GREEN INFRASTRUCTURE IN-DEPTH CASE ANALYSIS

THEME 6: GREY INFRASTRUCTURE MITIGATION

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1 Introduction

This case analysis centres on green infrastructure policy initiatives aiming to mitigate the negative effects of grey infrastructure on species communities occupying the surrounding landscapes. Grey infrastructure is a general term referring to man-made, constructed assets and can be specified via the usage of categories, namely (adapted from Natural Economy Northwest, 2009):

- Transport infrastructure (e.g. motorways, roads, car parks, railways, ports/freight terminals, canals, airports, dams);
- Commercial infrastructure (e.g. factories and industrial offices, retail, mines and quarries);
- Utilities and distribution of services (e.g. sewers, cables, water and gas pipelines, waste management and landfills, sewage treatment, energy generation);
- Social infrastructure (e.g. schools, hospitals, sports buildings, housing, coastal defences and flood control, government establishments).

Anthropogenic barriers such as those mentioned above have the potential to negatively interfere with wildlife species, particularly those having sizable home ranges and specific seasonal migration traditions. The often impermeable nature of man-made blockages can restrict exchanges between individual populations and reduce the feasibility of migration.

Transport infrastructure, in particular, has both direct and indirect effects on wildlife populations. Most obviously, animal populations can suffer casualties from auto accidents; in the US alone, more than 1.2 million deer die annually due to traffic related injuries (Bissonette 2002). Yet more consequential are the indirect effects of transport infrastructure, including habitat loss and reduced habitat quality, increases in habitat fragmentation with associated increases in edge density and habitat disconnectedness as well as barrier and cumulative effects (Bissonette 2002). These and other effects have been explored in depth in the COST 341 European review on 'Habitat fragmentation due to transport infrastructure' (Trocmé et al., 2003). The transport category of grey infrastructure is therefore the primary focus of this analysis and the selected case studies.

To counteract these negative effects on biodiversity, Green Infrastructure offering improved habitat connectivity is increasingly being employed as an explicit part of wildlife and landscape management (Woess et al., 2002) and being incorporated into regional spatial planning processes. It should be clarified that connective elements are not necessarily physically continuous and are therefore best defined by functionality. By creating such connections between habitats, Green Infrastructure serves to facilitate the dispersal, migration and exchange of genetic material between affected populations.

Many measures exist to achieve these aims, including overpasses (green bridges), fauna tunnels or agricultural underpasses, oversized viaducts, fencing and fish ladders. Within the context of this analysis, the distinction between wildlife passages and wildlife crossings distinguished in Austria's

Directive on Wildlife Protection in Road Construction (see first case study) will be utilised. Wildlife passages therefore include artificial but not specifically dedicated elements such as viaducts, tunnels or agricultural underpasses. Wildlife crossings refer to elements put specifically in place for wildlife migration, e.g. green bridges.

Compensation measures to mitigate the effects of habitat fragmentation induced by grey infrastructure are also being recognised in European national planning legislation, including provisions for, for example, digging new waterholes and ponds where these have been lost by the construction of a road or railway, planting new forests to substitute areas cleared for infrastructure development and planting shrubbery with fruits and berries to replace wood edges destroyed during infrastructure construction (European Commission, 2000).

This analysis focuses on three examples addressing the negative effects on wildlife of grey infrastructure via the use of Green Infrastructure. The primary example looked at in this analysis, wildlife crossings in Austria, was chosen for its representativeness of the measures considered most relevant to this theme. Specifically, the case illustrates how the demands of conservation organisations to develop new standards to address the development of wildlife crossings and passages and the implementation of wildlife protection measures in relation to road construction inspired the release of a wildlife protection directive for road construction in 2006. The success of this directive and its widespread national implementation has served as an example for other countries wishing to incorporate wildlife considerations in their planning policies.

An additional two examples have been selected for analysis which illustrate alternative approaches to grey infrastructure mitigation, while still following the same broad objectives. The first of these examples, the 1993 Traffic Action Plan in Denmark, addresses planning aspects of grey infrastructure and mandates that conservation orders are respected and assessed in establishing new transport infrastructure. The plan goes beyond assessment, however, and emphasises the importance of mitigation measures to compensate for habitat fragmentation. Finally, the Multi-Annual Defragmentation Programme adopted in the Netherlands in 2004, aims to remove the most important barriers for the National Ecological Network presented by the country's dense road, rail and waterway infrastructure.

The mitigation of impacts from energy and electricity distribution networks through a strategic approach relying on green infrastructure is outside the focus on this analysis. A few selected examples suggesting a number of ways to approach addressing the adverse impacts power lines or energy distribution networks may have on Green Infrastructure are, however, highlighted in the general conclusions of this analysis.

2 Overview of Initiatives

2.1. Lead Initiative: Directive on wildlife protection in road construction, Austria

In Austria, the initiative to develop new standards for the development of wildlife crossings in relation to road construction began in the early 1990s at the demand of conservation organisations. Though a directive on wildlife protection already existed as a regulation for road construction, it was perceived as being too general (e.g. no standards on the required width) and having major gaps (e.g. site selection and design). Consequently, in 1998 a scientific study (Völk et al., 2001) was launched to develop criteria, indicators and minimum standards for the development of wildlife corridors in road construction, to guarantee a more effective development of such corridors (in terms of biodiversity benefits as well as cost savings) and establish a basis of scientific evidence.

The new wildlife protection directive for road construction (*RSV Richtlinie 3.01 'Wildschutz'*) was developed based on the results of the scientific study described above and on international scientific literature. It was launched in 2006 and addresses the development of wildlife crossings, wildlife passages, implementation of wildlife protection measures, traffic signs, warning systems, fences and other barriers (e.g. slopes and trenches) for wildlife protection. Currently the Directive is only legally binding for the federal road network. A regional state applied its veto to avoid the Directive's implementation for roads lying within the responsibility of the states due to fear of the potential financial costs that would be incurred.

2.2. Secondary Initiative I: Traffic Action Plan (1993), Denmark

Denmark's Traffic Action Plan [*Trafik 2005*], adopted in 1993, seeks to ensure that conservation orders are respected in planning new transport infrastructure and that impacts of new road construction on the landscape and nature are thoroughly assessed. During the planning and EIA process for the construction of transport infrastructure, one of the priorities for decisions that seek to avoid, mitigate and compensate for habitat fragmentation is dispersal corridors in fragmented areas. Mitigation measures used include both wildlife passages and crossings, including overpasses, underpasses, level crossings and fencing. On less busy roads with good visibility, speed limits and warning signs have been applied to reduce the risk of collisions with fauna. Fauna passages have also been used to reduce the barrier effects of roads and railways. Compensation measures applied include the digging of new waterholes and ponds where these have been lost by the construction of a road or railway, planting of new forest to substitute areas cleared for infrastructure development, and planting shrubbery with fruits and berries to replace wood edges destroyed during infrastructure construction (European Commission, 2000). While the lead example is primarily concerned with delivering improved ecosystem resilience and connecting habitats, this initiative focuses more exclusively on the later point and the positive potential effects for affected species.

2.3. Secondary Initiative II: Multi-Annual Defragmentation Programme, the Netherlands

In 2004, the Multi-Annual Defragmentation Programme (*Meerjarenprogramma Ontsnippering*) was adopted by the national government in the Netherlands. During the period 2005–2018, the programme aims to remove the most important barriers for the National Ecological Network formed by the country's dense road and rail infrastructure as well as major waterways (Ministerie van Verkeer en Waterstaat, 2004). Relevant defragmentation projects include wildlife passages and crossings, specifically looking at fauna tunnels, green bridges, fish ladders, oversized viaducts and wildlife-friendly verges and river banks. To date, the obstacles in every province have been mapped and prioritised and a total of 208 projects having being approved. This initiative focuses on ecosystem resilience and improved functional habitat connectivity for targeted species.

3 Directive on Wildlife Protection in Road Construction

3.1. General Background Information

In Austria, environmental standards are mainly developed by private standardisation organisations and the Austrian Standards Institute (*Österreichisches Normeninsitut – ON*). Commonly, the first are not-for-profit organisations which consist of representatives of the private sector, government, academic institutions and, occasionally, civil society. Environmental standards are not legally binding per se, although their implementation is strongly encouraged. In the context of road construction, the main organisation responsible is the Austrian association for research on road, rail and transport (*Forschungsgesellschaft Strasse und Verkehr* – FSV). When developing directives and regulations for road construction (RVS), the responsible FSV committee includes representatives of the Ministry for Traffic, Innovation and Technology (BMVIT), the Ministry of the Environment, regional states, ASFINAG, the private sector, research institutions and civil society (WWF Austria).

The administration of the federal road network is the responsibility of ASFINAG, a public company centrally managing Austria's motorways and concessions. ASFINAG is responsible for the planning, implementation and maintenance of Austria's motorways and funds itself through toll collection and motorway vignettes.

BMVIT is mainly responsible for determining which environmental standards become compulsory for road construction by releasing a legal ordinance or internal departmental notes. If a project is subject to an EIA, the Ministry of Environment (BMFLUW) has the right to state its opinion but cannot create any legal obligation. On the other hand, nature conservation is the responsibility of the regional states, and every state has its own nature conservation act. Consequently, for any project with likely impact on wild flora and fauna the BMVIT has also to get the authorisation of the regional state affected.

The initiative to develop new standards for the development of wildlife corridors (*Wildtierpassagen*) in relation to road construction was started by the BMVIT. The first wild-animal crossings (*Wildtierquerungen*) were demanded by conservation organisations and developed in the early 1990s. At that time, the construction of the federal motorway A4 between Vienna and Budapest resulted into the development of six crossings with a width of 100 m and rather close to each other, but without any scientific evidence regarding their efficiency, according to BMVIT. Although a RSV directive on wildlife protection already existed, it was perceived as too general (e.g. no standards on the required width) and had major gaps (e.g. site selection and design).

3.2. Specific Objectives

Consequently, in 1998 the BMVIT launched a scientific study (Völk et al., 2001) to develop criteria, indicators and minimum standards for the development of wildlife corridors in road construction to guarantee a more efficient development of such corridors (in terms of biodiversity benefits as well as cost savings) and based on scientific evidence. Carried out by a wildlife ecologist of the University of Natural Resources and Life Sciences in Vienna, the study had two main objectives: 1) to analyse the effective need for wildlife corridors for the federal road system, and 2) to determine the required width for wildlife/green bridges based on scientific data. It focused on analysing what was required to guarantee the permeability of landscape for wild large mammals, whereas small fauna, amphibians and birds were excluded. The main approaches and deliverables of the study included determining the status quo of existing corridors by analysing about 700 artificial structures, developing a database of corridors, checklists for planning purposes, defining minimum standards to achieve the desired permeability (statistical analysis) and recommendations on restoration measures.

The new wildlife protection directive for road construction (*RVS 3:01 'Wildschutz'*) was developed based on the results of the scientific study described above and on international scientific literature. It was launched in 2006 and addresses aspects the development of wildlife crossings, wildlife passages, implementation of wildlife protection measures, traffic signs, warning systems, fences and other barriers (e.g. slopes and trenches) for wildlife protection.

Minimum standards for wildlife crossings apply to both roads and railway tracks, and in particular for:

- Roads with full-barrier effect:
  - New sections consisting of four or more lanes and roads and fenced above 2 km in length;
  - Roads with an average daily traffic of more than 5,000 vehicles, if a railway track runs in parallel in a distance up to 50 m, and traffic of 120–300 trains per 24 hours;
- Roads which need to be retro-fitted according to the BMVIT and the responsible regional government;
- Railway construction and expansion projects, if a strong barrier effect of 120 units/24 hours is given.

For the construction of new roads, the permeability of wildlife shall be ensured by implementing all category A for supra-regional wildlife corridors (see 3.3 Green Infrastructure elements below), and regularly provide category B and C elements:

- Minimum for category B: Maximum distance of 10 km (as sum of A+B categories), if an exchange of wildlife of regional and supra-regional importance takes place. The distance between two category B structures shall not fall below 2 km.
- Minimum for category C: on average every 2 km a wildlife passage or crossing (as sum A + B + C categories). The maximum distance between all the WTP shall not exceed 3 km.

As regards the retro-fitting of existing motorways based on the study by Völk et al. (2001) and on further research by Prosser (2005), the need for additional 19 category A green bridges was identified (minus already existing bridges and based on the most recent scientific evidence).

In addition, the Directive provides detailed guidance on the location and design of wildlife passages as well as the implementation of "guiding" structures such as hedges, watercourses etc.

Currently *RVS 3:01 'Wildschutz'* is only legally binding for the construction of new federal roads, declared as such through a departmental note issued by the BMVIT to ASFINAG. A regional state applied its veto to avoid the Directive's implementation for roads lying within the responsibility of the states due to fear of potential high financial costs.

3.3. Green Infrastructure Elements

The Directive distinguishes between wildlife passages (*Wildtierpassagen*) and wildlife crossings (*Wildtierquerungen*). Wildlife passages include artificial but not specifically dedicated elements such as viaducts, tunnels and agricultural underpasses. Wildlife crossings refer to elements put specifically in place for wildlife migration, e.g. green bridges.

RSV 3.01 Wildlife Protection recognises three types of wildlife crossings and passages:

- Category A (reference value: 80 m width): for all supra-regional wildlife corridors according to regional wildlife corridor maps;
- Category B (reference value: 50 m width): for regional wildlife corridors;
- Category C (reference value: 25 m wide): for locally important wildlife exchanges.

The definition of these categories is flexible to a limited extent, depending on local circumstances (e.g. increased width for asphalt forest roads).

3.4. Implementation Costs

The recently built wildlife passages which follow the new standards, the green bridge Pöttsching (90 m wide and 30 m long) on the S4 in Burgenland[1] and the green bridge Schütt (92 m wide and 30 m long) on the existing and heavily trafficked A2 in Kärnten, amounted to €3 millionand €2 million respectively, including all arising costs. These include 20% VAT and project planning and supervision costs of about 10% of the overall amount. Not included are any costs arising on spatial planning to secure the wider efficiency of the green bridges, which are carried by the regional states. According to ASFINAG, the figures above represent a good average of costs likely occurring for the construction of similar green bridges across existing roads in Austria. The costs incurred per square meter for the Pöttsching and Schütt bridges were as follows:

- Pöttsching: €1,111/$m^{2;}$
- Schütt: €726/m^2.

Green Bridge Pöttsching was completely financed by ASFINAG, whereas Schütt was partly financed by ASFINAG (49%, or €980,000), LIFE+ (36.5%, or €730,000) and the regional state of Kärnten (14.5%, or €290,000).

[1] Pöttsching was built over the existing S4motorway but was designed to be larger than was necessary, taking into account the planned expansion of the road.

Table 3.4.1: Overview costs (total & per Green Infrastructure element) / Cost associated with the implementation of the initiative.

	Total (Local Currency)	Core areas	Restoration areas	Sustainable use / ecosystem service zones	Green urban and peri-urban areas	Natural connectivity	Artificial connectivity features	Comments
Total Costs							€5 million	– Includes all arising costs, including 20% VAT and planning/supervision costs for the *Pöttsching and Schütt bridges*. – Not included are any costs arising on spatial planning to secure the wider efficiency of the green bridges, which are carried by the regional states. – These figures represent a good average of costs likely occurring for the construction of similar green bridges in Austria which are also to be built over already existing freeways. Green bridges constructed alongside the development of new motorways can be expected to incur lower costs. Source: Eidgenössische Finanzkontrolle (2007).
Time covered by total costs (years)								
Annualised costs								
Area covered [ha]								
Cost per hectare							Pöttsching bridge: €1,111/m^2 Schütt bridge: €726/m^2	– Price calculated per square meter. Source: Eidgenössische Finanzkontrolle (2007).
Financial Costs (list any details e.g. establishing management bodies)							€500,000	– Approximately 10% of total costs went to project planning and supervision. Source: Eidgenössische Finanzkontrolle (2007).

Opportunity costs (uncompensated) (list any details e.g. foregone resource use)								

Table 3.4.2: Detailed costs.

FINANCIAL COSTS		
	Cost	**Comments**
One-Off Costs		
Administrative, management and information costs		
• Establishing management bodies		
• Surveys		
• Research		
• Consultation		
• Management plans	Part of €500,000	Approximately 10% of the total costs were for project planning and supervision. Thus, this sum is divided between this category of one-off costs and supervision(ongoing - see below). Source: Eidgenössische Finanzkontrolle (2007).
• Land purchase:		
• Restoring GI:		
Costs of green infrastructure provision		
• Land purchase		
• One-off compensation payments		
• Creation of green infrastructure elements	€4.5 million	Approximate cost for the construction of the Pöttsching and Schütt bridges, including 20% VAT but excluding spatial planning costs. Source: Eidgenössische Finanzkontrolle (2007).
• Restoration of green infrastructure		
Ongoing Costs		
Administrative, management and information costs	Part of €500,000	Approximately 10% of the total costs were for project planning and supervision. Thus, this sum is divided between this category of ongoing costs and project planning(one-off – see above). Source: Eidgenössische Finanzkontrolle (2007).
• Running of administrative bodies		
• Monitoring		
• Ongoing management planning		
• Communications		
• Managing sites:		
Costs of green infrastructure provision		
• Maintenance of green infrastructure		
• Costs of management agreements		
• Costs of protective actions		

3.5 Observed and/or Projected Impacts

Biodiversity Benefits

A scientific analysis of the effectiveness of wildlife crossings and passages is not mandatory in Austria. When developing the Directive, the different stakeholders decided not to make the monitoring obligatory as this could give the impression that the experts were not sure whether the proposed structure would be effective. However, a wider range of analyses on mobility and gene flow axes was carried out to support the development of wildlife corridors (see references in Völk and Reiss-Enz, 2008) and is still ongoing.

Based on the feasibility and scoping studies conducted before revising the Austrian law, however, the scientific consensus was that connections between habitat fragments caused by transport infrastructure were crucial to the persistence of many species and populations and that the foreseen wildlife crossings and passages could play a crucial role in maintaining ecosystem functions. Particularly, bears and deer have already been seen utilising the crossings (green bridges). On the basis of further scientific studies, the connective elements can be expected to provide an opportunity for species to traverse through habitat not suitable for taking up permanent residency in order to identify more suitable habitats, disperse from natal areas, escape predation and other dangers, locate mates and access habitats needed seasonally or in different life stages (Hennings and Soll, 2010).

Regarding monitoring, ASFINAG possesses an inventory of all wildlife crossings, based on the Völk et al.(2001) study. It is responsible for checking the crossings' functionality every two years, based on a standardised questionnaire and as part of the monitoring system of all engineering constructions (RVS 13.71). Wildlife passages are also required to be checked every five years by a wildlife ecologist. ASFINAG is currently overhauling its monitoring concept. In addition, in some cases a couple of years after the opening of the road the BMVIT controls whether measures envisaged by the EIA have been adequately implemented. To date, however, no (quantifiable) conclusions can be drawn from these monitoring instruments as their implementation is not considered sufficiently advanced at this stage.

Socio-Economic Benefits

The wildlife crossings are foreseen to reduce the number of auto accidents caused by collisions with red deer and other wildlife species by providing an alternative route to cross the large motorways (Eidgenössische Finanzkontrolle 2007).

Table 3.5.1: Overview of biodiversity, ecosystem service and socio-economic benefits.

Biodiversity Benefits		
Species	**Habitats**	**Genetic Diversity**
The Pöttsching bridge provides an international migration path for red deer, leading from the Carpathian Mountains over Styria to the Danube region into Hungary.	Potentially strengthens ecosystem resilience by increasing functional connectivity and habitat area, as well as reducing fragmentation.	Enables the mixing of various, otherwise segregated wildlife populations who were previously incapable of easily crossing the large motorways.

Source: Eidgenössische Finanzkontrolle (2007).

Ecosystem Service/Socio-Economic Benefits	
Provisioning	
Regulating	
Cultural	
Supporting	Increased provision of and connection between habitats, potentially improving phylogentic diversity
Wider socio-economic benefits (e.g. fuelling economic activity, job creation, health benefits**)**	Reduction in the number of auto accidents caused by collisions with deer and other wildlife species and resultant human injuries. Supports regional economic growth via the large financial investments necessary for constructing e.g. green bridges (during the construction phase).

Source: Eidgenössische Finanzkontrolle (2007).

3.6. Observed and/or Projected Economic Impacts

No assessment publicly available.

3.7. Recent Developments and Outlook

To ensure long-term effectiveness of the elements, the need to establish and maintain "guiding" structures has been identified. In this regard, it is considered important that the wildlife corridors are covered by spatial planning regulations. ASFINAG is only responsible for the development and maintenance of elements directly related to the road construction, whereas spatial planning falls within the competences of the regional states, districts and municipalities. Depending on the regional states there are significant differences on how these competences are applied. ASFINAG and other actors are concerned that without the adequate provision of guidance structures and the coverage of wildlife corridors in regional and local spatial planning, the long-term effectiveness of the initiative cannot be guaranteed. These concerns are linked to cases where land close to green bridges was rededicated from green space to industry area by municipalities, almost nullifying the effectiveness of the element. A strategic partnership between the Austrian Federal Forest Holding (Österreichische Bundesforste AG), the regional hunting associations, BMVIT, ASFINAG, WWF, Distelverein and the University of Natural Resources and Life Sciences (Strategische Partnerschaft Lebensraumvernetzung) aims to ensure an effective habitat network across regional states and involving different sectors. In this regard, the partnership has committed itself to supporting the integration of wildlife corridors development into supra-regional, regional and local spatial planning. It was successful in initiating such a process in the regional state Steiermark and first assessments in Oberösterreich, Kärnten and Tirol.

The Directive above mainly focuses on wild large mammals, particularly wild game animals. The protection of amphibians in road management is covered by a separate directive (RVS 3.04), and directives on wild birds and small fauna are under development.

3.8. Summary

GREEN INFRASTRUCTURE BENEFITS	
Ecosystem resilience	✓
Climate change adaptation	
Disaster prevention	
Ecosystem service provision	✓
Main indicators for measuring ecosystem service provision	
1. Number of species by which the Green Infrastructure element is used	
2. Phylogenetic diversity	
3. Conservation status of habitats and species	

3.9 Contact Details

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4 Comparable Initiatives

1. Policy Initiative

Traffic Action Plan [*Trafik 2005*], Denmark (1993).

2. General Background Information

The 1993 Traffic Action Plan provides for the construction of wildlife crossings across new roads, including the power of compulsory purchase of the necessary land. During the planning and EIA process for the construction of transport infrastructure, one of the priorities for decisions that seek to avoid, mitigate and compensate for habitat fragmentation is dispersal corridors in fragmented areas. Mitigation measures used include wildlife crossings and passages, specifically overpasses, underpasses, level crossings and fencing. On less busy roads with good visibility, speed limits and warning signs have been applied to reduce the risk of collisions with fauna.

Compensation measures applied include the digging of new waterholes and ponds where these have been lost by the construction of a road or railway, planting of new forest to substitute areas cleared for infrastructure development and planting shrubbery with fruits and berries to replace wood edges destroyed during infrastructure construction (European Commission, 2000). General guidelines on creating wildlife corridors and passages have been developed by the Danish Road Directorate, Ministry of Transport and Energy in cooperation with the Danish Forest and Nature Agency under the Ministry of Environment and the National Environmental Research Institute, University of Aarhus in Denmark (European Commission, 2000).

3. Specific Objectives

The Traffic Action Plan seeks to ensure that conservation orders are respected in planning new transport infrastructure and that impacts of new roads on the landscape, human health and nature are thoroughly assessed. Specifically, 4% of private car passengers are aimed to be transferred to walking ad cycling by 2005, leading to a 30% increase in bicycle traffic and corresponding reductions in greenhouse gas emissions. Consideration is also to be given to large cohesive, undisturbed landscapes to ensure they remain as free from noise as possible. The plan notes the importance of giving animals the opportunity of passage through the establishment of wildlife crossings across infrastructure constructions, in particular in relation to road constructions in river valleys and ecological corridors (Ministry of the Environment, 2003a).

4. Green Infrastructure Elements

Artificial connectivity features which are designed to assist species in overcoming artificial barriers created by roads (wildlife crossings and passages), specifically overpasses, underpasses, level crossings and fencing.

5. Implementation Costs

A calculation of the costs of wildlife crossings indicates that it is cheaper to make such crossings when constructing new roads and railways than it is to decrease the barrier effect of existing transport infrastructure (European Commission, 2000). There have also been initiatives undertaken by farmers and hunters with their own funding, e.g. digging waterholes, although most new and re-established waterholes are the result of work by the counties (European Commission, 2000). National experts contacted also noted that a number of interesting projects are being carried out through local initiatives at the council/municipal level to develop wildlife crossings, prevent fauna being killed through collisions with road traffic etc. More detailed cost estimates on these or other aspects, e.g. from insurance companies, were not found with regards to this initiative. However, national estimates of the value of damages incurred as a result of wildlife collisions are outlined in the general conclusions of this chapter.

6. Observed and/or Projected Impacts

In Denmark, mitigation measures have been concentrated on animals such as the otter, amphibians and roe deer (European Commission, 2000). The establishment of wildlife crossings and passages in association with road installations and weirs was found to have reduced the number of traffic caused deaths of several mammals, such as the otter (Ministry of the Environment, 2003b). The effectiveness of wildlife passages and crossings is mainly related to their positioning in relation to animal dispersal routes rather than the design or dimensions of the crossing/passage (European Commission, 2000).

A survey on the effect of five wildlife passages with a length of 90–120 m and a diameter of 5–7 m situated in a small plantation was examined in 1993 (Marsden, 1993, cited in European Commission, 2000). The survey found that water vole, foxes, stoat, badger, otters, water bats, dipper and grey wagtails made little use of the wildlife passages. Brown hare and roe deer were not recorded as using the wildlife passages at any time. The lack of conduction planting and fencing connected to the wildlife passages and the inadequate size of the passages for roe deer were among the reasons for their limited effectiveness (European Commission, 2000). A survey of the use of 11 underpasses by larger animals found that the most frequently used underpass was a wide and high passage at Sporring A, while the least used passages were four dry underpasses and a wet underpass (Jeppesen et al., 1998, cited in European Commission, 2000).

An assessment by NERI from 1 June 2005 to 31 May 2006 of 11 wildlife passages along motorways in Northern Jutland and the wildlife crossing west of Århus found that, of the 26 species of mammals recorded in Northern Jutland, all species except red squirrel and red deer were recorded to have used one or more of the studied wildlife passages. The various passage types are used differently by the animals and also differently among species. A seasonal variation was also found dependent on the species and the wildlife passage types. The passages have been placed in connection with landscape corridors such as hedgerows, dykes and fences or by establishing wire fences along the road constructions that lead to the entrance of the fauna passage and prevent the animals from crossing the lanes. The animals have had 5–10 years to locate the wildlife passages, but there seems to be no linear relationship between the level of activity and the age of the passage. Apparently, the varied use of the passages is caused by the various densities of the animal species in the surroundings. There is no indication that wet wildlife passages (underpasses) will be used more frequent by roe deer, even if the dimension or profile of the entrance is enlarged. When wildlife crossings like landscape bridges and overpasses are taken into consideration, the activity of roe deer is markedly increased.

There is a clear relationship between the size of the wildlife underpasses and the number of medium-sized mammal species using them, when the activity level is related to the dimension of the entrance of the wildlife passage and the tunnel index. The larger the entrance or the tunnel index, the greater the number of medium-sized mammal species that use the wildlife underpasses. Dry passages are less frequently used by the smaller mammals than wildlife crossings since the dry passages miss internal vegetation cover. In general, the wildlife passages on the motorway system in Northern Jutland have been placed in connection with the natural corridors of the mammal species. Most of the passages are dimensioned so that roe deer can use them too (Danmarks Miljøundersøgelse, 2007).

Furthermore, health benefits for humans also come out of the initiative. Reductions in private car passengers and subsequent increases in individuals choosing to bike or walk instead of drive will have positive health effects on the population. This shift in transportation methods also implies a reduction in greenhouse gas emissions, thereby contributing to the mitigation of climate change.

7. Observed and/or Projected Economic Impacts

Detailed estimates of the economic impacts of this programme's wildlife passages were not found.

8. Recent Developments and Outlook

In the future, the finances provided for nature management (*Naturforvaltningsmidler*), which are provided by the state and administered by the Forest and Nature Agency and the counties, could also be used to improve the function of dispersal corridors (European Commission, 2000).

9. Summary:

TRAFFIC ACTION PLAN GI BENEFITS	
Ecosystem resilience	
Climate change adaptation	
Disaster prevention	
Ecosystem service provision	✓
Main indicators for measuring ecosystem service provision	
1. Number of species using the Green Infrastructure element	
2. Phylogenetic diversity of targeted species	

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1. Policy Initiative

Multi-Annual Defragmentation Programme, the Netherlands (*Meerjarenprogramma Ontsnippering*).

2. General Background Information

The national government adopted the Multi-Annual Defragmentation Programme in 2004. It has the status of a policy programme for the period 2005–2018. The goal of the programme is to remove the most important barriers formed by the country's dense road and rail infrastructure. Joint responsibility for the development and implementation of the programme lies with the Ministry of Infrastructure and Environment and the Ministry of Economic Affairs, Agriculture and Innovation.

The implementation of the programme is the responsibility of a wide of parties, as follows: the two ministries and their respective agencies, the 12 provinces, the railway network authority (ProRail), the water authorities, municipalities and nature conservation NGOs.

The obstacles in every province have been mapped and prioritised. A total of 208 projects have been approved, including many wildlife crossings (see Figure 1).

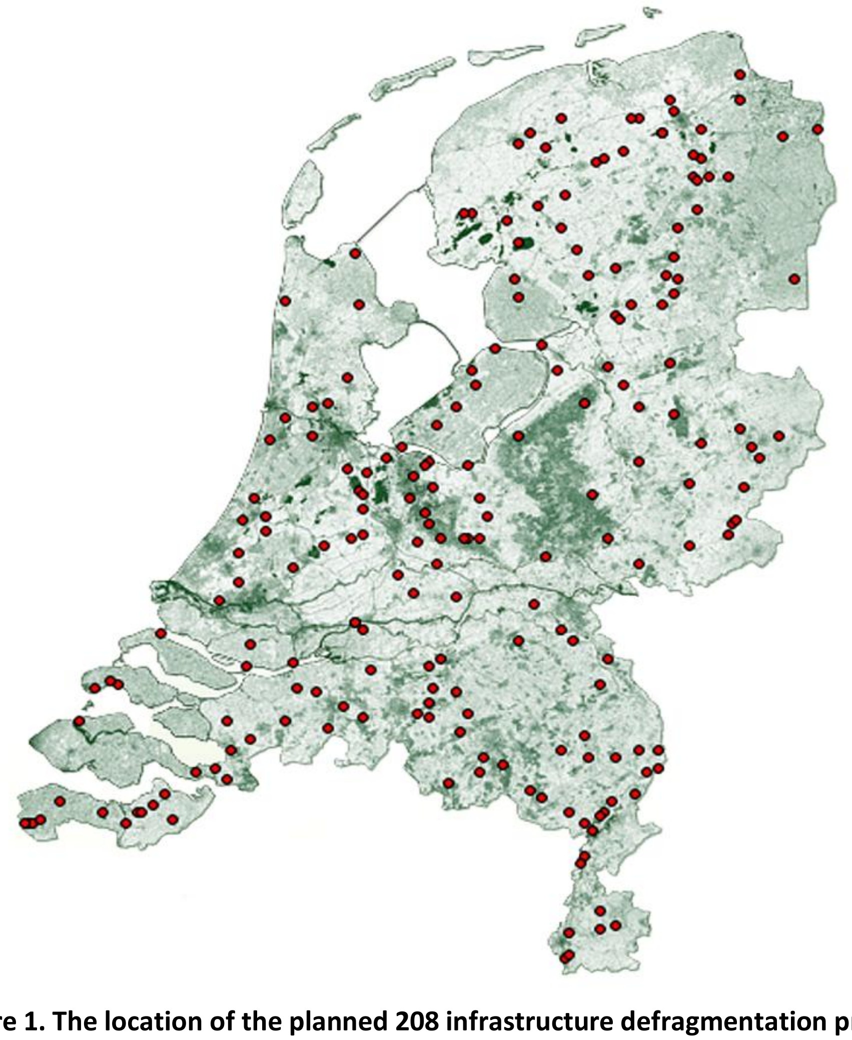

Figure 1. The location of the planned 208 infrastructure defragmentation projects in the Netherlands.

The defragmentation projects include both wildlife passages and crossings, specifically addressing the following types of measures:

- Fauna tunnels;
- Green bridges;
- Fish ladders;
- Oversized viaducts;
- Wildlife-friendly verges;
- Wildlife-friendly river banks.

3. Specific Objectives

The formal objective of the programme is as follows:

"The most important barriers for the National Ecological Network (including the robust corridors) are eliminated in 2018 (the planning horizon of the National Ecological Network), to the extent that these are caused by major roads, railways and major waterways" (Ministerie van Verkeer en Waterstaat, 2004, p.17).

4. Green Infrastructure Elements

Artificial connectivity features: Measures such as viaducts, wildlife underpasses or the large "robust corridors" (*robuuste verbindingen*) were designed specifically to assist species in overcoming artificial barriers such as roads and dams. Most of the actions targeted to reconnect large natural areas which have been fragmented by highways, railways and waterways.

5. Implementation Costs

The total costs of the programme were estimated at €410 million in 2004 for the period 2005–2018. This estimate does not include costs of additional provincial expenditures. The Ministry of Infrastructure and Environment is providing €250 million of this total, the Ministry of Economic Affairs, Agriculture and Innovation the remaining €160 million, specifically for defragmentation measures to the national infrastructure located within the robust corridors.

The distribution between the different types of infrastructure was estimated as follows:

- Navigable waterways: 5%;
- Railways: 29%;
- Major roads: 66%.

These costs include measures in the 12 projected robust corridors in the National Ecological Network (see also Case Analysis 1 on ecological networks). However, since the exact location of these passages and crossings had not been finalised when the programme was formulated, the respective costs are global estimates.

The total budget of €410 million is still applicable in 2011. However, no published information is available on exactly how the budget is being spent. An independent evaluation of the programme (Blekemolen et al., 2009) projected that in 2013 46% of the barriers will be resolved but that 58% of the total budget will have been expended, inferring a shortfall of €115 million if all the barriers are to be resolved. The report concludes that, in particular, the costs of resolving railway barriers and those in the robust corridors are relatively expensive. It is also expected that completing the National Ecological Network will require more barriers to be resolved than foreseen by the programme. It should also be noted that the provinces and many municipalities also contribute additional funding to resolving barriers over and above the budget of €410 million, but no consolidated information on these contributions is available.

If the implementation of the programme continues at the rate in the period 2005–2009, about 80% of the barriers will have been resolved by 2018 (Blekemolen et al., 2009).

The experience of the province of Gelderland, which has constructed several green bridges on its territory, is that on average the construction of a green bridge costs €2–6 million (Sundseth and Sylwester, 2009).

6. <u>Observed and/or Projected Impacts</u>

The key issue in assessing the impact of the Multi-Annual Defragmentation Programme is its effect on improving the dispersal, migration and genetic exchange of species populations within the National Ecological Network. This requires two separate questions to be answered:

1. Have the 208 barriers been correctly identified in terms of ecological value?
2. What will be the effect on species populations if these barriers are resolved?

An assessment of the programme by the research institute Alterra (Grift et al., 2007) concluded that four barriers need not have been included in the programme, but also that 116 new barriers should be added to the list, including 60 priority barriers. The assessment also notes that the precise fragmentation problem is not specified for each of the 208 barriers in the programme. This is essential if a clear target is to be formulated for resolving the problem caused by each barrier and also to be able to design an appropriate monitoring programme. Indeed, no systematic monitoring programme has been established by the programme. The programme also focuses on both specific species and species groups, which complicates any assessment of its ecological effectiveness.

These shortcomings in the design of the programme prevent a rigorous assessment of its ecological effectiveness in relation to its objectives. Monitoring data exist for many wildlife passages and crossings (both tunnels and bridges) which demonstrate to what extent they are used by species. For example, a two-year monitoring programme at a green bridge over a major road and a railway at Craillo (at 800 m the world’s longest green bridge, and also used by walkers, cyclists and horse riders) showed that it was intensively used by 13 mammal species and six amphibian species which otherwise would not have been able to traverse the barrier (Grift et al., 2009). However, to what extent these movements at the many wildlife passages in the Netherlands increase the long-term viability of the respective species populations remains unclear. Ecological theory would suggest that this is the case but this has yet to be empirically proven, not least because of the difficulty in establishing a large-scale and long-term monitoring programme and the several methodological challenges associated with establishing the value of ecological connections (Bennett, 2004):

- Do we know whether individuals would have succeeded in crossing the barrier if the connection had not been created?
- Are we sure that the observed presence of individuals in a connection actually means

that movement is taking place between the habitat patches rather than the connection simply being used as additional habitat?

- Has the monitoring programme extended over a long enough period to unequivocally establish the value of the connection?
- Are there other hypotheses that would explain the observed movement?
- Does the connection have negative ecological effects?
- Is a connection the most cost-effective way of achieving the conservation objective?

Therefore, as indicated by the limited data available regarding socio-economic as well as ecological impacts, this initiative requires the development of a focused methodological approach to evaluation. The suitability of targeted areas and uptake by species is necessary, in particular to assess the cost-benefit ratio of implemented measures.

7. Observed and/or Projected Economic Impacts

No assessment has been carried out.

8. Recent Developments and Outlook

By the end of 2010, about 40 barriers had been completely resolved (see Figure 2).

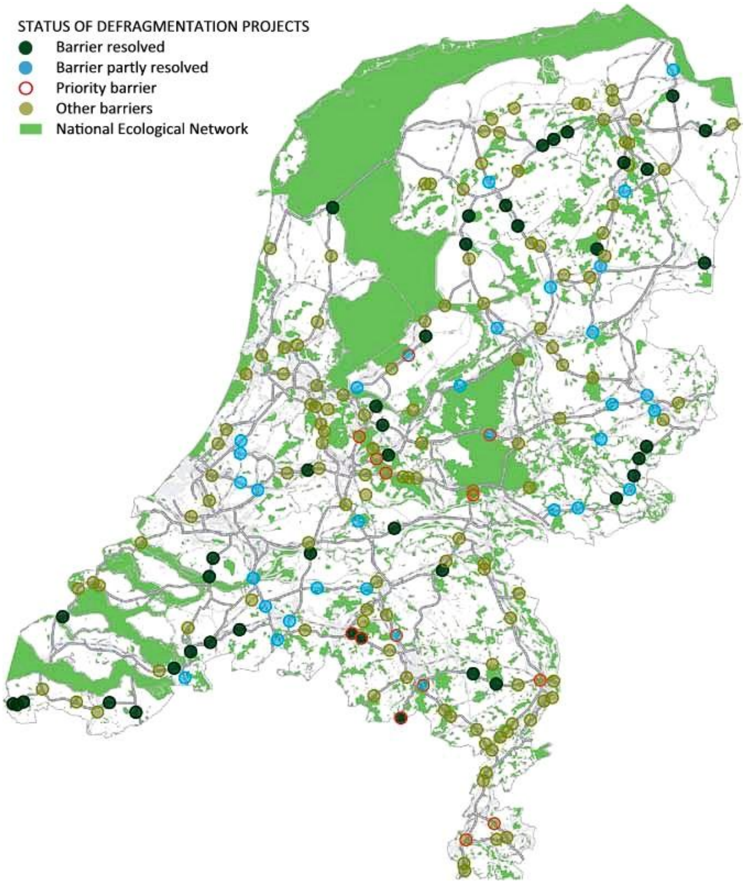

Figure 2. The status of the 208 defragmentation projects on 31 December 2009 (Ministerie van Verkeer en Waterstaat, 2011)

9. Summary

GREEN INFRASTRUCTURE BENEFITS	
Ecosystem resilience	✓
Climate change adaptation	
Disaster prevention	
Ecosystem service provision	✓
Main indicators for measuring ecosystem service provision	
1. Number of species by which the GI element is used	
2. Phylogenetic diversity	

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5 Conclusions

5.1 Overview of the Initiatives

The three pieces of legislation examined in this case analysis, as well as other emerging European policies targeting the negative effects of grey infrastructure, indicate the widespread support for and feasibility of implementing mitigation measures in many countries and contexts, particularly regarding transport infrastructure. While all three cases illustrate public sector support for green initiatives to address grey infrastructure effects via the creation of targeted legislation, the development and nature of these initiatives serve to distinguish them.

The potentially influential role of nature conservation organisations in implementing change within the area of transport mitigation is illustrated in the revision of Austria's motorway construction law as a response to NGO efforts. Denmark's Traffic Action Plan addresses mitigation and compensation measures for new grey infrastructure construction, but also extends its perspective by engaging the general public in healthier, more environmentally friendly transport decisions. Finally, the Dutch defragmentation programme adopts a cross-sectoral approach and engages both the private and public sectors, including NGOs, to implement the legislative measures outlined.

5.2 Achievements and Successful Measures

While wildlife considerations and habitat connectivity unite the three case studies, Denmark's Traffic Action Plan successfully expands on these aspects and incorporates additional sustainability concerns into its measures. The general public is addressed regarding their preferred method of transportation and alternatives are supported. This approach of engaging the larger population not only contributes to the reduction of greenhouse gases, but additionally holds the potential to raise awareness of the initiative and the underlying fragmentation concerns being addressed.

Furthermore, the scientific analysis conducted as the underlying argument for revising the former Austrian RSV directive on wildlife protection demonstrates a fundamental consideration which should accompany all such legislative items. The amendments indicate the divide between intention and effects and point to the need for standards and monitoring. This aspect also holds relevance for the Dutch Multi-Annual Defragmentation Programme (discussed in more detail in the next section). Regular assessments of the functionality of the implemented measures and the need for revisions can ensure the most efficient spending of funds and optimise the achievement of targeted results with the available resources.

5.3 Weaknesses of the Initiatives

Although the aims and ecological basis of the Dutch Multi-Annual Defragmentation Programme are well founded, a standardised approach to and methodology for monitoring the initiative's effects is lacking. Further, an external evaluation of the programme determined that additional crucial fragmentation areas were not addressed and that some of the existing targeted areas did not play a central role in habitat fragmentation. These points underscore the need for regular evaluations of the legislative focus as well as the adoption of a clear methodology for monitoring effectiveness and efficiency.

The second feature presenting difficulties in establishing comparability and drawing conclusions applicable to other cases is the lack of comprehensive data on the various costs and benefits associated with grey infrastructure mitigation legislation in general, and particularly regarding the selected cases. While this aspect acts as a weakness within lines of argumentation supporting such legislation, attempts have been made to extract as much detail as possible for the purposes of this analysis, including consulting external sources, and are presented here.

Although overarching figures are often lacking, specific measures falling under these legislative plans do have available cost figures and can be used as an initial reference point. In the case of the Austrian Directive on Wildlife Protection in Road Construction, for example, the cost of two green bridges constructed over existing freeways under the directive were found to be €1,111/m^2 and €726/m^2. These figures have been deemed representative of the average costs likely to be incurred for the construction of similar bridges over previously constructed motorways.

The Spanish national report (Rosell et al., 2002) as part of the COST 341 project on European mitigation measures to counteract habitat fragmentation caused by transportation infrastructure provides concrete costs of national mitigation efforts. Investments in actions aimed at reducing the impact of transport infrastructure range from 1.0–3.5% of the total working budgets, including direct and indirect costs; the costs of mitigation, compensatory and environmental integration measures were found to usually comprise 5% of the total budget. Here, wildlife passages were found to cost an average of €360,000 while underpasses cost between €12,000 and €20,000, not including the maintenance and monitoring costs.

Challenges also lie in quantifying the benefits from employing green infrastructure to address transport-related habitat fragmentation and degradation. Forman et al. (2002) have proposed a set of six criteria against which to measure the effectiveness of wildlife crossing structures, namely: reduce rates of road-kill, maintain habitat connectivity, maintain genetic exchange, ensure biological requirements are met, allow for dispersal and recolonisation and maintain meta-population processes and ecosystem services. While reductions in wildlife-related transport accidents and use of the Green Infrastructure measures by various species can be more easily determined, definitive impacts regarding, for example, the mixing of otherwise segregated populations, are more abstract and difficult to establish. A standardised and meaningful measure of mitigation effectiveness is also lacking, both in terms of use as well as increases in population viability. Finally, there is difficulty in measuring the "benefit" to assemblages, communities and ecosystems as compared to the negative impacts and compounding feedback of *not* installing a given measure (Ree, 2008).

That being said, a study by Bank et al. (2002) on wildlife habitat connectivity across European motorways reveals the high average uptake of numerous targeted species (e.g. bears, roe and red deer) in using the bridges given adequate spatial allowances and also cites reductions in wildlife-related traffic accidents following the construction of wildlife passages and crossings. Based on the assumption that high usage will lead to improved fulfilment of Forman's aforementioned criteria, the benefits of such measures as mitigation for grey infrastructure are likely to be significant. Currently, sparse quantitative estimates of mitigation benefits should not prevent the full consideration of their value in discussions and decision-making processes.

5.4 Potential to Contribute to Green Infrastructure

Despite the difficulties sometimes incurred in implementing these directives due to cost factors and the lack of quantified data on benefits, the findings from the case studies have important implications for the planning of future grey, and specifically transportation, infrastructure across Europe. Given the increasing need for transport across Europe, the following points are among the most significant:

- Creating connective green infrastructure alongside the construction of new grey transport infrastructure is far cheaper than decreasing the barrier effects of existing infrastructure at a later date (European Commission, 2000).

- There is a pressing need for integrated and coordinated approaches in local and regional spatial planning processes for new transport infrastructure to adequately cover wildlife corridors and ensure their long-term effectiveness.

- Avoiding valuable nature areas and conducting EIAs should have a high priority when planning new roads. However, as all environmental impacts cannot be avoided in constructing new grey infrastructure, the establishment of mitigation measures should serve as a necessary component in planning exercises.

- Studies on optimising roads to minimise fragmentation, adaptation to landscape, aesthetic values of sites, traffic safety and needs of fauna and recreational passages are crucial (European Commission, 2000) in order to maximise the efficient use of available funds and encourage the widespread implementation of mitigation measures.

- Despite the lack of a standardised methodology for valuing the wider external costs of fragmentation or respective benefits of mitigation measures, rough estimates should provide useful indications when cost-benefit analyses are not possible (Trocmé et al., 2003).

Additionally, although this analysis has primarily focused on the mitigation of impacts from transport infrastructure, the mitigation of impacts of energy/power distribution networks also merits attention, especially as the further development of such networks is expected across Europe in the next two decades as a result of the development of renewable energies. The number of examples of mitigation of such networks on Green Infrastructure is, however, limited, and the few existing examples do not allow general conclusions to be drawn on the costs and benefits associated with measures to mitigate the impacts of such networks.

That being said, the limited work which has been completed in this area deserves mentioning within the context of Green Infrastructure. Combining new electricity distribution networks (e.g. for the distribution of wind energy from the production sites to where it is being consumed) with other grey networks has been recognised as holding potential in terms of reducing the land take from electricity and power distribution. The German government has commissioned a feasibility study to investigate the possibility for the electricity distribution network of the railway network to be used to carry electricity produced from wind energy from the north to the south of the country (Sueddeutsche, 2011).

Furthermore, an initiative taken in Hungary, although not directly concerned with mitigating the impacts of the electricity distribution network, is nevertheless worth discussing in relation to reducing the adverse impacts of power lines on nature by modifying them to minimise their threat to birds. As part of the three-party agreement entitled “Accessible Sky” aiming to reduce the rate of power line-induced mortality of some of the most threatened bird species, the Ministry of Environment and Water, BirdLife Hungary and major electricity suppliers planned and installed 800 km of insulation for electricity lines in 2009. The programme was financed by EU funds (e.g. LIFE, Structural Funds) as well as electricity suppliers assuming the obligation of using safe elements for birds in their future constructions. The electric companies involved promised a “bird-friendly” transformation of all dangerous power lines in Hungary by 2020 and agreed to only use “bird-friendly” methods in managing newly constructed power lines (UNEP, 2011).

In the US, some experience has been gathered in reducing the impacts of natural gas pipelines on Green Infrastructure (Hoellen, 2010). This experience has allowed for the establishment and testing of a transparent, defensible decision-making process for selecting mitigation projects to deliver the greatest “bang for the buck” and to take advantage of economies of scale by pooling the impacts of many projects. The main elements of the framework applied are a range of steps including:

identification of mitigation needs, design of a Green Infrastructure network, establishment of mitigation project selection criteria and evaluation and selection of the best projects (The Conservation Fund, 2011).

Ultimately, the analysis points out that green and grey infrastructure are not inherently mutually exclusive. In contrast, both forms of infrastructure have the potential for compatibility and, when approached in a strategic and well-researched way, can support the needs of surrounding species specifically and biodiversity and habitat conservation more generally.

5.5 Lessons for a Potential EU Green Infrastructure Strategy

Practitioners can be hesitant to voluntarily incorporate mitigation measures into grey infrastructure construction without having clear cost-benefit analyses to refer to. Current and predicted financial pressure across European can also encourage quick-fix solutions that produce economic returns without necessarily maximising effectiveness in terms of mitigation potential. Further, for fear of potential costs, the mandatory status of such initiatives is often restricted in scope and therefore in effectiveness. In Austria, for example, the initiative's legally binding nature only applies to the federal road network. In this case, the responsibility for implementing the Directive for other roads falls within the relevant states and threatens the cohesive network character strived for by the individual Green Infrastructure measures.

Taking this tendency into account, a potential EU Green Infrastructure strategy could encourage long-term thinking and support efforts to determine more detailed cost-benefit analyses regarding grey infrastructure mitigation. Crucially, the benefits associated with such actions should not be forgotten in these analyses. The wider financial implications of wildlife accidents, for example, need to be considered in transport-related calculations. Studies indicate that the estimated social costs of such accidents is approximately €42,375 million/year[2] in Switzerland and €851,000/year in Spain. Spain further estimates approximately 5,000 wildlife accidents per year, averaging €2,700/claim. Sweden estimates a cost of between €8,325 and €21,853 per moose accident. An understanding of these costs is necessary when calculating the "value for the money spent" of mitigation measures.[3]

While a standardised method for determining other types of benefits is still lacking, additional conclusions have nevertheless emerged. Importantly, the costs for bridges being built in correlation with the construction of new motorways are generally lower than retroactive measures. The COST 341 study (Trocmé et al., 2003) provides an extensive overview of European mitigation measures to counteract habitat fragmentation caused by transportation infrastructure and supports this finding. The EU Green Infrastructure strategy could therefore highlight the importance of and support actions to avoid fragmentation by leaving existing habitats as intact as possible and/or contributing to their restoration to avoid substantial investments in modifying existing transport infrastructure.

[2] This estimate includes material damage, human injuries and human fatalities.
[3] Trocmé et al., (2003).

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