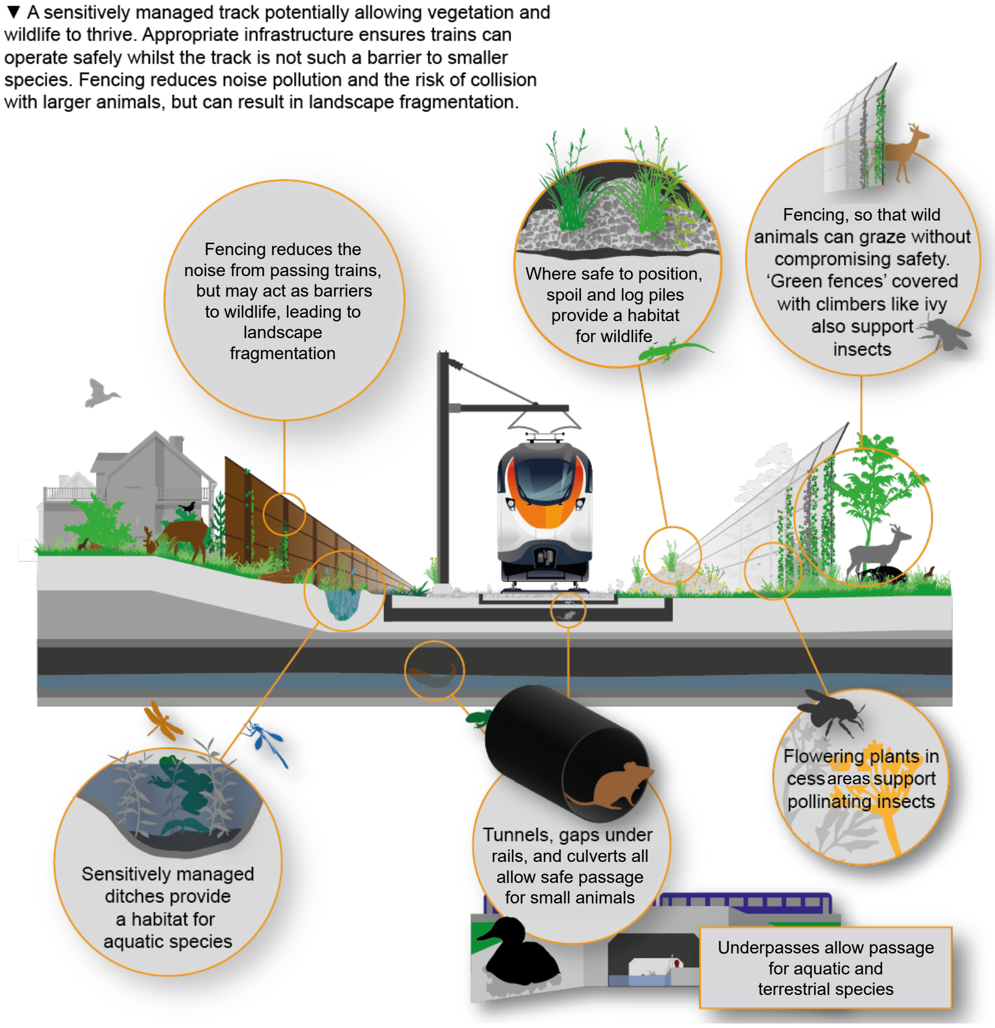


Figure 7: A track bed environment with idealised measures to enrich biodiversity, though adaptation and validation is required as conditions will vary in each company/country.

Avoidance

It is vitally important to carry out an ecological survey prior to major upgrading and maintenance operations to avoid any impact on sensitive wildlife habitats and species [26]. This should include an assessment of the legal requirements for particular species. In accordance with UN Targets, as well as in compliance with the EU Green Deal, the expansion of rail network and the upgrade of existing infrastructures shall support the position of railway as a sustainable transport mode, operating in compliance with environmental regulations. This should include an assessment of the legal requirements for particular species. Indeed, best practice strategies need to, where possible, avoid negative impacts on biodiversity for specific track bed upgrading or maintenance projects include the following measures.

Measures to support biodiversity and avoid negative impacts should be built into the very early phases of design, maintenance, and upgrade programmes, and avoiding breeding and hibernation sites for species using the track bed as a habitat. It also includes avoiding the use of creosote and other toxic timber chemical preservatives on wooden sleepers, which can especially harm amphibians and aquatic wildlife. For further information see the UIC's State of the art report on alternatives to creosoted wooden sleepers [27] and CER's Position Paper: Creosote use in railways [28].

Reduction

a) Barriers to wildlife movement

The barrier effect and the number of small animals trapped between the rails may be reduced by keeping enough space (5 to 10cm) between the ballast surface and rail for easy passage underneath. Other approaches include constructing small tunnels and installing special metal plate systems so that animals find the crossing points - see ProRail's example [29] as well as Case Study A5 in the UIC REVERSE report [1].

Existing bridges, water crossings, underpasses, pipes, and culverts can be improved to allow passage for different kinds of animals that use either water or land, for example badgers, beavers, otters and waterfowl (Figure 8) with these ecological corridors also improving the connectivity of the landscape. Similarly, specialist "canopy bridges" can be installed to allow protected arboreal mammals, such as Red Squirrels and Dormice, pass safely over the railway line [30].

Figure 8: Upgrade a waterway culvert near Cannock to protect the Chase line in Staffordshire © Network Rail [31]

b) Wildlife collisions

Collisions between trains and larger animals like roe deer and wild boar can be significantly reduced by installing fencing in combination with wildlife bridges and ecoducts [32] at known hotspots for wildlife crossing (see section 4.7) or by installing automated detection systems and sonic deterrents [33] (Figure 9). However, as this is mostly planned during the construction of new lines, due to the high construction and installation costs, existing lines should be upgraded, and new lines designed to avoid wildlife crossing hotspots as much as possible.

Figure 9: Animal deterrent system (left: E20 Line Warsaw, right: Lithuanian Railways),
© NEEL, Poland

Level crossings where animals can stray onto tracks may need special attention, for example fitting grid surfaces [34] [35]. Similarly, beaver lodges fitted with one-way gate installations can prevent them from digging new entrances and tunnels under the track bed.

c) Wildlife disturbance

As well as preventing nuisance to lineside residents, noise barriers can be installed to protect sensitive wildlife areas, such as colonies of ground-nesting and wetland birds. These barriers, whether made of concrete, composites, or other materials, can be equipped with openings at their base to allow reptiles and smaller animals to pass, and/or larger, staggered gaps that allow the passage of bigger animals, such as deer. Alternatively, profiled soil banks can be constructed [36] which themselves form valuable ecological lineside habitats (see section 4.9).

d) Track bed vegetation management

Guidance from the TRISTRAM project should be used when developing biodiversity sensitive vegetation management on the track bed [21], which recommends only carrying out vegetation control measures where required for the efficient and safe operation of the railway [37]. In addition, the process needs to be adapted to the different biodiversity conditions on the railway line. In sections where reptiles live, thermal and hot water methods may kill them and therefore it would be better to use other control methods, so it is important to check the species occurrence in the track area before carrying out general maintenance work. This can be done by using existing data on the species occurrence, consulting nature conservation authorities, and by on-site surveys.

Restore

Unfortunately, upgrading existing railway lines can sometimes permanently “destroy” and make it impossible to restore the habitat covered by the rail line. However, in areas surrounding the track bed, it may be possible to remediate soil and vegetation damage from the construction work, and open wildlife habitats may be restored or created by leaving small spoil heaps of recovered ballast (e.g., fines) and piles of dead wood from tree maintenance at the edge of the track bed where it is safe and appropriate to do so. These options would provide valuable micro-habitats for certain invertebrates (e.g., ground-nesting bees), amphibians, small mammals, and reptiles.

Ecological offsetting

During the construction phase of new and upgraded lines, rare plant species and important habitats may be permanently destroyed, and therefore should be replaced with equivalent habitats in quality and size, with the reintroduction of extirpated species under controlled conditions being considered. Ideally, the new habitat should have a net gain in biodiversity, in line with local, regional, national, and European programmes and strategies.

The translocation of species to a suitable habitat away from the railway should be considered where, for example, badger and beaver activity presents a threat to embankments carrying the track bed. However, beavers are legally protected across Europe and badgers are protected in many countries, so expert advice from the local nature conservation authority on the appropriate course of action should be sought. For instance, as shown by Network Rail, early focus on mitigating ecological challenges, such as with the use of Artificial Badger Setts, reduces risks to rail embankment and increases the accuracy of project outcome predictions. [38]. Moreover, proactive collaboration with local environmental NGOs is highly recommended, to find the areas where a net gain would be the most feasible and beneficial to biodiversity and to implement the necessary measures.

Monitoring and evaluation

It is important to monitor and evaluate the impacts that the measures described above have on biodiversity to ensure that they meet the necessary requirements (see Case Study 4 in the *Strategy and Actions for Biodiversity* report [1]). Monitoring and evaluation also provide feedback to improve biodiversity protection measures for future projects, for example arboreal bridges and underpasses for smaller animals [39]. As with other restoration or offsetting activities associated with railway assets,

Monitoring methods should comply with the requirements of each country. Technical advances are under development to automate this process, for example by using artificial intelligence (AI) technologies [40], eco-acoustic sensing [41] [42], and high resolution, multi-spectral sensors based on drone platforms [43]. These technologies offer new possibilities for the accurate and repeatable monitoring of animal populations, and the condition of their habitats, while avoiding the need for operators to risk their safety on the lineside. Similarly, mobile phone apps, such as Pl@ntNet [44] and the e-surveyor [45], allow non-specialists to easily identify and record native and non-native species of plant and animal species present on the lineside, and submit their records for verification by experts if required.

4.3. DRAINAGE

Characterisation

Drainage systems are a vitally important but complex railway asset, involving both "open" and "closed" elements that all serve the same purpose: moving water away from railway infrastructure in order to prevent instability, subsidence, flooding, dampness and other problems associated with uncontrolled water accumulation (i.e. due to material corrosion, erosion, and particle and soil displacement) [46] [47]. Effective drainage systems (including balancing ponds, humus filters, sedimentation and infiltration basins) will become even more crucial as climate change results in more extreme and unpredictable weather conditions. Drainage systems may be "natural", lined with soil and vegetation, or lined with concrete or other artificial materials (Figure 10).

Figure 10: Trackside drainage ditch lined with concrete and stone.
Left: Amphibian guidance structure © ÖBB Infra Right: Under the railway drainage pipes © Adobe Stock.

Open parts of a drainage system should be permeable to maintain the foundation's integrity and may include permanently wet ditches that drain into streams, and small ponds adjacent to the railway track, as well as temporarily dry assets such as swales and flood water storage sites. Closed elements include drains, culverts and pipework which take groundwater and rain away from tracks and buildings or re-route streams.

The effect and impact on biodiversity

Although their primary function is to ensure safety and the effective operation of the rail system, the open parts of drainage elements, in particular, can be vital habitats for wildlife, as dragonflies and mayflies, freshwater fish, amphibians like frogs and salamanders [48], aquatic plants, wetland birds, and beavers, otters, water voles and other mammals, may all colonise drainage assets. The environmentally friendly design of catch drains and drainage slopes can help biodiversity to thrive, even though adequate surface drainage is necessary to prevent ponding at the base of embankments and along the track. Additionally, the presence of open water can significantly influence local microclimates and contribute to the cooling of areas that may otherwise be uncomfortably hot and dry. Moreover, closed drainage assets bisecting the track bed, such as culverts, can have a secondary use as wildlife tunnels.

On the other hand, open drainage systems can also function as a barrier, particularly for smaller animals such as reptiles and small rodents that cannot cross them. Some of these animals may become trapped in the culverts if the sides are too steep and they cannot climb out.

In order to keep drainage systems functioning, they have to be regularly maintained by flushing or excavation to remove accumulated sediment, which may have a permanent impact on existing habitats, spawning areas, or even kill certain species. Therefore, it is important to carry out maintenance work in consultation with ecologists and consider periods when sensitive species such as birds and amphibians are not reproducing [48].

Selected key design features

- Create sensitively managed drainage ditches with soft edges made of soil and stones, which is colonised by native vegetation to provide habitats for aquatic species.
- Connect engineered drainage systems with natural wetlands to extend this habitat and allow native species to colonise them.
- Locate culverts at key animal migration points and provide animal passageways to facilitate movement.

Measures to protect biodiversity

This section focuses on measures linked to drainage. Any other suggested measures for lineside areas are described in section 4.9.

Avoidance and Reduction

There are strong similarities between the measures to avoid or reduce negative impacts on biodiversity from installing and maintaining railway drainage systems, which is why the two sections have been combined. If avoidance is not guaranteed, then the measures described should at least reduce the impact on biodiversity. For example, removing excess and trapped water from the track beds and other parts of the rail system is necessary and so maintaining and upgrading existing drainage assets may be unavoidable. However, the negative impact of this on biodiversity can be avoided through carefully considering the timing and frequency of maintenance and other railway activities.

Drainage maintenance, such as accumulated sediment removal, should be done at appropriate times of the year to avoid or reduce the disturbance to wetland nesting or the disruption to amphibian breeding [48]. Using geotextiles can also help to prevent the growth of vegetation and therefore prevent clogging.

A culvert's barrier effect can be reduced by constructing an artificial shoreline or a pathway well above the waterline (see Figure 11). Similarly, small animals can easily become trapped in concrete-lined drains and ditches so exit ramps are one solution for open systems. In general, man-made drainage should be covered wherever possible.

Figure 11: Examples of culverts that pass under the tracks and allow the passage of both water and animals © Jeff Ollerton & Adobe Stock

It is good practice to assess any environmental risks posed by the railway's operation and maintenance to water resources and its associated biodiversity. This risk assessment should offer alternative strategies that avoid or minimise environmental risks. A good example of this is the replacement of herbicides for vegetation control near water courses with mechanical cutting as recommended by the TRISTRAM report [21], (Figure 12).

Figure 12: Lineside vegetation management using mechanical strummers © Deutsche Bahn AG Volker Emersleben

Natural shorelines using porous stones and marginal vegetation can filter pollutants from the water flowing off the railway into adjacent water bodies, while near-natural retention basins are also important measures to reduce the negative impact on the local water balance (see Figure 13).

Figure 13: Examples of natural water basins in Austria © ÖBB-Infra AG

Restore

Where possible and appropriate for the safe and efficient running of the railway, new drainage assets should be connected to existing streams, ponds and wetlands in order to provide aquatic species a home and increase the amount of habitat available for wildlife (see Figure 14a).

Natural migration routes for fish by removal dams and weirs should be restored if the drainage systems are not compromised in the process, or purpose-built fish passes at weirs may also be an option (see Figure 14b).

(a) (b)

Figure 14: a) Wetland habitat associated with the lineside drainage system © Deutsche Bahn AG Mantel, b) Railway steel truss bridge in Poland, over the weir of a small river © Adobe Stock

Overgrown ponds and wetlands can easily be restored using earthmoving equipment during construction work. See ÖBB's restoration of an overgrown pond to make it deeper and more suitable for frogs as an example (Figure 15).

Before restoration **After restoration**

Figure 15: Pond-restoration in Austria © ÖBB-Infra

Ecological offsetting

If important wetland habitats are permanently destroyed through the necessary upgrading of drainage systems, an equivalent habitat as close to the original site as possible should be built. In newly constructed drainage ditches should, if possible, use natural planting rather than artificial materials to reduce erosion to the sides of the ditches [49].

Monitoring and evaluation

Regular monitoring of surface and subsurface drainage assets should be undertaken to evaluate the effectiveness of mitigation measures e.g., escape ramp functionality and species' population development after being impacted by construction work.

Systematic sampling of the railway drainage infrastructure should be carried out to monitor the concentrations of pollutants in the water which are harmful to wildlife and humans. The results of this monitoring should inform mitigation actions, such as future authorisation for herbicide use near the railway [50].

Finally, as with other restoration or offsetting activities associated with railway assets, it is important to monitor and evaluate any compensated wetland habitats to ensure that they meet the necessary vegetation type and condition requirements (see Case Study 4 in the UIC REVERSE report [1]).

4.4. BRIDGES AND TUNNELS

Characterisation

Bridges and tunnels ensure the railway runs on an even gradient with it reaching otherwise inaccessible regions and allowing it to safely intersect other transport infrastructure. Railway bridges and tunnels are constructed with different techniques and using various materials, including steel and concrete. Older tunnels are typically constructed from bricks or stone blocks which require considerable maintenance, whereas more recently constructed tunnels use concrete liners [51] [52] [53] (Figure 16)

(a) (b)

Figure 16: Example of a modern tunnel design as well as masonry arch viaduct a) © Deutsche Bahn AG / Wolfgang Klee, b) © ÖBB Infra AG

Railway bridges have two main types of construction with rails being embedded in a gravel bed (“closed construction” – Figure 17) or being fixed to the bridge construction itself with an open space in between ("open construction").

*Figure 17: Bridge with closed construction.
Left: © Deutsche Bahn AG Frank Kniestedt., Right: © ÖBB Rail Cargo, David Payr*

Effects and impacts on biodiversity

Bridges and tunnels can offer opportunities to enrich and protect the adjacent habitats, for example by routing a line over or under an ecologically sensitive area such as a wetland or old growth forest [54]. Bridges, especially pillars, can be used by nesting birds and in this way function similarly to rock ledges on cliffs, with the installation of nesting platforms enhancing them further, especially if the nests would otherwise interfere with maintenance and inspection activities (see Case Study A3 in the UIC REVERSE report [1]). Bridges over rivers and lakes can be perfect for placing artificial nesting areas for water-loving birds such as dippers and swallows. In addition, homes within bridges and tunnels may be provided for bats, particularly in those with stone and brick work, or, for example, in the cavities formed by box girders.

19th century masonry arch bridges and tunnels on rail networks deserve special care, as they might have ecological value due to their construction methods and materials, for example, by hosting lichen which can grow on natural stone but not concrete. Bridges may be less challenging than tunnels because the structures tend to be built outside of an urban context. Nevertheless, existing masonry arch tunnels (Figure 18), which require frequent maintenance and are in use in areas with low traffic and low operating speeds, provide habitats similar to natural caves, with relatively cool, stable temperatures throughout the year, making them ideal for bats, which are protected species across the European Union (see Case Study A2 in the UIC REVERSE report [1]).

Figure 18: An example of masonry arch tunnel with stone and brick construction.
Left: © Deutsche Bahn AG Volker Emersleben, Right: © Network Rail from Honiton Tunnel

However, tunnels and bridges can also have a negative impact on biodiversity. Large mammals such as moose, deer, and bears can become trapped in tunnels or on certain bridges, with no way to avoid oncoming trains. Open bridge constructions may reduce this risk, while closed constructions may increase its use as a wildlife crossing. Modern structures and construction materials also tend not to provide the same opportunities for nesting and roosting unless these features are actively incorporated into the design.

Selected key design features
Account for the presence of sensitive species, such as bats and birds via a site survey prior to maintenance.
Design new structures to provide hibernation and nesting sites away from likely collision points.
Allow the masonry to in integrated into the environment by using flowering plants to improve habitat quality and provide food resources (only where permissible for safety reasons).

Measures to protect biodiversity

This section focuses on measures linked to bridges and tunnels. Any other suggested measures for lineside areas are described in section 4.9.

Avoidance

Nowadays, tunnels are built out of concrete, which has the additional advantage of preventing bats from roosting. For existing older constructions, avoiding maintenance inspections and work during seasons when sensitive species, such as bats and birds are using bridges or tunnels for hibernation or breeding, is recommended. However, for operational reasons this might not always be possible, with disturbance reduction instead needing to be considered and an ecologist consulted on how to minimise unavoidable disturbances.

Reduction

New bridges and tunnels can be designed to minimise the risks of harm to sensitive species, for example by using construction materials and structures that discourage species from using the asset where there is a high risk of collision with trains.

To reduce collision risks alternative roosting and nesting sites for bats and bird can be provided away from collision hotspots, such as tunnel entrances [55]. A train hitting a larger animal is less likely, but is consequently more dangerous and has more severe, costly and life-threatening consequences if it does occur. Therefore, fencing in the immediate surroundings of bridges and tunnels and establishing a partnership with nearby landowners can minimise this problem. This approach should be used as a last resort, because fencing might trap animals in the rail corridor and jeopardise safety in the event of an accident, while also leading to landscape fragmentation.

If inspections or maintenance work are required while bats or birds are present, then a nature conservation administration expert should be consulted to find a less invasive solution.

Restore

Habitats that have been disturbed by maintenance or upgrading work on bridges and tunnels should be restored, provided they do not ultimately put the species at risk of collisions with trains. For example, in some circumstances it may be possible to restore lost or damaged bird nesting on bridge arches by building ledges or providing nest boxes.

Ecological offsetting

If bridge or tunnel maintenance results in the unavoidable destruction of a bat or bird habitat then it should be replaced away from the hazardous area, by new nearby roosting, breeding and hibernation habitat.

Each bat and many bird species are legally protected across the EU, meaning that it is important to seek advice from the local nature conservation administration and, if necessary, seek expert advice on the appropriate course of action.

Monitoring and evaluation

Regular monitoring is needed to evaluate the effectiveness of any measures to avoid, reduce, or offset the negative impact on biodiversity of bridge and tunnel maintenance or upgrading works. The monitoring and evaluating can be carried out by experts using new technologies, such as wildlife cameras or bat detectors to measure the impact of the work on affected populations and the success of any remediation measures. As with other restoration or offsetting activities associated with railway assets, it is important to monitor and evaluate any roosting and nesting habitats created to compensate for those lost during bridge and tunnel maintenance and upgrading to ensure that they meet the necessary requirements (see Case Study 4 in the UIC REVERSE report [1]).

4.5. OVERHEAD AND HIGH-VOLTAGE LINES

Characterisation

For this section, overhead line equipment includes the masts and their supporting structure for carrying high-voltage electricity to power electric trains via a roof-mounted pantograph [56] [9] (Figure 19). Weights are often installed on the masts at certain intervals to keep the tension needed for the supporting structure, with the poles being made of steel and concrete, usually reinforced with a concrete foundation. The high-voltage lines transport electricity from power plants to railway substations, which are then linked with the catenary. The poles of the two different systems may vary in design and height but are still built of steel with concrete bases.

(a)

(b)

Figure 19: a) Overhead lines made visible for waterfowl to prevent collisions n a sensitive area (wetland in the city of Vienna © ÖBB-Infra, b) Vegetation trimming along the Hann. Münden, © Deutsche Bahn AG Oliver Lang

The effect and impact on biodiversity

The overhead railway and associated high-voltage lines have the potential to injure or kill wildlife, with the species at highest risk being birds and some arboreal mammals like squirrels. Within the rail corridor, these animals may become injured if they bridge the insulation and get shocked and may subsequently be killed by passing trains or predators on the ground [57].

The wires of the more extensive and higher-voltage power lines supplying electricity to the rail network may pose a threat to migrating birds, causing collision and electrocution. Therefore, these risks should be accounted during the construction of overhead lines, and preventive factors should be also considered. Moreover, in close proximity to vegetation they could also cause forest fires in summer which negatively impact the local flora and fauna. Therefore, railway companies need to ensure that routine maintenance work is carried out so that trees and climbing vegetation do not interfere with the overhead catenary lines.

Selected key design features

- Install bird diverters to make the high-voltage lines more visible to migrating birds.
- Use extended insulators to reduce the electrocution risk for birds and mammals.

Measures to protect biodiversity

This section focuses on measures linked to overhead line equipment. Any other suggested measures for lineside areas are described in section 4.9.

Avoidance and Reduction

There are strong similarities between the overhead line measures to avoid or reduce their negative impact on biodiversity, which is why the two sections have been combined. If avoidance is not guaranteed, then the measures described should at least reduce the impact on biodiversity.

The risk of birds colliding with the wires from existing high voltage lines can be avoided by installing bird diverters (disks or small flags) to make the lines more visible. Electrocution can be avoided by extending insulators. In Germany, for example, insulators can be used on overhead lines with a length of 600mm to avoid electrocuting animals [58]. Another avoidance strategy is to cover critical electrical parts with non-conducting, plastic materials (so far mainly used on high-voltage power lines) (Figure 20). At ÖBB in Austria, these are 1510mm long and include guards to prevent animals from climbing over the isolator (see in Appendix - Technical limitations for the maintenance of vegetation on railways) Alongside these proven and operational technologies, there are some others under consideration, including the use of electrostatic or mechanical grids on the insulators (i.e., bird diverters) to prevent electrocution. Similarly, adopting alternative propulsion technologies for trains (e.g., hydrogen, battery, etc.) may help to reduce the need for additional high-powered lines in areas where diesel trains are still in use and electrification is expensive.

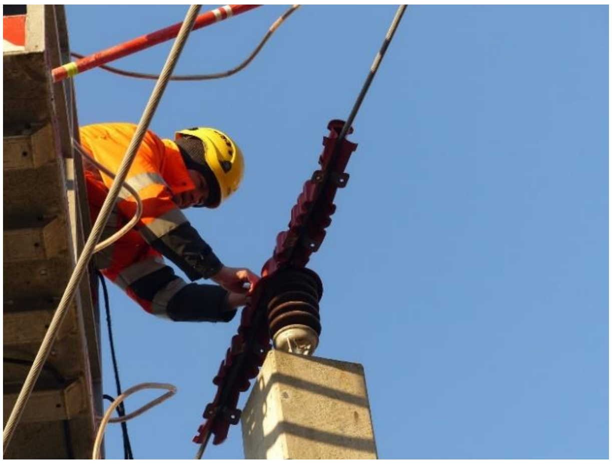


Figure 20: Bird protection caps on the overhead line masts © Renate Wunder, ÖBB-Infrastruktur, Austria

The regular maintenance work should be undertaken outside of the bird breeding season to avoid disturbing nests on the supporting structures of the overhead or high-voltage lines. If work during the breeding season is unavoidable for safety reasons, then specialist advice from the nature conservation administration should be sought.

Restore

For inspections or maintenance work, installing new equipment or dealing with operational hazards, it may become necessary to translocate a bird nest placed on a pole, which includes moving it to another location nearby. In the strictest sense this may be considered as ecological offsetting and the local nature conservation administration should be contacted and, if necessary, expert advice sought.

Figure 21: Nest of White stork (Ciconia ciconia) on pole of railway © Adobe Stock

Ecological offsetting

Potential measures to offset the impact of overhead line maintenance include constructing artificial nests or roosting places outside of the hazard zone in combination with upgrading the habitat in the surroundings area to make it more attractive for the translocated species.

Monitoring and evaluation

Regular monitoring is needed to evaluate the effectiveness of the measures to mitigate the impact on biodiversity of installing and maintaining overhead lines. The monitoring and evaluating can be carried out by experts using new technologies, such as wildlife cameras and drone surveys in combination with an artificial intelligence (AI) to estimate the population development of the affected wildlife (see Case Study 8 of the UIC Strategy and Actions for Biodiversity).

4.6. COMMUNICATION AND CABLE CHANNELS

Characterisation

Cable channels route electrical and communication cables, which are vital for the safe and efficient running of the rail network. In general, these can be divided into 2 different constructions. The first is ground based (cable troughs), mainly made from concrete or a plastic material (Figure 22). The constructions have a cover, which is easy to remove for inspections or maintenance work, and the cable troughs are usually located within or close to the track area itself – mainly in the transition area (i.e., spacing area or side walkways, as described in [1]). Elevated constructions, in contrast, consist of a combination of steel poles and gutters with a plastic cover, which can range from a few centimetres to about one metre in height. These constructions are mostly located in embankment areas or lineside habitats.

Figure 22: A closed cable channel. © Deutsche Bahn AG Volker Emersleben

The effect and impact on biodiversity

During routine railway operation both communication and signalling channels are covered, with little impact on wildlife due to their general inaccessibility. However, inspections, and maintenance or other work on the ground-based cable troughs may require the covers to be removed over a prolonged period of time or long distance, or they may be poorly replaced. This may allow access to small animals like lizards, snakes or amphibians, which may lead to the troughs serving as temporary habitats for some species or leading to others becoming trapped [48].

Selected key design features

- Maintain secure covers to cable channels.
- Monitor channels opened for maintenance and rescue trapped animals.

Measures to protect biodiversity

This section focuses on measures linked to communication and cable channels. Any other suggested measures for lineside areas are described in section 4.9.

Avoidance and Reduction

The measures for avoidance and reduction are identical, which is why the two sections have been combined. Correctly replacing the covers on open channels immediately after completing work is the best way to avoid trapping animals. If this is not possible then single cover pieces must be placed as ramps every few meters, so that animals have an exit. In addition, the channels must be checked for trapped wildlife which then must be rescued as part of regular construction supervision.

Restore

As existing and well-maintained cable channels are not an artificial habitat, there is no need for restoration if they are removed or modified.

Ecological offsetting

As with the previous section, ecological offsetting is not necessary. Existing communication and cable channels are not artificial habitats (if closed properly) and therefore there is nothing for inspections or maintenance work to destroy

Monitoring and evaluation

Monitoring by counting and rescuing trapped species as part of regular construction supervision can be used to verify the effectiveness of implemented mitigation measures.

4.7. FENCING AND BOUNDARIES

Characterisation

The "fencing and boundaries" category covers a wide range of different systems and constructions, including security fencing along railways, chain-link fencing, post and wire livestock fencing, ornamental and native plant hedges, and stone and brick walls. It also includes noise barriers (see section 4.1).

The effect and impact on biodiversity

These assets are designed to prevent people and animals from accidentally or deliberately straying into prohibited areas, with noise barriers having the additional function of reducing rail traffic disturbance for people and wildlife. On the other hand, fences can form a barrier that prevent larger animals from crossing the railway line which could cause major issues, and its impact on biodiversity is currently poorly understood. Nevertheless, whether fences cause habitat fragmentation or not strongly depends on the species and/or type of fence/boundary. For example, hedges are usually not considered to be a barrier, because they are more or less passable, and are therefore, are not included below.

It is useful to classify the different types of fences/boundaries by how passable they are:

- Noise barriers as a special construction to maximise noise mitigation and reduce nuisance – usually not passable (Figure 23).

Figure 23: Installation of a noise barrier. © Deutsche Bahn AG Oliver Lang

- Chain-link and wire-mesh fencing – possible passage for animals depends on the mesh size and animal species. Allowing climbers such as wild clematis or bindweed to grow up them can provide resources for pollinators [59] (see Figure 24), although necessary maintenance and care is needed so that they do not become too heavy.
- Stone, brick, and concrete walls – possible passage for animals depends on the material, wall height, and the animal species. Traditional walls made from stone or brick can also provide habitats for small species, such as mining bees and reptiles.

Figure 24: Wire mesh fences allow plants such as bindweed to grow up chain link (left: © Network Rail, right: © Jeff Ollerton)

Selected key design features

- Consider ecological requirements in the design and select the most appropriate fencing system.
- Install fencing at hotspots for train collisions with large mammals.
- Install openings and gates to prevent animals becoming trapped in the fenced rail corridor.
- Allow climbing vegetation to colonise fences to provide foraging resources for pollinating insects, if permissible for safety reasons and if the fence is strong enough.

Measures to protect biodiversity

This section focuses on measures linked to fencing and boundaries. Any other suggested measures for lineside areas are described in section 4.9.

Avoidance

a) Design and location

When planning the design and location of railway fences, consideration should be given to balancing the need to avoid wildlife-train collisions, without fences acting as physical barriers to animal movement which causes habitats to be fragmented.

Specific avoidance strategies include installing light-proof, noise-dampening fences to protect sensitive nesting and roosting sites from the noise of passing trains and possible light pollution.

In areas where higher noise mitigation is not required, and where restricting passage runs against safety requirements, such as tunnel entrances and bridges, where possible, natural-based solutions can be applied, including embankments, berms, shrubs, hedges, and so on.

In general, plastic-coated fencing should not be used, as the coating can break down over time causing micro-plastics to leach into the environment which will have a negative impact on some species. Likewise, the use of timber fence poles treated with environmentally damaging preservatives, such as creosote, should be avoided.

Artificial fencing should be made visible to large mammals and birds to avoid the risk of collision and injury. The base of noise barriers can also be given openings at ground level to allow small animals like hedgehogs to pass (see in Figure 25) unless there is good reason not too, for example where maximum noise mitigation is required. Appropriate fencing should be installed along stretches of track that are known to be wild animal crossing points (see Monitoring and Evaluation, below). The design should consider entrance and exit holes for small animals [60] and wider gates to allow large mammals (e.g., deer and wild boar) to exit the lineside and not become trapped within the fenced area, taking national regulations on factors such as the distance of vegetation from fences into account.

Figure 25: Timber panels in Muirend, Hedgehog Highway Plan on a track in Scotland's Railways © Network Rail [61]

b) Construction and maintenance

In general, if the initial surveys of areas, where new fencing is to be installed, identify important habitats and/or rare species, these areas should be avoided if at all possible. Old stone and brick walls can sometimes contain bat roosts and hibernacula for reptiles and amphibians, meaning that these sites should be surveyed by professional ecologists in consultation with the responsible nature conservation authority prior to any maintenance work. Depending on the protected status of the species found, the work should be shifted to a noncritical period for the animals, or other lower impact solutions (see section Restore, below) should be discussed with the nature conservation authority.

Finally, maintenance work may need to remove vegetation from the fences, which should be carried out outside the breeding season. In case of uncertainty, professional ecologists and the nature conservation authorities should be contacted.

Reduction

Many of the measures described under avoidance will also serve to reduce impacts on biodiversity. Key measures include:

- Using appropriate fencing along stretches of track that are known wild animal crossing points (see Monitoring and evaluation, below).
- Installing deer gates will allow large mammals to exit the lineside and not become trapped within the fenced area.
- Focusing on known migration points for large mammals, including the installation of automated warning/deterrent systems [62].

Restore

If artificial fencing is to be erected or major maintenance undertaken, it may be necessary to translocate small animals, such as reptiles and amphibians, during the construction phase. There may be cases where the presence of newly added gravel and concrete makes the soil drier than the surrounding area, which may alter the original vegetation, especially at the base of the fence posts. However, flowering plants have great value as pollen and nectar sources for bees and other pollinators and can be supported by the establishment of “bee hotels” for solitary bees. In addition, nest boxes for birds can be set up to bridge the time until the vegetation is fully restored. However, to avoid disturbance, it’s best to place them away from areas where people regularly pass by.

Ecological offsetting

If important habitats are permanently destroyed during fencing operations, action should be taken to compensate habitat damage and loss as close to the original site as possible. Large or particularly ecologically important habitats may be gifted to regional conservation bodies, or other agreements negotiated, for the long-term management of the site.

Monitoring and evaluation

Monitoring areas where trains collide with large animals should be used to identify animal crossing hotspots and where it would be prudent to install fencing. Monitoring should also be carried out where fences are erected, to assess how effective they are. Using remote cameras to monitor the number of animals getting trapped within the fenced lineside is also useful for determining whether gates should be installed. As with other restoration or offsetting activities associated with railway assets, it is important to monitor and evaluate any compensated habitats to ensure that they meet the necessary vegetation type and condition requirements (see Case Study 4 in the *UIC REVERSE* report [1]).

4.8. STATIONS AND LINESIDE BUILDINGS

Characterisation

Stations and lineside buildings cover a very wide variety of assets with a large range of uses, from the buildings that sell train tickets and provide timetable information, to signal boxes, electrical substations that are placed along stretches of electrified tracks, to engine and coach maintenance sheds, with the similarity being that they are usually comprised of at least three, and usually four, walls with support a roof. New railway stations are also often built from steel with glass-covered surfaces. Virtually all railway buildings provide to some form of habitat to wildlife, some desirable and others less.

The effect and impact on biodiversity

1. **Buildings:** Railway buildings and the associated infrastructure, such as lighting or vertical glass surfaces, which can cause collisions, can have a major negative impact on biodiversity. However, measures can be taken to reduce these, and buildings can be designed to provide essential feeding, nesting and breeding grounds for wildlife. On top of this, to minimize birds collision in areas and buildings where glass or transparent panels are used, such as platforms and wating lobbies, necessary preventive measures should be taken into account. As shown in Figure 26, black birds stickers on glass may not be a sufficient visible measure. For instance, the addition of horizontal black lines on transparent surfaces in Austria was seen as a much more effective solution to avoid collision. Lines are 4mm wide and placed at a 48mm distance from each other, as in accordance with specific internal regulation in Austria to make glass-fronts visible for people and wildlife.

Figure 26: Make glass-fronts visible for people and wildlife © ÖBB-Infrastruktur AG

2. **Walls:** The advice for biodiversity management for walls which is similar to that provided for stone and brick walls in section 4.7 will not be repeated. Ivy is an ecologically vital part of native woodlands and associated habitats and when on walls should only be removed if absolutely necessary [63] This applies even when safety tolerances are tight due to the ivy potentially damaging the walls in stone or brick structures. Its flowers provide nectar for pollinators, the berries are eaten by birds, and the evergreen foliage provides a habitat for birds and other animals, as well as insulating buildings and protecting walls from the weather.

3. **Roofs:** Roofs and roof spaces require particular attention because they provide opportunities for adding biodiversity value to buildings, either deliberately (e.g. by installing green roofs) or because bats and cavity-nesting birds such as swifts are exploiting roof spaces. On the other hand, action may be required to prevent pest species from accessing buildings, e.g., rats, grey squirrels, and pigeons. It is therefore important that the measures are as selective as possible towards the unwanted species and avoid negatively impacting desirable species (i.e., using wildlife deterrent systems). Inspections and maintenance work in roofs and roof spaces may also have a negative impact on biodiversity, for example, by disturbing bats.

The measures described can be seen in Figure below.

(a)

(b)

Figure 27: Examples showing how railway buildings can have an effect on biodiversity, together with opportunities for designing more biodiversity-friendly infrastructure a) artificial roof to provide swallows with new nesting sites, b) example for a green roof in Austria © ÖBB-Infra

Selected key design features

Design new and renovate old buildings to include features to support biodiversity, including green and brown roofs with native plant species for insects and birds, bat and swift nesting boxes, bee hotels, controlled systems to reduce light pollution, bird deterrents on windows, and native planting.

Measures to protect biodiversity

This section focuses on measures linked to stations and lineside buildings. Any other suggested measures for lineside areas are described in section 4.9.

Avoidance

As a general principle, important ecological habitats containing rare species, or a high diversity of plants and animals should be avoided when constructing new buildings/estates. Wherever possible, they should be built in areas already changed by humans such as within the area of a recently demolished building. However, sites that were cleared of buildings long ago can have significant ecological value (see the comments about brownfield sites in section 4.9 below.

If maintenance work is planned on the roofs of buildings, however minor, proper inspections must be carried out by a professional ecologist to determine if bats or swifts are using the roof space. Then, to avoid displacing them, the maintenance work should be move to periods of time when animals are not present. If this is not possible, other solutions should be found in discussion with the local nature conservation authority.

Reduction

The impact on biodiversity of constructing a new building can be significantly reduced by installing green roofs and/or living walls. In both cases it is important to use appropriate native plant species, especially those which provide nectar and pollen for bees and other insects, and fruit or seeds for birds. So-called “brown roofs” (self-seeding roofs) are also an option [64].

The risk of birds colliding with glass windows can be reduced by implementing recent developments such as ultraviolet-reflective films [65], when planning building upgrades and new buildings. However, practical experience suggests that the use of other methods, such as silhouettes of predators on the window, appear to have little effect except if they cover half of the glass pane. It is also important to install motion sensor lights, while considering the type and placement of this external lighting to reduce light pollution.

Restore

If roof spaces have to be completely renovated, swift and bat boxes that provide breeding opportunities for these species can be installed. Likewise, “bee/insect hotels” can be fixed on warm and sheltered walls as appropriate. If the design is unable to support impact reduction, then permeable noise barriers and insect-friendly lighting (e.g., LED) should be used instead. For instance, Figure 28 shows the full cut off lamp, that direct the light downward and outward, rather than upwards towards the sky and helps reducing light pollution in platforms with LEDs.

Figure 28: Reduce light pollution with insect-friendly lights © ÖBB-Infra, and make stations green © Network Rail

Particularly for stations, planting green spaces with wildlife-friendly native vegetation (e.g. plants attractive to pollinating insects - see Case Study 3 in the Strategy and Actions for Biodiversity report [1]) is particularly effective and is aesthetically pleasing to the travelling public [59].

Ecological offsetting

If ecologically important habitats are permanently destroyed during the construction or upgrade of lineside buildings, they should be replaced with equivalent habitats as close to the original site as possible. Where buildings have been constructed on old, established brownfield sites, habitat translocation using "brown roofs" [64] that use some of the substrate from the original site may constitute a partial compensation for their destruction. If important habitats are permanently destroyed or there is a residual negative impact, action should be taken to compensate habitat damage and loss as close to the original site as possible, in line with local regulations and European programs and strategies. Large or particularly ecologically important habitats may be gifted to regional conservation bodies, or other agreements negotiated, for the long-term management of the site.

Monitoring and evaluation

The use of bat and swift boxes should be closely monitored to ensure that they have been correctly installed and are lived in. Green and brown roofs should be checked annually to remove unwanted trees and shrubs from growing, including invasive alien species, such as buddleia (see Case Studies A6 and A7 in the UIC REVERSE report [1]).

As with other restoration or offsetting activities associated with railway assets, it is important to monitor and evaluate any compensated habitats to ensure that they meet necessary vegetation type and condition requirements (see Case Study 4 in the UIC REVERSE report [1]). For instance, only a narrow strip close to the platform shall be mowed regularly and the rest of the embankment can only mow once a year, prior to the nesting -see in Figure 29.

Figure 29: Insect-friendly railway station with green spaces in Rankweil/Vorarlberg OBB

4.9. LINESIDE HABITATS

Characterisation

The land running adjacent to the lineside represents the largest railway asset for which a railway company is responsible, and due to its large area, has the potential to have the greatest positive impact on biodiversity. Lineside supports different habitats and vegetation with different sizes (Figure 1) and a good starting point to understanding them is Network Rail's *Railway Sustainability Design Guide* [8] which includes practical advice and case studies managing many different types of lineside habitat.

The effect and impact on biodiversity

Lineside habitats often reflect the natural and semi-natural plant, animal and fungi communities, that occur just beyond the land owned by rail companies, meaning that they need to be treated as extensions of potentially valuable habitats for biodiversity. The extensive nature of the rail network means that the lineside can play an important additional role in reconnecting habitats and biodiversity in otherwise fragmented landscapes.

Lineside habitats in Europe are incredibly diverse because the network runs through different biomes, such as boreal tundra and coniferous forests in the far north, to shrublands and other Mediterranean habitats in the south and everything in between. In addition, urban lines may have distinctive plant life associated with brownfield sites, which are often the remnants of track construction (see Figure 1 for summary).

As well as supporting a diverse range of habitats which are home to many native plants, the lineside can harbour undesirable, invasive species, particularly on verges adjacent to railways, while waterways play an important role in spreading these alien plant species. The problem is often exacerbated by a lack of clarity between rail operators and their neighbours regarding whose responsibility it is for controlling the alien species, so joint awareness raising on this issue is required to bring about positive change.

Plant life close to tracks needs to be balanced between safety requirements and the desire to conserve and support biodiversity, especially as some of these plants play a direct role in the habitats associated with other assets, especially drainage (section 4.3) and fencing and boundaries (section 4.7). Therefore, decisions about management should take this into consideration.

Selected key design features

- The land running adjacent to the railway, which is managed by rail operators, has the greatest potential to have a positive impact on biodiversity. The targeted restoration of lineside habitats can maximise the railways' roles in providing and enhancing landscape connectivity.
- Having native woodland habitats comprising of mixed-age stands with both upright and fallen dead wood, and planting appropriate native species are an especially valuable contribution.
- Heathland comprising of an open and diverse mosaic of mosses, lichens, grasses, and dwarf shrubs is a declining but ecologically important habitat.
- Grasslands comprising of dry, open habitats supporting diverse communities of flowering plants, insects, reptiles, small mammals, and birds are also important.
- Former industrial and residential (brownfield) sites comprising of dry and open habitats can contain unique collections of plants and animals.
- Wetland habitats comprising of ponds and ditches with native marginal vegetation, reed beds, and swamps provide habitats for many aquatic species.
- Saltmarshes and coastal wetlands with mudflats, lagoons, and sand dunes provide habitats for many marine invertebrates, fish, and bird species.
- Montane ecosystems with cliffs, rock ledges, scree slopes, and arboreal forests, provide habitats for many rare and specialised species which are now extinct in the lowlands.

Measures to protect biodiversity

This section focuses on measures linked to lineside habitats and the areas surrounding stations and may link to measures in sections 4.2 to 4.8. The key characteristics of the major lineside habitats and their associated value to biodiversity are described in the summary box above and in Figure 1.

Avoidance

Work along the lineside which may lead to habitat and animal displacement during critical times for biodiversity, such as during bird breeding seasons and amphibian migration should be avoided [48]. Biodiverse brownfield habitats that have developed on the lineside should especially be conserved due to their importance for ground-nesting bees and other insects, so full entomological surveys should be carried out before any work is done. No native trees may be removed unless they pose a direct safety concern, as they not only provide shelter for birds and other animals but are also an important carbon store to offset the impact of climate change (see Figure 30).

The occurrence of wildfires can be avoided through appropriate vegetation management [3]. which needs to strike a balance between fire safety concerns and species conservation. Principally due to this vegetation management, these ecosystems should not be disturbed, and planned works should be shifted to periods when protected species will not be displaced (avoiding migration times and breeding seasons). Ecosystems must also not be changed in a way which results in protected populations being destroyed. For example, in some countries animals such as badgers are protected by law and disturbing their setts can lead to prosecution [66].

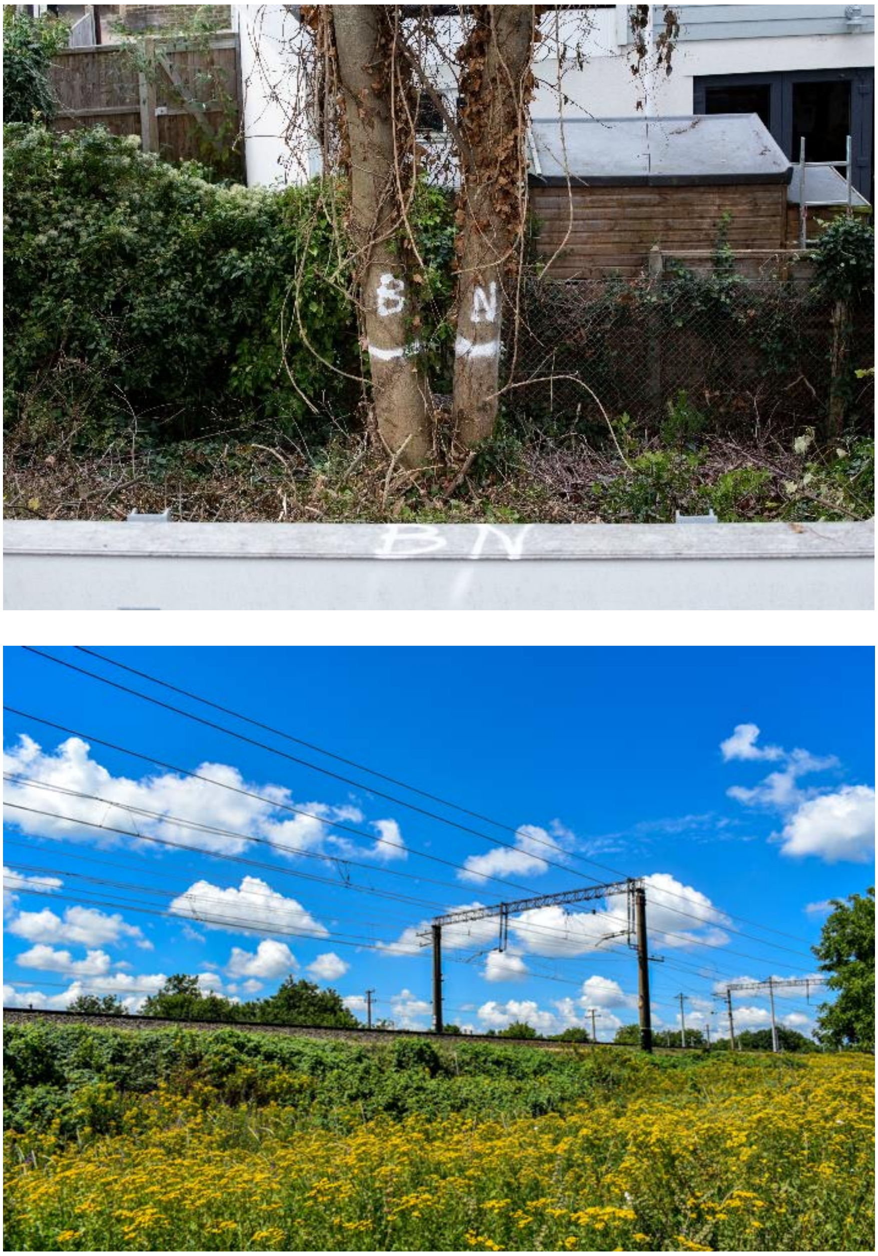


Figure 30: Sign for birds nesting - don't cut down! © Network Rail and © Adobe Stock

Reduction

In lineside areas where it is safe and appropriate to do so, the intensity of its management, such as vegetation cutting, should be reduced with the aim of creating heterogeneous vegetation and ecotones. With plants of different heights, including ground flora, shrubs, trees and climbers, more opportunities are provided for wildlife to find food and nesting sites. Therefore, a “light touch” approach should be adopted when it comes to lineside habitat management, for example by limiting the cutting of grasses to once every two years, where possible. Vegetation along the tracks can be a vital source of nectar and pollen for bees and other pollinators (Figure 31). Consequently, the use of conventional chemical herbicides should be avoided to the greatest possible extent and alternative means to control undesirable species should be considered.

Figure 31: Trackside vegetation can provide nectar and pollen rich flowers for bees and other pollinators © Adobe Stock, © SNCF Reseau

Restore

Many semi-natural lineside habitats have become degraded (e.g., dry clay pit which is unsuitable for swallows – see Figure 32) due to a lack of appropriate management. Where once open and biodiverse habitats, such as wetlands, grasslands, and heathland, are left unmanaged, then natural succession leads to the dominance of a few competitive tree and shrub species, including non-native species.

Figure 32: Keep the clay pit wet, not suitable for swallows © ÖBB-Infrastruktur AG

The resultant vegetation communities typically have a simple structure and composition that support relatively few associated plant and animal species. Appropriate management can be applied to restore these degraded lineside habitats and enhance their value for biodiversity. These actions involve cutting back the competitive species and, where possible, grazing the vegetation to more open and structurally complex vegetation communities at a range of successional stages from open grass and heath to gradations (ecotones) of native scrub and woodland. These require the targeted application of traditional vegetation management practices (see Network Rail's *Railway Sustainability Design Guide* [8] for more details) and can be summarised as follows:

Woodlands [67]

- Selective felling to remove trees that pose a risk to rail safety (e.g. close to overhead lines, diseased trees) and competitive non-native trees.
- Targeted felling to create a varied canopy structure with open glades.
- Leave deadwood where there is a low fire risk and create log piles as habitats for specialist fungi, insects and mammals.
- Replant existing woodlands and plant new woodlands with appropriate native tree species away from overhead lines and on habitats with a low existing biodiversity value, e.g. fertile, species-poor grasslands (see in Figure 33).


Figure 33: Creating habitat log piles and new woodland planting in areas that do not pose a threat to safe rail operation in Wick - Scotland's Railway © Network Rail

Grassland and scrub [68]

- Remove dense thickets of scrub to open up the grassland, aiming to leave scattered bushes to provide perches and shelter for birds.
- Remove competitive and non-native species by cutting them down or using selective herbicides where safe to do so.
- Cut the grassland in either autumn or early spring every 1 to 2 years to allow native herbaceous plant species to shed their seeds. Care needs to be taken to avoid disturbing ground-nesting birds or anthills.
- Vary the timing and location of cutting (rotation) to leave some areas uncut as overwintering habitats for insects and to provide seed heads for birds.
- Ideally remove the cut herbage as this reduces the impact of atmospheric nitrogen deposition and resulting eutrophication.

- If possible, fence in the site and graze extensively with livestock to maintain a diverse structure and floral composition. The dung from the livestock will provide an additional environment for specialised insect communities.

Heathland [69]

- Remove dense thickets of scrub to open up the heathland, aiming to leave scattered bushes to provide perches and shelter for birds.
- Remove competitive and non-native species by cutting them down or using selective herbicides where safe to do so.
- On very degraded sites, consider re-seeding bare areas with native heathland species to accelerate restoration.
- Where safe to do so, graze the heathland with livestock at very low density to create diverse vegetation structure. The dung from the livestock will provide an additional environment for specialised insect communities.
- Alternatively, cut even-aged dwarf shrub stands on a 5-to-10-year rotation to create a varied mosaic of different aged vegetation communities.
- Create small areas of bare soil as habitats for reptiles and insects.

Wetland and coastal [70]

- Where ponds and ditches have dried up and filled with silt then periodically remove this (desilting) and dense vegetation to create open, shallow water, using an excavator or by hand.
- Re-vegetate bare and eroding banks with appropriate native species by seeding or plug planting to ensure flood protection and prevent excess sediment washing into the water.
- Control blue-green algae through the use of barley straw and by preventing excessive nutrients from entering the water. The latter may require additional pollution control measures.
- Remove non-native aquatic species using mechanical, biological, or other control techniques.
- Manipulate drainage systems, where safe to do, so to ensure there is an adequate supply of water all year round.

Figure 34: Coastal Area Railway and Bridge, © Network Rail

Brownfield [71]

- Remove dense thickets of scrub to open up the vegetation, aiming to leave scattered bushes to provide perches and shelter for birds.
- Remove invasive non-native species using prescribed methods including mechanical, biological, and mechanical control.
- Remove and safely dispose of toxic substrates and hazardous materials, e.g. industrial and household rubbish.
- If necessary, fence in the site to prevent fly tipping and continued accumulation of hazardous materials.
- Re-engineer inert substrates (e.g., crushed concrete, bricks and ballast) to create varied topography, including gentle mounds and shallow scrapes.
- On very recent brownfield sites, consider re-seeding some bare areas with appropriate native species (for example cornfield annuals and dry grassland species) to accelerate restoration.

Ecological offsetting

If important habitats are permanently destroyed, action should be taken to compensate habitat damage and loss as close to the original site as possible. There are a wide range of well-researched and effective approaches for the creation of semi-natural habitats appropriate for a given location and site, with the aim of accelerating the natural process of colonisation by native plant species and overcoming localised seed limitation. These include:

i. sowing seed mixtures of native species, ideally collected from nearby semi-natural habitats

ii. spreading seed-rich cut material (green hay)

iii. planting container-grown native herbaceous species, shrubs, and trees

iv. translocating propagule-rich topsoil or turf from the area being destroyed

Providing good quality seedbeds (e.g., fine tilth that is free of competitive weed species) to encourage plant establishment is critically important to the success of habitat creation. Aftercare management is also important to deal with competition from undesirable species during the early stages of succession.

If rare or protected species or habitats are present on the lineside and are threatened by planned construction or maintenance work, their translocation may be a legal requirement (including using an “Ecosystem Hotel” approach [72]). It is also possible to translocate whole plant ecosystems, including soil, in some circumstances (see Case Study 4 in the UIC REVERSE report [1]), noting the guidance about “brown roofs” in section 4.8. Large or particularly ecologically important habitats may be gifted to regional conservation bodies, or other agreements negotiated, for the long-term management of the site.

Monitoring and evaluation

It is important to regularly monitor the effects of lineside management and restoration on habitat quality and target species in order to actively revise and improve management plans. It is also important to monitor the survival of any translocated species or habitats. There are a wide range of techniques and technologies available to do this (see chapter 5 of the *European Railways: Strategy and Actions for Biodiversity* [1]). These include earth observation using high spatial resolution multi-spectral sensors on satellites, and airborne and drone platforms (Figure 35). Repeated surveyance using these sensors can detect changes in the type and extent of habitats present on a site, and how they are responding to management actions. Light detection and ranging (LIDAR) sensors can provide additional information on the structure of habitats and vegetation. Similarly, new sensor technologies using computer vision and audio detection, together with AI, can identify plant and animal species, and how they may respond to lineside management and restoration. Finally, where it is safe to access the lineside, traditional ground surveys by skilled ecologists can provide detailed data on habitats and species. Finally, lineside habitats may provide many opportunities to engage staff in "citizen science" projects to monitor plants, butterflies, birds, and so on, provided it is safe to do so (see Case Study A8 in the UIC REVERSE report [1]).

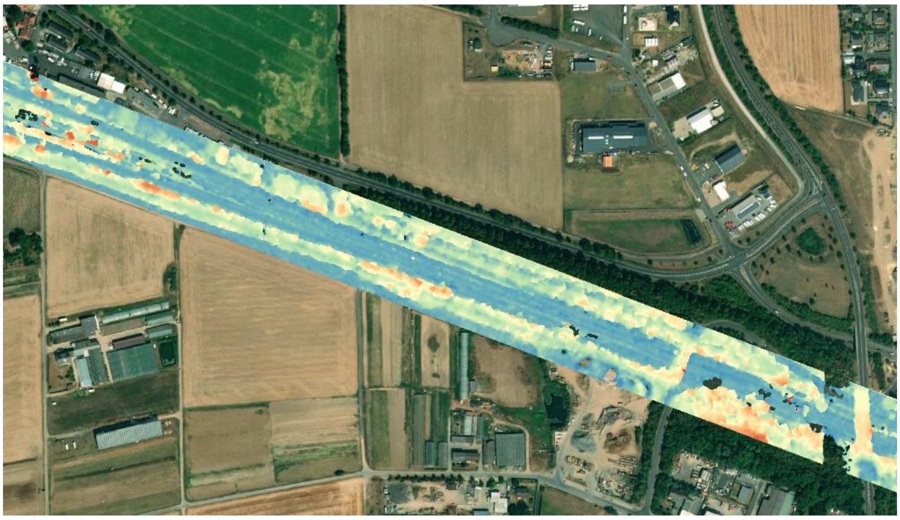


Figure 35: Mapping lineside tree populations using satellite data and artificial intelligence to identify potentially hazardous trees near the line, © Deutsche Bahn AG / LiveEO

5. CONCLUSIONS

Railways shall play a key role in fostering synergies between the priorities of the transport sector and the ecological environments they own and manage, considering the urgent need for green transport to minimise harmful emissions and support our natural heritage. UIC's Strategy and Actions for Biodiversity report calculated that the rail network already intersects more than 2,500 of the approximately 14,000 protected areas of high conservation value in Europe [1]. Therefore, there is huge potential for biodiversity enhancement projects and to be a frontrunner in providing space for wildlife to thrive.

Several European railway companies represented in the REVERSE project already incorporate biodiversity protection and conservation into their network operations and management plans. These guidelines bring together lessons learnt from the best practices on the most effective ways of managing railway assets for biodiversity. Moreover, the guidelines are intended to provide guidance for each railway key asset and to encourage other experts to work on biodiversity enhancement. The key points from these guidelines can be summarised as follows:

Enhance connectivity and create opportunities by applying the mitigation hierarchy

Applying the mitigation hierarchy to important railway assets, as they are maintained, upgraded, and re-built, embeds effective biodiversity conservation into all elements of rail business whilst ensuring the safe and reliable operation of the network. It also provides technical rail managers with a fuller understanding of how their work can support and mitigate the negative impact on biodiversity.

Gain international high-quality knowledge by sharing best practices

These guidelines demonstrate the effectiveness of the international collaborative effort between infrastructure managers and stakeholders in developing and sharing knowledge and best practices to mitigate the negative impact and maximise the benefit of railways on biodiversity.

Monitor the effectiveness of mitigation measures

How effective measures are in mitigating adverse effects on biodiversity should be monitored using reliable and repeatable approaches, systematic detailed habitat monitoring, and evaluation. Where appropriate, this should be done using smart and remote monitoring systems, and information should be openly shared among railway infrastructure managers in order to broaden and improve future approaches and practices.

Follow regulatory frameworks

These guidelines do not replace the legal requirements for appropriate environmental impact assessments, appropriate national planning regulations, and the EU's Habitats Directive. Experts shall be aware of local and national regulatory framework on the habitat management.

Seek specialist advice

Expert advice from professional ecologists and the relevant nature conservation authorities should be sought at all stages of railway asset management - design, installation, maintenance, upgrading and decommissioning. In addition to employing ecologists, railway companies should invest in training and upskilling the workforce on the importance of biodiversity and the ecosystem services it provides.

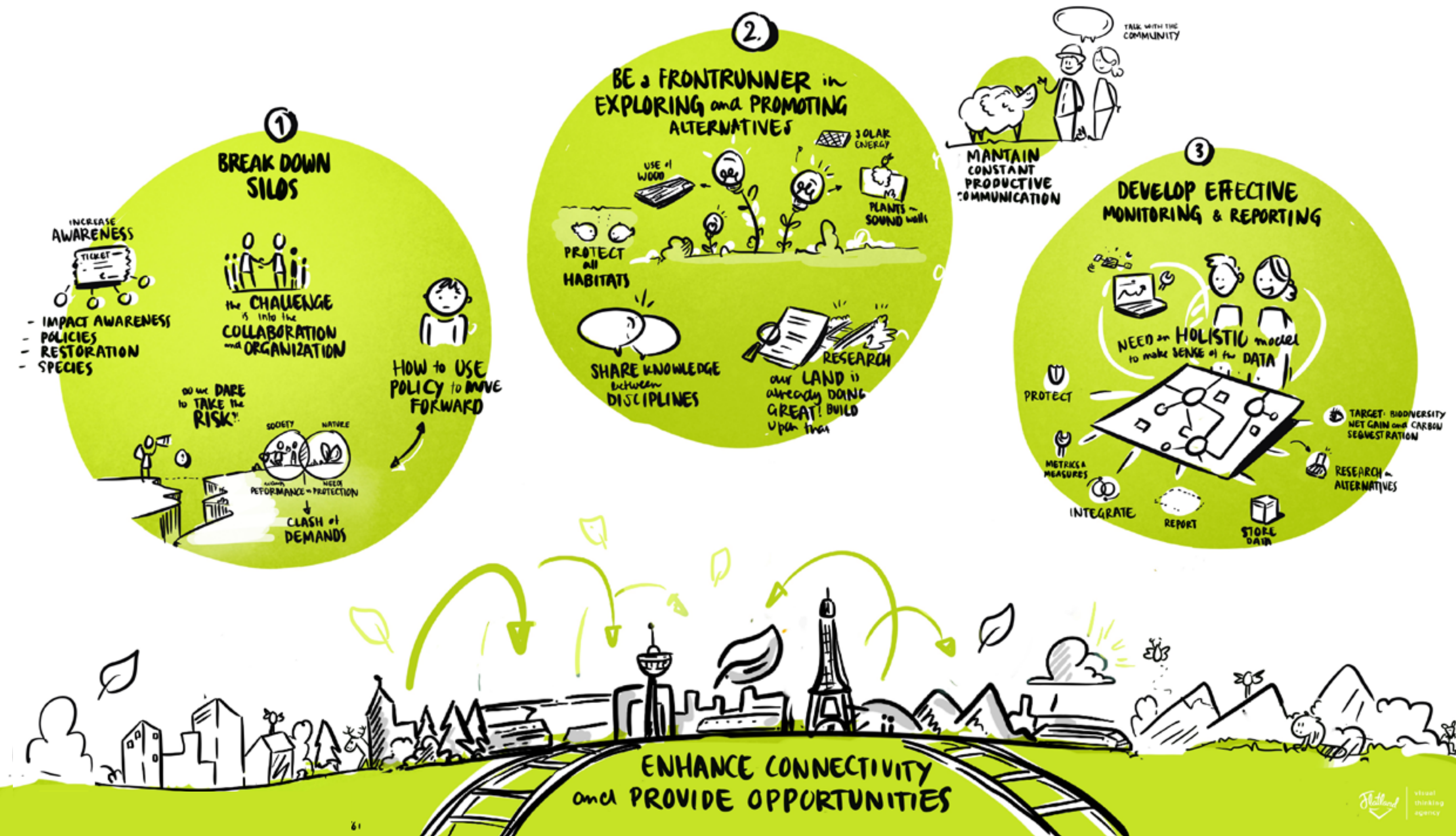
Consider the wider frame

The indirect impact on biodiversity beyond the rail network itself cannot be neglected. Extracting excessive amounts of aggregates can result in permanent habitat destruction, and the use of either European or tropical hardwood sleepers can contribute to deforestation. Sourcing materials such as steel, aluminium, and concrete and the use of energy (both renewable and fossil) also has an environmental impact.

While the scope of this guidance does not consider the indirect impact of the rail network on biodiversity, experts shall take it into account in wider sustainability strategies and planning.

Continue to explore future opportunities and trends

Following on from this guidance, UIC aims to further its work on sustainable railway management by launching the Ecosystem Valuation for Railways (ECOV4R) project. The project will focus on the valuation of ecosystem services provided by habitats and wildlife around the railway network and will demonstrate how they contribute to our lives and economies. UIC, together with its members, will also develop complementary technical guidance on the planning and construction of new lines, which is not included in this document, with the aim of ensuring that the impact on biodiversity is minimised.



6. APPENDIX - TECHNICAL LIMITATIONS FOR THE MAINTENANCE OF VEGETATION ON RAILWAYS

A detailed engineering drawing concerning vegetation limitations used by ÖBB-Infra AG for a newly constructed double-track line, including noise protection barriers, embankments, and vegetation management. It describes different track zones and overhead line safety buffers. The following drawings are shared for information purposes only and any active use should be agreed upon with ÖBB.

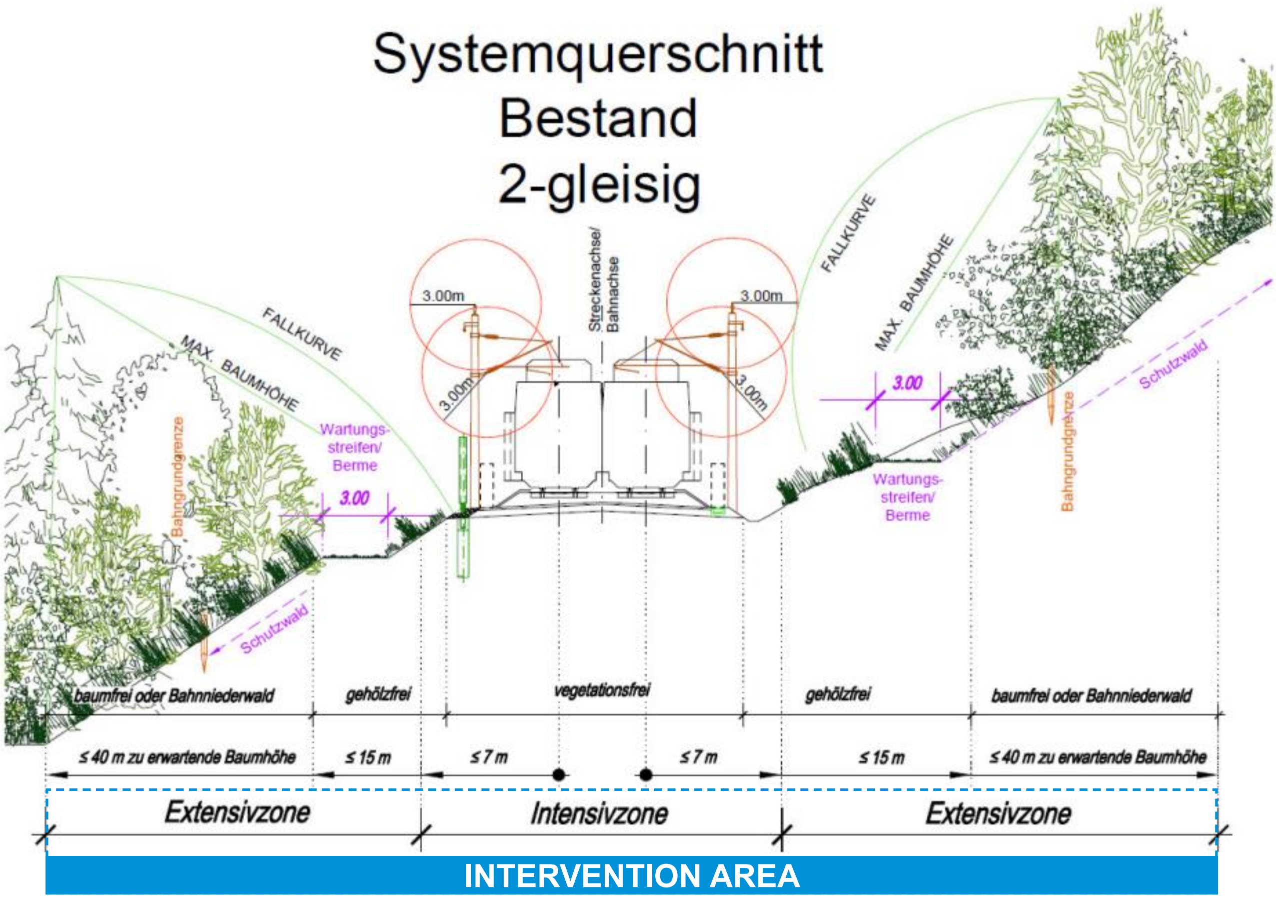


Figure 36: ÖBB-Railway track lateral cut – new built double tracked line, with noise protection embankment

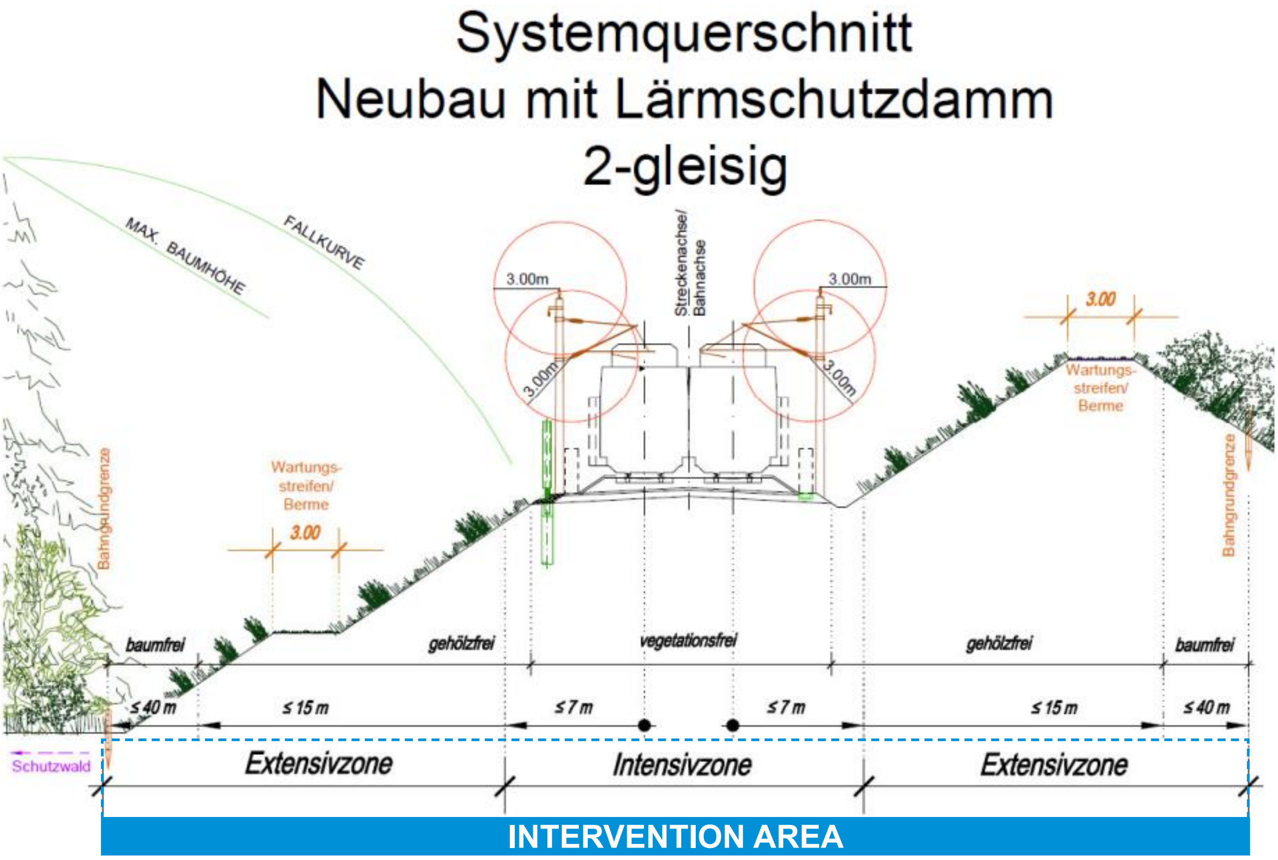


Figure 37: ÖBB-Railway track lateral cut – new built double tracked line, with noise protection embankment

ÖBB Terminology	English Translation
Systemquuerschnitt Bestand 2-gleisig	Railway Corridor System Cross-Section: Double Tracked
Fallkurve	Fall Curve of Trees
Max. Baumhöhe	Max. Height of Trees
Schutzwald	Protective Forest
Wartungsstreifen/Berme	Maintenance Berm
Bahngruundgrenze	Borderline of Railway Estate
Baumfrei oder Bahnnniederwald	Trees or Coppice Allowed
Gehötzfrei	No Trees or Coppice
Vegtationsfrei	No Vegetaton
≤40m zu erwatende Baumhöhe	Expected Height of Trees Below 40m
Streckenachse/Bahnachse	Route Axis/Railway Axis
Systemquuerschnit Neubau mit Lärmschzdamm 2-gleisig	System Cross-Section: New Construction With Noise Barrier, Double Tracked

7. FIGURES AND TABLES

8. GLOSSARY

Arboreal – referring to animals that live for all or most of their lives in trees.

Biodiversity – a contraction of “biological diversity” which refers to the multiplicity of life on Earth at all its levels, from gene variation within a population, to the number of plant, animal and fungi species and other living organisms within a habitat, and the range of ecosystems in a region.

Biome – a set of natural ecosystems and habitats that form a distinct, biogeographical unit within a similar regional climate. Examples in Europe include grasslands, tundra, deciduous and coniferous woodlands, and dry scrub.

Brownfield habitats – semi-natural populations of plants and animals that have appeared spontaneously on previously developed land.

Community – in an ecological sense, a community is a group of two or more species coexisting and interacting in the same area at the same time.

Ecotone – a transition between two or more plant communities, for example grassland, scrub and woodland.

Ecological corridor – a continuous stretch of habitat that allows the movement of species between areas and thus increases the connectivity of habitats.

Ecosystem – all of the organisms in an area (i.e., the ecological “community”) plus the physical environment (water, geology, weather) with which they interact.

Ecosystem services – the aspects and functions of ecosystems that directly benefit humans by enhancing welfare or helping economies.

Ecotone – a transitional area between two different ecological communities, for example grassland and woodland, where those two communities have species in common.

Fragmentation – the process by which contiguous ecological habitats become divided into smaller, separate patches.

Habitat – a location in which the immediate requirements of a species are met, for example a woodland where the trees support a range of wildlife. See also “Semi-natural habitats”.

Habitat restoration – the process of assisting the recovery of an ecosystem that has been degraded or damaged, usually by human activities but sometimes by natural disasters.

Habitat creation – the process of forming a new and different habitat that replaces an existing, severely degraded habitat or bare substrate.

Habitat translocation – the physical movement of a habitat from one area to another, for example by stripping the turf and subsoil from a grassland and moving it to a new location.

Invasive alien species – a species that has been moved into a habitat where it would not naturally occur and which is causing significant ecological damage or is having an economic impact.

Mitigation banking - a highly regulated system used to ensure that habitat loss from construction and other development is compensated for by the preservation and/or restoration of habitats in other areas.

Mitigation hierarchy – a best-practice approach to avoiding, minimising and offsetting negative impacts from planned developments.

Semi-natural habitats – ecological communities that look natural but have been modified by human activities.

Succession – natural changes to a plant or animal community that happens over time, for example the transformation of grassland into woodland, or bare earth being colonised.

Tilth – the state of a soil’s aggregation especially in relation to its suitability for plant growth.

Translocation – the movement of species or whole habitats from a place where they will be destroyed to a new, appropriate location.

9. AUTHORS AND ACKNOWLEDGEMENTS

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