
Fauna passages and other technical solutions

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Classification of measures to reduce barrier effect and animal mortality

Measures to reduce barrier effect and animal mortality can be in general divided into several groups:

- measures allowing safe crossing of infrastructure for animals (fauna passages)
- measures preventing animals to enter infrastructure (fences, barriers)
- measures warning animals of transport infrastructure or of approaching vehicles
- measures warning drivers about approaching animals or about accident risk sectors (warning signs, speed limitation, warning systems based on animal detection)
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General principles for proposing measures

Proposing measures to reduce barrier effect of roads, motorways and railways and specific local conditions:

• The **efficiency of a proposed measure** is the function of ecological conditions and technical solutions. Required efficiency with:
  (i) suitable ecological conditions
  (ii) suitable technical solutions
Logical and essential prerequisite, demanding equal attention to be paid to both technical solutions and characteristics of close and wider surroundings. This has a relation to the next principle.

• **Individual approach**: Taken into account the complexity of the relationship between fauna and transport infrastructure, individual approach to each measure should be the basic principle for their proposals. All general recommendations need to be always applied to specific local conditions.
• **Combination of fauna passages and fences or other barriers.** Reducing negative effects with:
  (i) measures allowing fauna to pass (fauna passages which reduce isolation of populations)
  (ii) measures preventing fauna to access the infrastructure (fencing which lowers animal mortality).
Suitable ratio should be determined in a migration study based on local conditions.

• **Solving long-term sustainability of measures:** involves not only technical lifespan of the objects, but changes in the surroundings that can radically limit or even completely cancel the functionality of fauna passages. It is therefore essential in implementation of large special fauna passages to ensure spatial protection of both close and wider surroundings. This represents the very fundamental task of integrating the issues of fragmentation into spatial planning at landscape level.

• **Economic optimization of proposed measures:** important criterion in proposing measures is cost-efficiency. It does not involve only the investment funds themselves, but also indirect effects on the environment. On the other hand, costs should be also calculated for wildlife-related accidents and for impacts of climate change related phenomena (if we extend a bridge across a watercourse to fulfil the function of a fauna passage, such a bridge will also allow to carry out the flood flows).
Complex approach to proposing technical measures

Large and costly measures such as special fauna passages: necessary to apply a complex approach, which lies in proper assessment of ecological and technical conditions, including conditions of the surroundings.

Required final classification of a fauna passage with respect to overall potential efficiency for migration is important in evaluating the permeability of entire motorway/railway sections but the overall assessment of migration potential is not the arithmetic mean of ecological and technical element. In case one of the components is unsatisfactory, the entire fauna passage is unsatisfactory, even if the second component is excellent. Partial subjectivity is involved in each classification: very important figure for ensuring optimal permeability of roads and railways.

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<th>Characteristics</th>
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<td>habitat</td>
<td>habitat type, its closer specification, quality assessment</td>
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<tr>
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<td>target animal group</td>
<td>a group of animals for which the passage is made, significance and state of migration route, its long-term perspectives</td>
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<td>secondary animal groups</td>
<td>groups that can also use the passage, significance and state of their migration routes</td>
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<tr>
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<td>supporting elements for migration</td>
<td>landscape structure, watercourses, forests, scattered green areas, ecotones, morphological shapes (ridges, valleys), etc., perspectives on sustainability</td>
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<td>B. Technical parameters</td>
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<td>dimensions</td>
<td>width, height, length, openness index index (according to passage type)</td>
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<tr>
<td></td>
<td>conveyed elements</td>
<td>watercourse, field and forest paths, etc., placement in the passage, technical solution</td>
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<td>type of surface</td>
<td>natural, artificial; soil, grassy, etc., placement of paved surfaces when conveying roads</td>
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<td>vegetation adjustments in/on the passage</td>
<td>solution of planting, species composition, placement</td>
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<td>hiding places for animals</td>
<td>type and localization of hiding places, shelters (stones, logs, branches etc.)</td>
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<td>noise-protection embankments and walls, height and material of the walls, barriers for vehicle access</td>
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<td>fencing</td>
<td>length and means of fencing the road/railway in relation to the passage</td>
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<td></td>
<td>vegetation adjustments on the road / railway</td>
<td>species composition and solution of vegetation adjustments on the road / railway as they are linked to the passage</td>
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<td>terrain adjustments outside of the road / railway</td>
<td>partial terrain adjustments (levelling off the terrain, terrain walls, etc.) with the aim to better connect the passage to the surroundings</td>
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<td>guiding structures outside of the road / railway</td>
<td>planting vegetation, connecting landscape structures to the passage</td>
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<td>keeping disturbing elements away from the road / railway</td>
<td>ground walls, vegetation belts</td>
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<td>C. Adjustments of surroundings</td>
<td>ecological conditions</td>
<td>overall assessment of ecological conditions, narrative evaluation + classification on the scale: excellent – above average – average – under average – unsatisfactory</td>
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<tr>
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<td>technical solution</td>
<td>overall assessment of technical solution; narrative evaluation + classification using the scale: excellent – above average – average – under average - unsatisfactory</td>
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<tr>
<td></td>
<td>conclusion</td>
<td>overall assessment of potential migration efficiency of the passage; narrative evaluation + classification using the scale: excellent – above average – average – under average - unsatisfactory</td>
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</table>
• **Rules for placement of fauna passages**

Placement of fauna passages should be done within migration studies. The following can be mentioned as the main principles:

- Permeability of a given section is addressed for all animal groups.

- Basic approach lies in implementing sufficient number of passages for all involved animal groups. The values represent only a framework and have to be adapted to local conditions.

- Each object under or over an infrastructure should be considered as potential fauna passage.

- When proposing measures, objects planned on the route for conveying watercourses, valleys, local roads, etc. should be used with priority and be optimized for fauna passages + supplementary new special fauna passages only when permeability of a given section is still not sufficient

- Placement of fauna passages on defined migration corridors: evaluated in a special way. In this case it is always necessary to implement suitable fauna passage and to reach its maximal optimization.
Parameters of fauna passages and other technical measures according to the requirements of particular groups of species

- Terrestrial invertebrates
  - Overpasses

= sufficiently large, providing the same soil, light and precipitation conditions as on both sides of a given road/railway → full connection of habitats can be reached

- Dimensions of green bridges (minimum width of 40 m): ensure good conditions for connectivity of populations of a whole spectrum of invertebrates

- Multi-purpose overpasses: solution ensuring connectivity for at least part of involved invertebrates but not yet a commonly used solution.

Example in Germany: their efficiency has been verified
→ useful for other species groups as well (small terrestrial mammals up to the size of fox, dormice, squirrels, bats, birds and others).

Low construction costs

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• **Underpasses**

Large underpasses: similar function as large overpasses (green bridges)

- Growth of vegetation possible = connection of habitats on both sides of the motorway

- Smaller motorway bridges: light and precipitation shadows already have some effect under the motorway, which does not allow for full growth of vegetation.

- Usability of such bridges for invertebrates quickly drops

Small motorway bridges: can be used by some species, mostly by fast moving ones

Setting minimum parameters of underpasses for such a diverse group: impossible

*The larger the openness index of an underpass and the more natural (less technically adjusted) the space under the bridge, the broader the spectrum of invertebrates that are capable of using it.*
Fishes and other aquatic animals

Transport infrastructure crossing a watercourse: always essential to keep the bi-directional migration permeability

- Optimal solution: maintain the watercourse under the bridge in a natural state, without technical modifications. If not possible: necessary to maintain the same water depth and the same speed of water flow as in the follow-up sections.

- Vertical steps or similar barriers: cannot be created by any means; necessary to emphasize keeping natural river bed and banks

- Use of tube culverts: always excluded (even in case of small streams when they are inhabited by aquatic fauna)

Rectangular culverts: better alternative to ensure the continuity of the watercourse from the aspect of fish migration

+ plate-shape bottom profile recommended for rectangular culverts: ensures sufficient water depth in periods of drought, creates a gradual transition between aquatic environment and dry banks

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Amphibians

- Collisions with transport infrastructure:
  - during spring migration to places of reproduction
  - during the migration of adults and juveniles back to their terrestrial habitats
- All bridges over watercourses including culverts should be made permeable for amphibians → optimal to maintain the stream and its banks in natural state
- Bridges (culverts) with running water without dry banks: Completely unsuitable for amphibian migration
- Technical adjustments to streams: make the stream bed with a plate shape with slight bank slopes
  Tube culverts usually not optimal solution for amphibian migration: absence of dry, walkable banks and lack of light → Only tube culverts of larger diameters

Always prefer rectangular culverts that constitute an optimal solution for amphibians
- Vertical steps, sedimentation sumps on the inflow or stilling basins to moderate water energy under the culvert outflow: fundamental problem for amphibians

→ often completely eliminate access of amphibians to the culvert, sometimes they even form deadly traps

- If no suitable bridge or culvert exists in the place of important amphibian migration: possible to overcome the transport infrastructure by a special passage (amphibian tunnel)

- If permeability of a road not sufficiently ensured between terrestrial habitats and places of reproduction: build new wetlands for reproduction on the “terrestrial habitat side” of the road, so that amphibians do not have to cross the road.
• Overpasses

Most suitable solution for most reptiles

- Important condition: direct continuity to the used habitat and suitable vegetation cover on the overpass

- Overpasses of the green bridge type (width of 40 m or more) = optimal solution, but even narrow overpasses with at least grassy vegetation and some hiding opportunities are sufficient
Underpasses

Suitable solution especially in species bound to aquatic environment

Always essential in this case that the watercourse including its banks remains in natural state with minimum technical adjustments

- Requirements very similar to those of amphibians
- Utilization of passages in xerophytic species limited by lack of vegetation, hiding places and with culverts also by lack of light
- Only sufficiently large bridges without technical adjustments underneath and covered by vegetation can be fully functional

Smaller bridges: the function of vegetation needs to be replaced by placement of elements that create hiding opportunities and allow reptiles to overcome otherwise unsuitable environment.

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- Birds

No special fauna passages constructed

- Should be considered when fauna passages for other animal groups are being built
  Especially important: bridges over watercourses → birds can fly under the bridge

- Transport infrastructure and traffic: many other effects:
  • Crossing of transport infrastructure with a bird migration corridor
  • Impact on a wetland by transport infrastructure
  • Attractive (fruit-bearing) low vegetation on both sides of a road (resulting mortality of smaller species then often causes also higher mortality of birds of prey)
  • High concentrations of small rodents in road edges (especially owls are susceptible)
  • Concentration of insects near road lights can attract nocturnal insectivorous birds
  • Roads or other infrastructure elements equipped with different types of protection walls, especially when transparent material is used.

+ Transportation = disturbance → eliminate visual and noise disturbances by suitably proposed protection walls

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Terrestrial mammals up to the size of fox and badger

- **Overpasses**

Field and forest paths leading over a motorway. These bridges are usually used as fauna passages only very rarely, but still some species are able to use these overpasses, for example fox, hare or wildcat.

Field and forest paths leading over a motorway and widened by a green strip on both sides. Here the range of species able to use such passage is significantly broadened. All species of this group are capable of using this overpass.

**Green bridges.** All species of small mammals (except semiaquatic ones) use these measures.
• Underpasses

Culverts – when suitably constructed and placed they are used by most species with the exception of underground insectivores, hare and wildcat

Bridges up to 5 m wide - when suitably constructed and placed they are used by most species with the exception of underground insectivores and hare

Bridges wider than 5 m – are used by all representatives of this group, use by underground insectivores will depend on means of compacting
Otter and other semiaquatic animals

- Often migrate along watercourses: important that all bridges over streams are permeable for them

Most of them do not use bridges without existing dry banks. Unsuitable bridges then cause the animals migrating along streams to cross roads.

- Sufficiently wide dry banks under all bridges where transport infrastructure crosses a watercourse.

Bridges where the watercourse has natural banks without technical adjustments on both sides are the preferred solution. If not possible, create dry banks from a stony paving

- Watercourse with occurrence of otter crossing a transport infrastructure via an unsuitable bridge or culvert: satisfactory solution can be a parallel “otter tunnel” with a diameter of 30 cm
Mammals living on trees

Special passages for this group: based on connecting tree crowns on both sides of a road/motorway → system of ropes with a shelter to hide from predators

Effectivity of such measures is still being verified, but it can represent relatively cheap measures with high efficiency

Examples from other fields showing good efficiency of such measures exist (for example with dormice). A good solution for this group can be adaptation of small bridges over motorways (bridges for unpaved roads). If such a bridge was slightly widened and a row of bushes was planted on both sides, a functional passage even for species living in tree crowns would be ensured. Moreover, such a bridge would be of more multifunctional use – it would be used by smaller mammals (up to the size of fox and badger), small birds, bats and many other animals as well.
Bats

- Research studies: species which avoid open spaces almost never overcome a motorway by simply flying, but use either overpasses with vegetation or sufficiently large underpasses → good enough solution might be both-sided rows of bushes on a bridge where unpaved road overcomes a motorway.

- Higher mortality: in places where a road/motorway crosses a watercourse with bankside vegetation
  Solutions: a bridge with sufficient capacity (bats fly under the road), or high enough walls on the bridge

- Lighting attracts insects and bats then use the surroundings for feeding. Especially lighting along roads near water bodies can cause high bat mortality.
Medium-sized mammals (European Roe Deer, Wild Boar)

These species are widely spread and inhabit both forest and agricultural landscape. The group is much more demanding than smaller mammals (up to the size of fox and badger) when it comes to using fauna passages. Due to that, Roe Deer and Wild Boar cover up the requirements of much broader animal spectrum. Requirements to ensure permeability for these species represent a usual standard in a landscape without the occurrence of large mammals (Red Deer, Eurasian Moose, large carnivores).

Overpasses

Field and forest paths leading over a motorway – it has been proven by monitoring (citations?) that these bridges are usually not usable as fauna passages for this group.

Field and forest paths leading over a motorway and widened by a green strip on both sides - these bridges can be (with a suitable design) used by this group of species

Green bridges: represent an ideal fauna passage for this group.

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• Underpasses

Culverts – are not usable for this group of animals.
Bridges up to 5 m wide – are used by this group only exceptionally.
Bridges wider than 5 m – are in case of suitable design used by this group. Width is not the only important factor. It has been verified that it is usually possible to express suitability of a bridge by openness index of its passage.
Large mammals (Red Deer, Moose, large carnivores, European Bison)

Large areas in low population densities; mostly rare and protected, fragmentation of their environment can cause their extinction in vast areas. Long movements and migrations in distances of hundreds of kilometres
- Sensitive to disturbances, highest requirements for parameters of fauna passages.
- Determining density of passages which will be sufficient for long term survival of the species: small population abundances → low frequency of using the passages
- Recommendations vary in different areas, which can be partly caused by distinct environmental conditions and different behaviour of animals in these areas. Another important factor that has to be taken into account in case of large mammals is traffic safety, since collisions with these animals are very dangerous for drivers.
Ensuring permeability through transport infrastructure for this group:

✓ In areas of permanent occurrence: sufficient density of passages needs to be planned, so that original home ranges are not disrupted

✓ In areas where only migratory/dispersal occurrence is expected, it is necessary to define migration corridors in the landscape their significance and to propose fauna passages in the most suitable (with respect to functionality) places of crossings between transport infrastructure and the migration corridors. The use of fences and other leading structures is very important to improve the function of fauna passages for large mammals, as well as managing functionality of migration corridors at landscape level.

Technical parameters of passages are always an essential question in this group of animals. It does not concern just parameters, but type of construction, used materials and other factors as well.
Thank you!