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CEDR Contractor Report 2018-3

Call 2013: Roads and Wildlife

The Roads and Wildlife Manual

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The aim of the CEDR Transnational Road Research Programme is to promote cooperation between the various European road administrations in relation to road research activities. The topics covered by this Call were developed by TG Research to fulfil the common interests of the CEDR members.

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Foreword

Roads are a crucial part of modern society, allowing people and freight to move to where they are needed. However, the effect of roads is not wholly positive as they do result in habitat fragmentation which has a detrimental effect on these habitats and the species therein.

The COST 341 action recognised the need to mitigate against the effects of habitat fragmentation. A key output of that action was the COST 341 Handbook, "WILDLIFE AND TRAFFIC, A European Handbook for Identifying Conflicts and Designing Solutions". Ten years after the 2003 publication of the COST 341 Handbook, the Conference of European Directors of Roads (CEDR) released their transnational research call 2013: Roads and Wildlife. The call, which funded the projects "SAFEROAD", "SafeBatPaths" and "Harmony", aimed to address the conflict between roads and wildlife and to identify more cost-efficient methods for building and maintaining roads, and structures for reducing the impact on wildlife such as fauna passages.

CEDR has now commissioned the ECOROAD project partners to produce this CEDR Roads and Wildlife Manual. This manual complements the work of COST 341 and is the result of an integration of the outputs of the "Harmony", "SAFEROAD" and "SafeBatPaths" projects, along with further input from European road ecology experts. The aim of the manual is to update the information in COST 341 to reflect changes such as those in European Union legislation and policy. This CEDR manual also identifies best practice in areas such as procurement, maintenance and monitoring which received less emphasis in the COST 341 handbook.

We envisage this manual acting as a companion to the COST 341 Handbook, providing a basis to consider the effects on wildlife throughout the various stages of the life of a roadway. We hope that the guidance provided herein goes some way to solving the conflict between roads and wildlife.

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Table of Contents

Chapter 1. Environmental Policy & Legislation for Road Planning

Summary

European Union (EU) policies and legislation specify a variety of requirements and ambitions that are of concern for road projects. This chapter provides practical guidance for National Road Authorities (NRAs), statutory consultees and professionals in the EU Member States involved in the Environmental Impact Assessment (EIA) process.

In 30 years of application, the EIA Directive has been amended several times but has not significantly changed, though policy and the legal context have evolved considerably. The new EIA Directive 2014/52/EU, applicable from May 2017, aims to correct for identified shortcomings in implementation, reflecting both European Court of Justice (ECJ) case law and ongoing environmental and socio-economic priorities. The new Directive provides NRAs with provisions to enhance the effectiveness and efficiency of EIA of road projects, by being simpler, clearer and more predictable.

This chapter provides:

- Essential information on policy, agreements and conservation legislation;
- Legal requirements for species protection and the principles for derogation including remedial action, research and monitoring are provided for environmental assessment;
- Practical guidelines are presented on how to avoid legal pitfalls during key phases of the road life cycle, drawing from experience and case law;
- Practical guidelines on effective procedures for the Appropriate Assessment (AA) process; and
- Guidance on the treatment of ecological corridors, green infrastructure and natural capital in road planning.

1.1 Introduction

The key messages in this chapter come from effective environmental assessment approaches across Europe, EU judgments and best practice identified in the Conference of European Directors of Roads (CEDR) projects, notably Harmony[1] and SAFEROAD[2].

1.2 Environmental Policy

Article 11 of the Treaty on the Functioning of the European Union (TFEU) states that environmental protection requirements must be integrated into the definition and implementation of the Union policies and activities. Environmental policies should be considered through the different phases of the road life cycle. The key environmental policies relevant to road development are summarised in Table 1-1.

Table 1-1 Key environmental policies relevant to road development

Policy	Overview and Purpose for NRAs
EU Biodiversity Strategy to 2020: EC Communication (COM 244/2011)	The EU Biodiversity Strategy aims to halt the loss of biodiversity and ecosystem services in the EU and help stop global biodiversity loss by 2020 while speeding up the EU's transition towards a resource efficient and green economy. Targets set out in the strategy relevant to NRAs relate to implementation of the Habitats and Birds Directives, combating Invasive Alien Species (IAS) and establishing green infrastructure. The EU Biodiversity Strategy also introduces the goal of "no net loss (NNL) of biodiversity and ecosystem services". NNL is not explicitly stated in EU legislation but it is implicit in a number of EU laws and is also relevant to legislation which requires compensation and remediation of damage to biodiversity (refer to Table 1-2). Habitat banking may be a connected future policy tool that can be used to further the aims of the Biodiversity Strategy in the context of road planning and development.
Green Infrastructure (GI) – Enhancing Europe's Natural Capital: EC Communication (COM 249/2013)	Green Infrastructure (GI) is a tool for providing ecological, economic and social benefits through natural solutions, avoiding reliance on "grey infrastructure" that is expensive to build when nature can provide cheaper, more durable alternatives. GI aims to contribute to the effective implementation of a strategically planned network of natural and semi-natural areas with other environmental features designed and managed to deliver a wide range of ecosystem services. NRAs should reconcile transport infrastructure with ecological networks at a regional scale and optimize the ecosystem services provided by GI to mitigate the impacts of roads on biodiversity.

1.3 Environmental Agreements and Conventions

Agreements and conventions are legally binding for the Member States who become Contracting Parties to them. Conventions may have a legal impact similar to that of Directives in some Member States.

[1] CEDR (2015) Environmental Legislation and Guidelines. Harmony Deliverable C.
[2] CEDR (2016) Roads and Wildlife: Legal requirements and policy targets. SAFEROAD Technical Report 1.

Table 1-2 Key environmental agreements and conventions relevant to road development

Agreement	Overview and Purpose for NRAs
European Agreement on Main International Traffic Arteries (1975) (AGR)	Clause IV.6.3 of Annex II of the AGR states that main international arteries should not only be protected from animals, but also constructed to protect animals from traffic. Such protection should not only include adequate fencing, but also over- or underpasses of suitable size and shape. As per Clause VI of Annex II of the AGR, NRAs must preserve the quality of the environment; consider carefully the impact of a road on the environment with the general aim of maximising positive effects on the environment and correcting negative ones; and consider the direct effects of roads and traffic on fauna and flora during construction and operation of a new international road.
Ramsar Convention (1971)	The Ramsar Convention's mission is the international conservation of all wetlands through wise use; designation of suitable internationally important wetlands as listed Ramsar sites and their effective management; and co-operation to ensure this applies to trans-boundary wetlands. The NRA must operate under the "wise use" concept as its minimum level policy for promoting wetland conservation in view of national wetland policies and the implementation of necessary environmental measures.
Convention on the Conservation of European Wildlife and Natural Habitats (1979) (Bern Convention)	The Bern Convention aims to conserve wild flora and fauna and their natural habitats, to promote co-operation between parties, and to give particular attention to endangered and vulnerable species, including migratory species. The NRA must take into account the impact that road planning and other development policies may have on species and habitats.
Convention on the Conservation of Migratory Species of Wild Animals (1979) (Bonn Convention)	The Bonn Convention aims to prevent, remove, compensate for or minimize, as appropriate, the adverse effects of activities or obstacles that seriously impede or prevent the migration of listed species. The objective of the Convention is to restore the migratory species concerned to a Favourable Conservation Status (FCS) or to maintain them in such a status. NRAs must strive to protect listed species; conserve or restore habitats of listed species; mitigate for migration barriers and control other factors that may endanger them.
Agreement on the Conservation of Populations of European Bats (1991) (EUROBATS)	EUROBATS was set up under the auspices of the Bonn Convention and aims to protect 53 European bat species through legislation, education, conservation measures and international co-operation with Agreement members. Resolution 7.9 urges parties to take bats into account during the planning, construction and operation of roads and other transport infrastructure projects. The aim of EUROBATS strategically for NRAs is to ensure that pre-construction Strategic Environmental Assessment (SEA) and EIA procedures and post-construction monitoring in relation to bats are undertaken.
Convention on Biological Diversity (1992)	This Convention seeks a comprehensive approach to sustainable development. Relevant goals for an NRA are the conservation of biological diversity and the sustainable use of its components.
European Landscape Convention (2000) (LC)	This Convention promotes the protection, management and planning of European landscapes and organises Member State co-operation on landscape issues. NRAs are required to conserve and maintain significant or characteristic features of landscapes in road planning.

1.4 Environmental Regulations

1.4.1 Overview

NRAs must have full knowledge of any likely significant effects on the environment to ensure road planning decisions avoid and reduce disturbance, barrier, fragmentation and road mortality effects before road projects can be given development consent. Environmental assessment of road infrastructure development in Europe is carried out to meet the requirements of the EIA Directive. All parties engaged in EIA therefore need to be familiar with relevant road planning legislation and policy, as presented in Table 1-3.

The SEA and EIA Directive build the framework for the planning approval process and the evaluation of impacts on humans and nature. The Aarhus Convention determines the participation of civil society within the planning and approval process.

Table 1-3 Key environmental legislation relevant to road development

Directive	Overview and Purpose for NRAs
Directive (92/43/EEC) on the conservation of natural habitats and of wild fauna and flora (Habitats Directive)	The Habitats Directive contributes towards ensuring biodiversity through the conservation of natural habitats and of wild fauna and flora in the European territory of the Member States. The focus is on maintaining or restoring, at FCS, natural habitats and species of wild fauna and flora of community interest, which are all listed in Annexes II, IV and V of the Directive (Articles 1 and 2). The HD establishes a network of Special Areas of Conservation (SACs) for habitats listed in Annex I and species listed in Annex II. Together, Special Protection Areas (SPAs) and SACs make up the Natura 2000 network. NRAs must endeavour to encourage the management of features of the landscape that support the Natura 2000 network (Articles 3 and 10). Relevant to NRAs is Article 6(2) and contribution through planning to preventative measures[3,4] and Articles 6(3) and 6(4) on safeguards governing plans and projects[5]. NRAs must comply with the strict system of measures established to protect species listed in Annex IV(a) of the HD (Articles 12 and 13) and this parallels Article 6 of the Bern Convention. The system of protection envisaged under Articles 12–15 is qualified by the possibility of derogations under Article 16 of the Directive.
Directive 2009/147/EC on the conservation of wild birds (Birds Directive)	The Birds Directive (BD) aims to protect all wild bird species naturally occurring in the EU and covers the protection, management and control of these species and lays down rules for their exploitation. The BD establishes a network of SPAs for endangered and migratory species to be included in the Natura 2000 ecological network, set up under the HD. Provisions in the Directive most applicable to NRAs are Article 2 (to maintain bird populations at a level which corresponds to ecological, scientific and cultural requirements) and Article 4 (protect important bird habitat).

[3] Case C-418/04 *Commission of the European Communities v Ireland* [2007].
[4] Case C-6/04 *Commission of the European Communities v United Kingdom* [2005].
[5] Case C-241/08 *European Commission v French Republic* [2010].

Directive	Overview and Purpose for NRAs
Directive 2000/60/EC establishing a framework for community action in the field of water policy (Water Framework Directive)	The Water Framework Directive (WFD) aims for "good status" for all ground and surface waters in the EU. The WFD's key objectives are to: prevent deterioration of the status of all surface and groundwater bodies; protect, enhance and restore all bodies of surface water and groundwater; to achieve good surface water and groundwater status; and to mitigate the effects of floods. The WFD does this by establishing a River Basin District (RBD) structure within which environmental objectives are set, including ecological targets for surface waters. The WFD requires NRAs to avoid any direct or indirect impacts ("water damage") arising from road development that may lead to the deterioration of watercourses and/or water bodies. The length of the NRA's road network within each RBD will vary greatly. The NRA must review any potential risk of pollution from its network and endeavour to ensure its activities do not compromise the objectives set out within an RBD Management Plan, and wherever possible, work towards achieving the desired outcomes.
Directive 2001/42/EC on assessment of the effects of certain plans and programmes on the environment (SEA Directive)	The SEA Directive applies to a wide range of public plans and programmes (e.g. on land use, transport etc.) and addresses governmental planning in order to integrate environmental considerations and allow better public participation before a decision is made to adopt it. The SEA Directive does not refer to policies. An SEA for transport planning assesses the environmental impact of plans and programmes, which, inter alia, set the framework for future development consent.
Directive 2004/35/EC on environmental liability with regard to the prevention and remediation of environmental damage (Environmental Liability Directive)	The Environmental Liability Directive (ELD) establishes a framework based on the "polluter pays" principle to prevent and repair environmental damage. The operator liable under the ELD must bear the cost of the necessary preventive or remedial measures. The Directive defines "environmental damage" as damage to protected species and natural habitats, damage to water and damage to soil. NRAs must avoid occupational activities that are damaging to habitats and species listed in the HD, BD and to waters relevant to the WFD. Member States have discretion as to how they apply this requirement to species protected under their national law. Annex I describes the measurable data required to determine significant adverse change or damage.
EU Directive 2011/92/EU (as amended by Directive 2014/52/EU) on the assessment of the effects of certain public and private projects on the environment (EIA Directive)	The aim of the EIA Directive is to reduce the environmental impacts of projects. To do so, the Directive prescribes that projects likely to have significant effects on the environment are made subject to an environmental assessment, prior to their approval or authorisation. The Directive defines projects to which it applies and provides procedures for the assessment process, including public consultations. An EIA is mandatory for all projects – listed in Annex I – considered as having significant effects on the environment. These include, for example, long-distance railway lines, motorways and express roads. Annex II lists the projects which require EIA. The criteria for carrying out the EIA are provided in Annex III.

Directive	Overview and Purpose for NRAs
EU Regulation No. 1143/2014 on the prevention and management of the introduction and spread of Invasive Alien Species	IAS pose a significant threat to biodiversity in the EU, and this threat is likely to increase in the future. This regulation seeks to address the problem of IAS in a comprehensive manner so as to protect native biodiversity and ecosystem services, as well as to minimize and mitigate the human health or economic impacts that these species can have. "*Three distinct types of measures are envisaged, which follow an internationally agreed hierarchical approach to combating IAS:* • *Prevention: a number of robust measures aimed at preventing IAS of Union concern from entering the EU, either intentionally or unintentionally.* • *Early detection and rapid eradication: Member States must put in place a surveillance system to detect the presence of IAS of Union concern as early as possible and take rapid eradication measures to prevent them from establishing.* • *Management: Some IAS of Union concern are already well-established in certain Member States and concerted management action is needed so that they do not spread any further and to minimize the harm they cause.*" The NRA must ensure that robust action is taken at all phases of the road life cycle to prevent and manage the introduction and spread of IAS of Union concern as listed in EU Regulation 2016/1141. Priorities on IAS will differ between Member States on a case by case basis; however, cross-border co-operation between regional NRAs with the same IAS risks is essential to prevent situations where action taken in one Member State is undermined by inaction in another Member State.

The HD, BD, ELD, EIA Directive, the Bonn Convention, the Bern Convention and the AGR are the most relevant European Directives and international agreements with regard to the barrier and mortality effects of roads, setting out objectives and responsibilities for:

- Species conservation;
- Levels of acceptable impact;
- Priority species;
- Principles for derogation;
- Requirements for remedial action; and
- Research and monitoring.

The key environmental legislation is transposed and implemented through national legislation in most Member States. The Commission can, through the ECJ, take legal action against a Member State which fails to implement or transpose legislation correctly.

1.5 Legal Implications for Road Planning and Design Phases

To be legally environmentally compliant, NRAs need to ensure that road projects meet the requirements of the EIA and HD where these Directives apply. Each form of assessment has separate legal provisions and procedural requirements. The three separate forms of environmental assessment are summarised in Figure 1-1. In many cases, information obtained in the SEA or EIA is of importance in carrying out the AA.

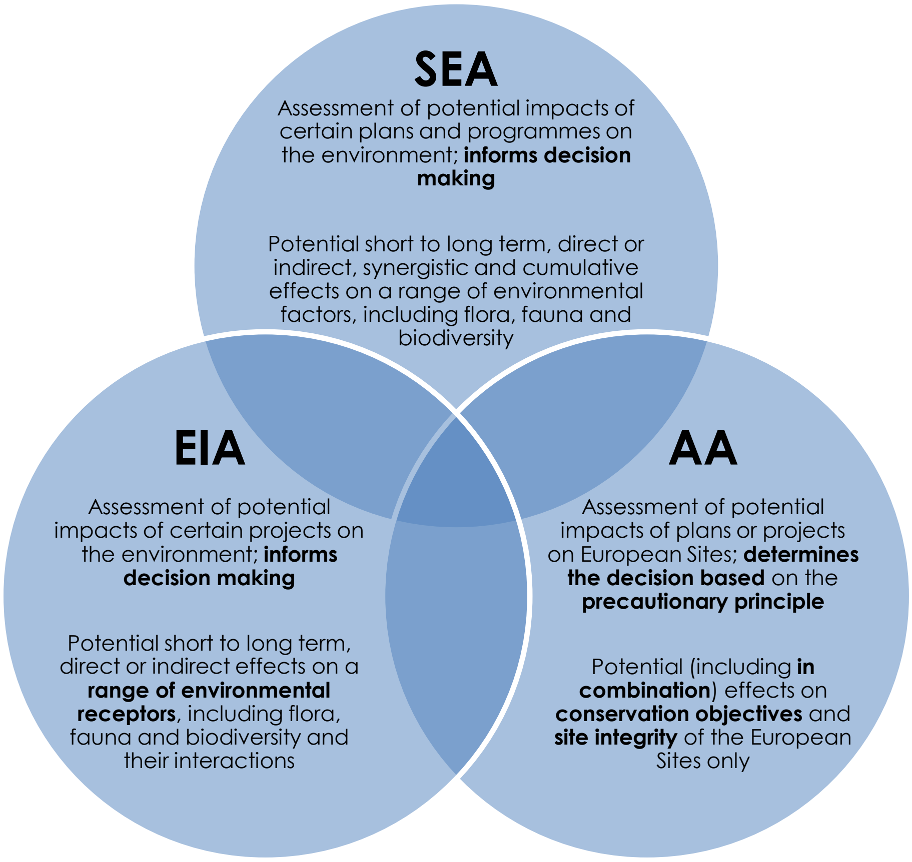

Figure 1-1 Summary of SEA, EIA and AA

1.5.1 SEA

The SEA Directive requires that an environmental assessment be carried out of certain plans and programmes which are likely to have significant effects on the environment. SEA is a multi-staged process and involves:

- Screening stage where the competent authority establishes if the infrastructure plan is likely to have significant environmental impacts;
- Consultation with relevant public bodies to reach a determination;
- A scoping phase which identifies the scale of detail required in the provision of a draft Environmental Report which describes the effects on the environment of the plan and its reasonable alternatives;
- An Environmental Report identifies, describes and evaluates the likely significant effects on the environment of implementing the plan or programme; and
- A Post-Adoption phase sets out how consultation responses and findings of the Environmental Report have been integrated into the decision-making process prior to project level environmental assessment.

1.5.2 EIA

EIA is a mandatory requirement for projects listed in Annex I of the Directive (e.g. express roads). Article 2(1) of the EIA Directive requires Member States to adopt all measures necessary to ensure that, before consent is given, projects likely to have significant effects on the environment are made subject to an assessment of their effects. Key points of EIA include:

- Article 2 of the EIA Directive requires the preparation of an EIA Report (EIAR), including any supplementary information necessary, by the NRA in accordance with Articles 5–7;
- Article 3 requires that the assessment identifies, describes and assesses the direct and indirect significant effects of a project. For example, environmental effects by virtue of, inter alia, the nature, size or location of the project (i.e. including secondary, cumulative, short, medium and long-term, permanent and temporary, positive and negative effects);
- EIA should be iterative, undertaken in parallel with other project processes and allow the consideration and incorporation of environmental effects and mitigation. It is important that consideration of the effects on biodiversity, flora and fauna in EIA are not limited only to European protected species or the interest features of designated areas (e.g. Natura 2000 sites or other national designations); and
- The technical report for the EIA is termed (as per the new EIA Directive) an EIAR. It must clearly set out all the ecological information necessary for a planning decision to be made.

1.5.3 Article 6 and AA

The HD sets out a step-by-step sequence of statutory procedures to be followed to protect European sites, whilst implementing plans for sustainable economic growth. Article 6(3) of the HD requires that any plan or project, which is not directly connected with or necessary to the management of a European site[6], but would be likely to have a significant effect on such a site, shall be subject to an AA of its implications for the European site in view of the site's conservation objectives.

1.5.4 Stages of AA

The Article 6 permitting procedure for plans and projects involves four stages which are followed in the correct sequence in order to comply with the requirements of the HD. The need for each stage is dependent on the outcomes of the preceding stage.

i. Screening for AA.
ii. AA.
iii. Assessment of alternative solutions.
iv. Assessment where no alternative solutions exist and adverse impacts remain, i.e. the Imperative Reasons of Overriding Public Interest (IROPI) test, and compensatory measures.[7]

Section 1.9 discusses AA in further detail.

[6] Case C-209/02 *Commission v Austria* [2004].
[7] EC (2007) Guidance document on Article 6(4) of the "Habitats Directive" 92/43/EEC.

1.5.5 Interaction of SEA, EIA and AA

SEA and EIA are treated separately. However, an SEA is conducted before a connected EIA. This means that information on the environmental impact of a plan can cascade down through the tiers of decision making and be used in the EIA of the project at a later stage as illustrated in Figure 1-2.

Article 3(2) of the SEA Directive stipulates that if a plan is likely to impact a nature conservation site which is protected by the HD then an SEA must be conducted.

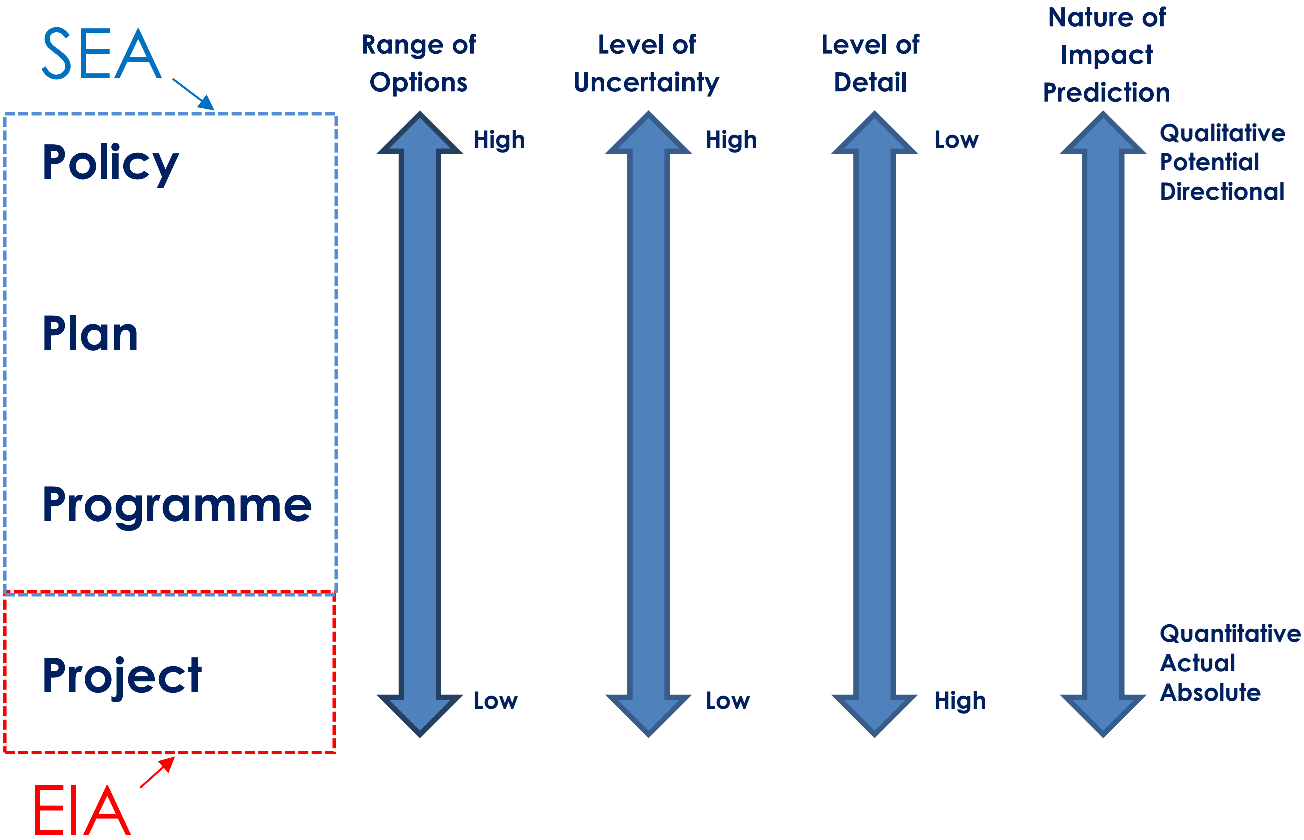

Figure 1-2 Information Cascade

1.6 Summary of Key Issues in EIA

The Harmony project reviewed 87 Environmental Impact Statements (EISs – term of old EIA Directive) across 10 Member States to identify the similarities and differences in the implementation of the duties required by EU environmental legislation. SAFEROAD reviewed the current European laws with respect to the barrier and mortality effects of roads on wildlife. It analysed practice of how the legal incentives are addressed, as implied by a selection of 14 recent examples of case law and EISs for road projects (refer to Box 1-1).

Box 1-1: SAFEROAD and Harmony Findings

- A significant proportion of EISs did not use survey data carried out within the past two years (baseline data should be contemporary and valid).
- EISs should more clearly differentiate construction and operational phase impacts or detail separately from the requirements for prevention and remediation.
- EISs need to account for cumulative effects.
- EISs must include more comprehensive details of post construction monitoring plans (albeit old EIA Directive made no legal demand for post-project analysis).
- The effects of human disturbance (noise, lighting and human presence) should be fully assessed and mitigated.
- The mitigation measures must fully address the impact of road casualties on wildlife conservation.
- EISs must consider continuity of wildlife movement in the landscape through clear stipulation and inclusion of fauna passages.
- The quantification and interpretation of effects must relate to the acceptable level of impact on populations set out in the HD, BD, ELD and Bonn Convention.
- Bat mitigation measures should be incorporated more appropriately into road scheme design.

1.7 Practical Guidelines for Effective Provision of EIA

The EIA process is often complex and involves many decisions and judgments. Guidelines in this section are formed from the Harmony/SAFEROAD review documents and are also framed in the context of the new EIA Directive to ensure that current statutory requirements are fully realised in the road planning process and that substantial compliance with the principal legislation is achieved.

1.7.1 EIAR Should be prepared by Qualified and Competent Experts

Due to the high biogeographical diversity in Europe, each infrastructure development will represent unique and complex compliance challenges in regard to environmental assessment and mitigation. Therefore, the following is required:

- Sufficient, relevant, expertise for the purpose of examination by the competent authorities in order to ensure that the information provided by the developer is complete and of a high level of quality. This has been enforced by the amended EIA Directive requiring in Article 5(3) "*In order to ensure the completeness and quality of the environmental impact assessment report: (a) the developer shall ensure that the environmental impact assessment report is prepared by competent experts;*"
- Input from ecologists at all stages in the decision making and planning process, from early project design to its implementation;
- Experts involved in the preparation of EIARs should be accredited, technically competent and sufficiently experienced;
- It is the responsibility of each competent authority to determine the competency of experts preparing an EIAR. The level of expertise required depends on the nature and potential environmental impact of that element. The EIAR should state who prepared

each element along with their qualifications and experience in order to satisfy the competent authority as to the competency of the experts; and

- The list of EIA contributors with their qualifications and experience should be submitted to the competent authority prior to the commencement of the EIAR to ensure that they are satisfied with the qualifications and competency of the experts.

1.7.2 Gather Environmental Information

Route Corridor Selection Study

The principal objective of the Route Corridor Selection (RCS) study is to evaluate and compare the alternative route corridor options, taking account of engineering, environmental, traffic and cost considerations. The ecological impacts for each route option should be identified so that those with unacceptably high levels of impact can be avoided to the extent feasible as part of the overall route assessment process. Every effort should be made to ensure that the original route options selected avoid significant effects on European sites. RCS is the single most effective means of avoiding or reducing ecological impacts.

Desk Study

A comprehensive desk study should be undertaken, reviewing all available datasets to form an initial view of the existing ecological environment and features likely to occur within an "effects distance" from the proposed road development.

Generally, this will include a review of designated sites for nature conservation and previous records of rare and protected habitats. It will also include species obtained from statutory and non-statutory consultees. Sources of information should be clearly stated in the EIAR.

Define the Study Area

The assessment approach should fit the scale and scope of the proposed road development and be clearly defined in the EIAR. The following approach should be taken both at RCS stage and EIAR stage:

- Provide a clear rationale for deciding which ecological features and resources justify more detailed consideration to enable all stakeholders to understand the reasoning behind the scope of investigations;
- Adopt a precautionary approach to ensure that the study area incorporates all areas where significant effects could occur throughout the life of the road project;
- Identify resource dependency for ecological receptors throughout various life stages, e.g. habitat suitability and trophic interactions. Movement corridors are recognised as being important factors;
- Reference ecological features to a geographical context in which they are considered important. For example:
    - International scale – e.g. impacts to European sites, Biosphere Reserves, World Heritage Sites, Ramsar sites, etc.;
    - National scale – e.g. impacts to sites supporting (either permanently or seasonally) isolated internationally or nationally significant populations or sites important for long distance migratory species;
    - Regional scale – e.g. impacts at linked sub-population level with potential to limit topographical connectivity;

- Sub river basin scale – impacts to watercourses or ecological features dependent on hydrological processes;
- Local scale – e.g. impacts to habitats, resting and breeding places of individuals or territorial social groups.

- Refer to relevant best practice survey methodology for assessing impacts on identified receptors to refine the scale of investigations.

Compliance with Article 12 of the Habitats Directive

Site specific field investigations within the study area are needed to supplement background information as it is not possible to establish the full extent of likely significant effects from the desk study. Multidisciplinary and species specific survey work should aim to obtain scientific and technical knowledge, essential for compliance with the strict protection measures set out in Article 12 and relevant national conservation legislation. Survey effort needs to be detailed enough to identify when avoidance, mitigation or compensation is needed. To ensure the EIAR accurately assesses and characterises road impacts and their effects, the ecologist must:

- Use baseline data from ecological surveys that are comprehensive and have been carried out within a relatively recent timeframe;
- Undertake ecological surveys at optimal times of year for the habitats and species under assessment and address seasonal change; and
- Adhere to NRA guidelines regarding timing and scope of surveys for different target species and habitats.

1.7.3 Describe the Project Characteristics

All relevant phases of the road scheme must be fully described in the EIAR. The description in accordance with Annex II A and Annex III of the Directive must include the following topics:

- Characteristics of the projects
    - The size and design of the whole project,
    - Combination with other existing and/or approved projects,
    - The use of natural resources, in particular land, soil, water and biodiversity,
    - The production of waste,
    - Pollution and nuisances,
    - The risk of major accidents and/or disasters, and
    - The risks to human health.
- Location of projects
    - The existing and approved land use,
    - Relative abundance, availability, quality and regenerative capacity of natural resources in the area and in the ground underneath, and
    - The absorption capacity of the natural environment.
- Type and characteristic of the potential impact
    - The magnitude and spatial extent of the impact,
    - The nature of the impact,
    - The transboundary nature of the impact,

- o The intensity and complexity of the impact,
- o The probability of the impact,
- o The expected onset, duration, frequency and reversibility of the impact,
- o The combination of the impact with the impact of other existing and/or approved projects, and
- o The possibility of effectively reducing the impact.

The need for the EIA must be considered in respect of the total development and the cumulative effect of all phases should be assessed in the EIAR to comply with the Directive[8]. Legal and judicial issues regularly arise when considering the approval of road projects which are divided into several sections. The EIAR should ensure all aims of the EIA Directive are not impeded by the submission of multiple or sub-divided applications.

1.7.4 Legal Ecological Implications for Road Development

The contemporary baseline should be considered with regard to the legal implications before describing and predicting impacts of the road scheme in the EIAR. The EIA must address the requirements of the BD and HD, including effects on European sites that are not the focus of the AA process. These include legal implications for species protected under Articles 12–16 of the HD (e.g. Annex IV and V species), pollution or deterioration to habitats supporting important populations of birds (Article 4(4) of the BD) and landscape features important for listed flora and fauna (Article 10 of the HD).

Incidental Road Kill

The AGR places emphasis on the need to protect wildlife from traffic. However, in principle, the HD (Article 12), BD (Article 5) and the Bern Convention prohibit the deliberate disturbance and killing of listed species, or deterioration or destruction of their breeding sites or resting sites.

In the case of the HD and the Bern Convention, the species concerned are those listed, while the BD encompasses all wild birds. The term "deliberate" goes beyond a direct intention and means that the unwanted but accepted risk of killing is also prohibited[9].

However, infrastructure projects may derogate from the killing prohibition (HD Article 16), provided that impacts on species are kept within an acceptable level of impact.

NRAs must ensure that incidental road kill does not exceed an acceptable level of impact and undertake appropriate anticipatory measures where necessary to comply with the objectives of the HD and the ELD.

Acceptable Level of Impact

The HD and the ELD jointly define FCS as the conservation goal for species of community interest. Similarly, the Bonn Convention defines FCS as the conservation goal for species of transnational interest. Many of the species designated in the agreements are known to be affected by roads. According to the HD and the Bonn Convention, FCS is reached when:

- Population dynamics data indicate that the species is maintaining itself on a long-term basis as a viable component of its natural habitat;

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[8] Case C-142/07 *Ecologistas en Acción-CODA v Ayuntamiento de Madrid* [2008].
[9] EC (2007) Guidance document on the strict protection of animal species of Community interest under the Habitats Directive 92/43/EEC.

- The range of the species is neither being reduced nor is likely to be reduced in the foreseeable future; and
- There is, and will continue to be, sufficient habitat to maintain the species on a long-term basis.

Population dynamics and range are of particular relevance in relation to barrier effects and road mortality. In addition, the ELD points out that the assessment of FCS should take into account natural population fluctuations and species´ capacity to recover.

Species of community interest are listed in the HD Annex II, IV and V and the BD Annex I. Any lawful derogation of these species requires that FCS is still reached. Accordingly, an acceptable level of impact on populations can be defined as any impact not jeopardizing FCS and within the natural amplitude of population fluctuations. Available case law however has shown:

- Where high ambition of technical design, assessment and mitigation has been demonstrated, this is sufficient to relieve the developer of the requirement to show that impacts have stayed within acceptable levels, despite risk of increased mortality and barrier effects on target species – the burden of proof rests with the opposing party[10];
- In some cases, significant mortality or barrier effects on target species could not be proven[11] or it could not be proven that mitigation was unsuccessful in mitigating barrier effects[12,13]; and
- The Commission's task is to prove an alleged failure of a Member State to fulfil its obligations[14].

The BD presents a differently defined conservation goal for populations, namely a level that corresponds to ecological, scientific and cultural requirements (including economic and recreational requirements). However, the goal of the BD is not further defined in the Directive nor in any related guidelines. Thus, subsequently it gives poor support to more specific targets for population levels or indications on how to follow up these targets.

1.7.5 Describe and Predict Impacts in the EIAR

Accurately Characterise Impacts and their Effects

The EIA Directive specifies, in Annex III, the information which must be included in an EIAR. The EIAR must clearly explain what the significant impacts of a road scheme will be. Impact significance in EIA is based on four essential components of significance as follows:

- To ensure that a clear operational framework for significance determination applies throughout the EIA;
- Attention should focus only on significant issues;
- The term significance should be specified and applied consistently; and
- Significance determinations should be transparent to all EIA stakeholders.

[10] Case C-308/08 *Commission v Spain* "Iberian Lynx" [2010].
[11] Case RJCA/2011/824 "4th Centennial Dual Carriageway" Spain.
[12] Case ECLI:NL:RVS:2012:BW3863 "Ring-Road Buitenring Parkstad Limburg" Netherlands.
[13] Case ECLI:NL:RVS:2012:BV3215 "Wind energy dikes Noordoostpolder" Netherlands.
[14] Case C-179/06 *Commission v Italian Republic* [2007].

Predicting Impacts

Predicting the effects of a proposed project is a fundamental stage in EIA and requires particular attention in the EIAR, especially in cases where there are challenges due to:

- A complex receiving environment;
- Uncertainty over the response of ecological receptors to some impacts;
- Inadequate information and a resultant extensive reliance of the process on professional judgement; and
- The evolving and assumptive nature of modelling and predictive techniques.

Detailed quantification of effects is needed overall in order to relate the expected effects of the road project to the acceptable level of impact on populations, in compliance with standards set out in the HD, BD and Conventions (i.e. FCS). EIARs should therefore clearly address key issues such as:

- The effects of human disturbance on wildlife;
- The impact of wildlife-vehicle collisions (WVCs) on wildlife conservation;
- The continuity of wildlife movements in the landscape; and
- The difference between impacts during construction and operational phases and quantification of the expected effect levels.

Differentiate between Construction and Operational Impacts

Environmental impacts of construction and operational phases vary in nature and duration. This fundamentally triggers different requirements for impact prevention and remediation. Construction and operational stage impacts and mitigation should be considered separately in the EIAR to adequately identify, assess and mitigate effectively.

1.7.6 Define Avoidance and Mitigation in the EIAR

Mitigation

Mitigation measures for a proposed road development are integral to the direct footprint of the road, the areas it traverses and any subsequent biophysical changes to the natural environment. Mitigation outlined in the EIAR must be:

- Sufficient;
- Relevant; and
- Situated where the effects will occur and be in direct connection with, and necessary for, the road project.

The NRA must develop and fully integrate specific best practice and evidence based design measures to protect sensitive ecological receptors, ensuring avoidance of potential impacts during pre-planning design and through appropriate site location (refer to Chapter 2 on Mitigation).

Compliance with Article 16 of the Habitats Directive

A number of activities that would normally be prohibited under Article 12 of the HD can be permitted by means of an Article 16 derogation but must be justified in relation to the overall aim of the Directive. Article 16 derogation licences are subject to three specific conditions:

- One or more of the reasons listed in Article 16(1) (a)-(e).

- Activities listed in Article 16(1) include activities which protect wild fauna and flora and conserve natural habitats, activities which prevent serious property damage, activities in the interests of public health and safety, activities involving research and education and activities which allow the taking or keeping of certain specimens of the species listed in Annex IV.

- Absence of satisfactory alternative.
    - Recourse to Article 16 derogations must be a last resort with an evident need and purpose demonstrating that there are compelling reasons to justify a derogation.
- Not detrimental to the maintenance of populations at a FCS.
    - The granting of derogations for species in an unfavourable conservation status or the use of compensation measures is explicitly provided for in the Directive. However, the less favourable the conservation status and trends, the less likely that the granting of derogations can be justified. An assessment of the impact of a specific derogation will normally have to be at a lower level (e.g. site, population level) in order to be meaningful in the specific context of the derogation and evaluated in the context of natural range at the biogeographic level in each Member State.

Derogations are administered at the national level by the statutory conservation agency and therefore can be integrated into the consent or post consent monitoring and mitigation process.

Submit Derogation Licence Applications as Part of Planning Submission

Derogation licences should be applied for in advance of the granting of EIA consent, where feasible, as this:

- Ensures that full consideration can be given to the impacts of the proposed project on protected species; and
- Should avoid the possibility of delay to the proposed project or of a refusal of a derogation licence which would prevent the works from being carried out as planned.

The ECJ has indicated that the practice of requiring information on protected species derogations only after development consent has been granted, undermines the EIA process[15].

Performance Based Mitigation

All environmental legislation, except EIA, refers to population viability as one of the criteria in the HD and Bonn Convention to assess whether a protected species has reached FCS. In addition, the BD and Bern Convention implicitly emphasise the importance of population size in view of, not only species conservation, but also economic and recreational requirements. There is strong emphasis on population-level indicators as the ultimate goal of all these regulations is to protect nature and preserve biodiversity. Population level indicators should be used to determine whether significant impacts occur but simultaneously have the potential to be used to determine whether impacts are sufficiently mitigated. The contemporary baseline is used as a reference point for monitoring the performance of mitigation of the road project during construction and operational phases. Including population-related requirements in outcome-based specifications would be the best logical and compliant approach through all stages of the road life cycle, including road mitigation procurement. However, it is recognised

[15] Case C-183/05 *Commission of the European Communities v. Ireland* [2007].

that implementation in some Member States will be constrained by administrative and contractual challenges.

1.7.7 Consult and Collaborate

Adopt a Consultative Approach for an Effective EIA Process

The NRA should adopt a proactive consultative approach to better focus the EIA parameters and determine relevant environmental factors and objectives.

While the whole EIA is progressed in a staged way and many procedures are required by law, it is largely an iterative process, with early stages (notably project design and scoping) often revisited as the assessment proceeds. The effectiveness of the EIA therefore relies heavily on a systematic and consistent approach to good practice. To be effective, the EIA process must provide a demonstrable and substantive contribution to the goal of sustainable development across the EU Member States through improved infrastructure planning. Overall principles of EIA need to be well understood by all contributors and the impact assessment needs to be conducted in an integrated and complementary way.

The Benefits of Collaborative Planning

Consultation with the statutory nature conservation agency is a crucial technical element of the AA, SEA and EIA processes. The assessment cannot therefore be finalised until representations have been received and the plan-making body has had an opportunity to review and respond. The statutory conservation agency can advise on any significant likely effects of the proposed road development on sensitive ecological receptors. It can also provide advice on ecological conditions and indicative mitigation and monitoring required.

In many circumstances where a legal challenge on environmental impacts has precluded road development from being adopted, a lack of collaborative engagement in the preparation of the EIA has been identified as a constraint to the proper interpretation and implementation of legislation and policy. The following forms of consultation, when adopted, ensure the EIA or SEA process is collaborative:

- Early co-ordination between public administrations provides an opportunity to discuss the environmental information likely to be required;
- Engagement should be progressed at the scoping stage of the SEA or EIA to appraise the proposed project description, informally discuss alternatives and scope the parameters of assessments and methodologies;
- Focused pre-planning consultation with the statutory nature conservation agency on parameters of the SEA or EIA should be undertaken;
- Ongoing and proactive communication channels between the planning team and key stakeholders should be established and maintained; and
- Early contractor involvement in the tender procedure and infrastructure planning procedure could be simultaneously progressed, in parallel with project design.

1.7.8 Produce a Clear and Concise EIAR

Set out Information Clearly

The EIAR must be understandable for the public. The grounds for development consent decisions must be clear and transparent. The EIAR should set out clearly all the ecological information necessary for a decision to be made[16].

Further clarity was provided by the amended EIA Directive which states: "*The environmental impact* assessment *shall identify, describe and assess in an appropriate manner, in the light of each individual case and in accordance with Articles 4 to 12, the direct and indirect significant effects of a project on the following factors: Biodiversity with particular attention to species and habitats protected under Directive 92/43EEC and Directive 2009/147/EC.*"

Other items the EIAR must address include:

- Describing the ecological baseline and trends if the project were not to go ahead;
- Explaining the criteria used to evaluate ecological resources and assess the significance of impacts of the project;
- Stating the ecological methods used, including the timing and duration of surveys;
- Presenting any analytical techniques used and the analysis itself;
- Identifying likely ecological impacts[17] and explaining their level of significance;
- Monitoring projects using procedures determined by the Member States. Existing monitoring arrangements may be used to avoid duplication of monitoring and unnecessary costs;
- Stating the certainty with which ecological impacts have been determined and describing limitations; and
- Describing the legal and policy consequences.

Standardise Language

The uneven implementation and interpretation of the EIA process across the EU is likely to increase the wider socio-economic costs associated with planning and cause delays and legal disputes. This may subsequently impair the functioning of regional infrastructure plans and projects. An EIAR should be consistent in terminologies used for identifying, quantifying and evaluating the significance of impacts within its documentation.

Quality Control

The EIA Directive includes quality control of EIAR preparation and review, and some Member States systematically review EIAR before they are used for decision making. This is often a mandatory stage in the EIA procedure. In undertaking an EIAR review, NRAs should:

- Ensure the EIAR addresses the impact of disturbance; the barrier and habitat fragmentation effects and road casualties, as this may affect the type and number of mitigation measures; and
- Ensure recognised terminology is used systematically throughout all EIARs.

[16] Case RJ/2013/6909 *NGO vs. Cantabria Autonomous Government* "East variant in Comillas" Spain [2013]
[17] Case M7639-11 *Gävleborgs län County Board vs. Nordex Sverige* "Gullberg wind farm" Sweden [2011]

Road Construction and Operational Phase Monitoring

The EIA Directive includes monitoring obligations. If projects involve significant adverse effects on the environment, Member States should ensure that mitigation measures are implemented and that appropriate procedures are determined regarding the monitoring of significant adverse effects on the environment. The EIA Directive requires Member States to enforce "effective, proportionate and dissuasive" penalties to non-compliant developers and decision makers. Ecological monitoring will often be stipulated via conditions clearly outlined in the SEA Environmental Report or the EIAR attached to consents, consistent with the provisions for enforcement of planning applications as applied in each Member State.

The NRA should formulate a monitoring scheme to fit the scale and scope of the development in the context of the ecological and constitutive characteristics of the site, identify any predicted/unforeseen adverse impacts and address any identified data gaps.

The HD does not explicitly provide for such monitoring. However, when advocating a proportional and flexible use of the derogation system, it is necessary that the flexible approach does not lead to undesired effects. Monitoring is a key element in this regard.

Competent national authorities not only have to ensure that all the conditions of the derogation scheme are met before derogations are granted. It is also recommended that they should monitor the impact of derogations and the effectiveness of compensation measures, if any, after they are implemented. This should ensure that any risk for a species, arising unintentionally through the derogations (possibly in combination with other negative factors), is detected.

1.8 AA Procedure

The Harmony project reviewed 39 AA Reports across a number of Member States to identify the similarities and differences in the implementation of the duties required by Article 6 of the HD, focusing on cases related to road building and retrofit. The points identified are listed in Box 1-2.

Box 1-2: Harmony Findings on Key Issues with AAs

- Poor quality of the AA undertaken.
- Lack of skills/knowledge/capacity in the Article 6.3 procedure.
- An inadequate knowledge base on which to assess impacts.
- Inconsistent screening of plans and projects.
- Lack of understanding of key concepts and legal terms.
- Persistent lack of assessment of cumulative effects.
- Confusion with the EIA/SEA procedures.
- Lack of early dialogue.
- Lack of effectiveness of AAs on plans.
- Problems during public consultation.
- A lack of proposals for monitoring.

1.9 Practical Guidelines for Article 6 of the HD

Avoidance of Natura 2000 Sites

The HD sets out a hierarchy of avoidance, mitigation and compensatory measures. The Ecologist and NRA must develop realistic and achievable alternatives as strategic solutions as early in the planning process as possible to ensure protection of Natura 2000 sites.

Protected habitats listed in Annex I of the HD cannot suffer irreparable loss for development purposes, to the whole or part, except for IROPI.

NRAs must endeavour to maintain and manage features of the landscape that support the Natura 2000 network (pursuant to Articles 3 and 10 of the HD).

Synergy of AA with SEA and EIA Processes

Public plans or programmes that require AA under the HD are also subject to an environmental assessment under Article 3(i) of the SEA Directive. Projects that require appraisal under the HD may also require the preparation of an EIA.

Early consultation on the AA during these earlier stages, in parallel, can aid environmental information gathering, prediction of plan effects, and provide some early consultation.

If the AA is undertaken in parallel with SEA or EIA, it is important that the findings of both processes are separately and clearly documented, taking into account their statutory implications.

NRAs must fully incorporate SEA/EIA and AA (and vice versa) findings in the form of mitigation measures and recommendations into the programme, plan or project.

1.9.1 Screening for AA

Screening involves the following:

- Description of plan or project, and local site or plan area characteristics;
- Determination of a likely zone of impact (defined by nature and scale of the plan/project);
- Identification of relevant Natura 2000 sites in the likely zone of impact and compilation of information on their Qualifying Interests (QI) or Special Conservation Interests (SCI) and conservation objectives;
- Identification of pathways of risk to those QI or SCI, in relation to the project;
- Assessment of likely effects – direct, indirect and cumulative – undertaken on the basis of available information as a desk study or field survey or primary research, as necessary; and
- Screening statement with conclusions.

If effects are considered likely to be significant, potentially significant or uncertain, or if the Screening process becomes overly complicated, the process must proceed to Stage 2 (AA) with the preparation of an Impact Statement to inform the AA that is to be conducted by the competent authority.

Absence of Effects Must be Proven

An effect that could undermine the conservation objectives of a Natura 2000 site would be a significant effect and the likelihood of it occurring is a case-by-case judgment, taking account of the precautionary principle and the local circumstances of the site. A likely effect is one that cannot be ruled out on the basis of objective information. The test is a "likelihood" of effects rather than a "certainty" of effects. A project should be subject to AA "if it cannot be excluded, on the basis of objective information, that it will have a significant effect on the site, either individually or in combination with other plans and projects". Hence, "likely" should not simply be interpreted as "probable" or "more likely than not", but rather whether a significant effect can objectively be ruled out.

Precautionary Principle

Following a European Communication in 2000[18], the Precautionary Principle is widely applied by Member States where preliminary scientific evaluation in the Screening stage shows that there are reasonable grounds for concern that a particular activity might lead to damaging effects on the environment. In these cases, the lack of full scientific certainty cannot be used as a reason for postponing cost-effective measures to prevent environmental degradation.

The statutory conservation agency should encourage competent authorities to adopt the precautionary approach in making a determination at Screening Stage or considering environmental information, when deciding whether to consent to projects.

The NRA should apply the precautionary principle; however, in a way that recognises the general nature of road development, and does not unnecessarily or unreasonably prevent or impede the adoption of projects.

Classification and Conservation Objectives

SCI and QI are the bird species, habitats or other species for which a Natura 2000 site has been classified as an SPA or SAC, respectively. Each SCI or QI in each Natura 2000 site is assigned a Conservation Objective. These are referred to, but not defined, in the HD.

A Conservation Objective is the specification of the overall target for the species and/or habitat types for which a Natura 2000 site is designated in order for it to contribute to maintaining or reaching FCS of the habitats and species concerned.

Conservation Objectives are set by the statutory conservation agency for each SCI or QI of each Natura 2000 site and endorsed by the Government. They form the basis of assessing the potential effects of plans and projects on Natura 2000 sites.

Linked to such conservation objectives, and in light of the scope of SEA/EIA, provisions are made in Articles 10, and 12–16 of the HD and in Article 4 of the BD to take into consideration:

- Protection of birds and annexed species from habitat destruction, pollution and deterioration; and
- Protection of landscape features that are of major importance for wild flora and fauna.

[18] Communication from the Commission on the precautionary principle (COM (2000)).

1.9.2 AA

Stage 2 includes detailed impact prediction and assessment of the likely effects on the Natura 2000 sites(s) "screened in" and the proposal of specific mitigation measures, where necessary. The Impact Statement for the AA must be based on complete, precise and definitive findings[19]. Plans and projects can only be permitted by the competent authority, after having ascertained beyond reasonable scientific doubt that there is no adverse effect on the integrity of Natura 2000 sites. If adverse effects on the integrity of such a site cannot be ruled out, then the process continues to Stage 3 to assess whether alternative solutions exist.

If no alternative solutions exist and impacts on Natura 2000 sites are unavoidable, then a proposed plan or project can only be implemented where there are IROPI, as detailed in Article 6(4) of the HD. Article 6(4) of the Directive addresses specific exceptions (i.e. from the protection granted by the Natura 2000 network) to the general rule of Article 6(3) that authorisation can only be granted to plans or projects not adversely affecting the integrity of the sites concerned. The application of Article 6(4) has to respect the various steps and the sequential order established in the Directive. Measures for the improvement or management of the Natura 2000 sites cannot be compensatory. Stage 2 AA involves five steps as follows[20]:

- Step one: Information required;
- Step two: Impact prediction;
- Step three: Conservation objectives;
- Step four: Mitigation measures; and
- Step five: Outcomes (preparation of the AA Report).

Site Integrity

The concept of "integrity of the site", which must not be adversely affected, is only specifically referred to in Article 6(3). It is not defined but is described in European Commission (EC) guidance as: "The integrity of a site involves its ecological functions. The decision as to whether it is adversely affected should focus on, and be limited to, the site's conservation objectives."[21]

Site integrity must be determined by reference to the lasting preservation of the constitutive characteristics of the site concerned. Both indirect and minimal adverse effects on a site are relevant.

Considering Cumulative Impacts

Cumulative impacts must be suitably addressed and examined in the Screening for AA, Impact Statement and fully incorporated into the SEA Environmental Report and/or EIAR. The SEA and EIA Directives both recognise that in some cases the effects of a plan or project on its own would be insignificant. Nevertheless, the Directive also recognises that there may be a number of plans or projects, each of which would be unlikely to have a significant effect alone, but which, when taken in combination, would be likely to be significant.

Protective measures of the Directive could be seriously undermined if these combinations of plans or projects escaped assessment.

[19] Case C-258/11 *Sweetman v An Bord Pleanála* Republic of Ireland [2013].

[20] European Commission, 2001. Assessment of plans and projects significantly affecting Natura 2000 sites. Methodological guidance on the provisions of Article 6(3) and (4) of the Habitats Directive 92/43/EEC

[21] Managing Natura 2000 sites, European Commission, [2000].

While a single activity may itself result in a minor impact, it may, when combined with other impacts (minor or significant) in the same likely zone of impact, and occurring at the same time, result in a cumulative impact that is collectively significant.

The "in-combination" test, therefore, is about addressing "cumulative effects". Cumulative impacts can be defined as the additional changes caused by a proposed development in conjunction with other similar developments or as the combined effect of a set of developments, taken together.

In best practice, the terms "effects" and "impacts" are used interchangeably.

Projects considered in the cumulative impact assessment must contain detailed information for each project, including:

- Nature of the project;
- Project phasing or stage of planning;
- Proximity to Natura 2000 sites, scale and layout of the project; and
- Emissions to land, air or water.

Any element of the road project that was screened out alone as having minor residual effects should also be screened for the likelihood of significant effects in combination arising from other similar elements of other plans or projects.

Article 6(4)

In cases of a negative assessment of the implications for the site but where a project is needed and there are no alternative solutions which better protect the integrity of the site, then consent can be granted if it must be carried out for IROPI including those of a social or economic nature. Although the concept of IROPI is not defined in the Directive, projects must be in the public interest and must be overriding in the sense that they take precedence over the preservation of the integrity of the site in question. The Directive also states that where a priority natural habitat type will be affected, the only considerations shall be "*human health or public safety to beneficial consequences of primary importance for the environment or, further to an opinion from the Commission, to other imperative reasons of overriding public interest*."

In such cases where IROPI 6(4) is followed, the Member State shall take all compensatory measures necessary to ensure that the overall coherence of the Natura 2000 site is protected.

1.10 Protection of Annex I Habitats Outside of Natura 2000

The protection of important sites for migratory species outside of Natura 2000 is recognised in Article 4(4) of the BD. Article 11 of the HD (requirement to undertake surveillance of the conservation status of habitats and species referred to in Article 2 of the HD) is not restricted to Natura 2000 sites. It requires monitoring of the conservation status of habitats and species of Community interest, as defined in Article 1 of the Directive, throughout the territories of all Member States. It is important that, for listed habitats and species not largely covered by the network, measures are also taken outside the network to maintain or restore their FCS.

All Member States also have a duty under overlapping conservation legislation and agreements to have regard to habitats and species of recognised conservation concern, nationally and outside of designated areas.

Article 10 of the HD places an emphasis on the importance of linear and continuous features in the landscape, maintaining migration, dispersal, and genetic exchange. The onus is on Member States to endeavour to improve the ecological coherence of the Natura 2000 network.

Article 3(3) of the HD also promotes the improvement of ecological coherence between Natura 2000 sites, as referred to in Article 10.

NRAs must consider the distances that some species may travel beyond the boundary of the Natura 2000 site and the processes or pathways by which the road project may influence the site's SCI or QI. Protecting connectivity and promoting the management of features of the landscape which are of major importance for wild fauna and flora should be enforced by the NRA throughout the road life cycle.

Ecological adaptation in road development and maintenance should aim at achieving more for biodiversity than simply compliance with EU Directives. NRAs should:

- Promote wider protection and enhancement of biodiversity and ecosystem functions beyond avoiding barrier effects and animal-vehicle collisions (AVCs) and beyond mitigating impacts on listed habitats and species in the HD and BD; and
- Implement species action plans or national pollinator plans[22,23] with road mitigation and maintenance and further the aims of the EU Biodiversity Strategy.

1.11 Green Transport Infrastructure Principles

Green Infrastructure (GI) can provide substantial added value and contribute to the objectives of Articles 3(3) and 10 of the HD by ensuring the ecological coherence of the Natura 2000 network, reconnecting existing fragmented natural areas and restoring degraded habitats. Implementing the following guiding principles in road planning can further support the aims of green linear infrastructure and defragmentation projects[24]:

- The legal structure for GI must be established and strengthened;
- Strategic planning needs to precede any major development projects;
- Civil society has to be involved in the planning phase of linear infrastructure projects;
- Multi-disciplinary cooperation should be established among different professionals such as engineers and environmentalists;
- The "Polluter Pays" principle must be implemented by including concrete mitigation measures, right from the beginning of the planning phase and through the tendering and contracting phases;
- Maintenance of mitigation measures should be included in the budget of the ordinary programme for maintenance of infrastructure;

[22] The National Pollinator Strategy. Department for Environment Food & Rural Affairs, UK.

[23] All-Ireland Pollinator Plan 2015 – 2020. National Biodiversity Data Centre Series No. 3.

[24] Georgiadis (2015) Planning and Applying Mitigating Measures to Green Transport Infrastructure. Infra-Eco Network Europe (IENE).

- Environmental supervision of technical features of the infrastructure and monitoring of the habitat and wildlife populations' status should be required for all phases of the projects from design to full operation; and
- A culture of learning should be established to support continuous evaluation and exchange of knowledge between the relevant organizations and state services.

CEDR Call 2013: Roads and Wildlife Documents
Further information on material discussed in this chapter can be found in SAFEROAD Technical Report 1 and Harmony Deliverable Reports C and D. Details on these reports and other key references can be found at the back of the Manual.

Chapter 2. Road Mitigation Strategies

Summary

The detrimental effects of roads on wildlife are widely recognised and a variety of road mitigation measures have been taken across Europe to reduce these effects. This chapter provides a set of guidelines for preparing an effective road mitigation plan: (1) Identify and quantify the road impacts; (2) Identify clear goals of mitigation; (3) Aim to have the goals agreed upon by all stakeholders; (4) Select road mitigation measures for which effectiveness is proven; (5) If road kill reduction is the aim, fencing is best practice; (6) If road permeability is the aim, installing wildlife crossing structures is best practice; (7) Select mitigation measures that have proven to be sustainable; (8) Explore the economic benefits of road mitigation. The set of guidelines is not a step by step guidance document, but should be merely seen as a checklist that helps to address all relevant issues in the preparation of a scientifically-sound mitigation plan.

2.1 Introduction

Roads and traffic impact upon wildlife populations. Roads and traffic may increase mortality of wildlife due to WVCs, act as barriers to animal movement and migration, and affect both the amount and quality of wildlife habitat. Over the last four decades, concern for the impacts of roads on wildlife has resulted in efforts to mitigate these effects. Road agencies and conservation organisations are currently investing large amounts of money in developing and implementing numerous mitigation strategies and techniques. However, what is the most efficient mitigation strategy? Should we focus on reducing wildlife mortality due to vehicle-wildlife collisions? Is increasing road permeability for wildlife the better option, or should we do both? How can we ensure that the mitigation measures we take will be effective? What can be said about the cost benefit of a road mitigation initiative? These questions are addressed in this chapter and guidelines are provided for preparing an effective road mitigation plan.

2.2 Guidelines for Road Mitigation

This chapter presents guidelines on mitigation measures that aim to reduce WVCs and increase the permeability of the road for wildlife. The guidelines remain at a high level; detailed recommendations on how mitigation can be best designed and fitted into the landscape can be found in the COST 341 Handbook, Chapter 7. These guidelines should be merely seen as a checklist that helps to address all relevant issues in the preparation of a scientifically-sound mitigation plan, based on the current knowledge of what works and what does not.

2.2.1 Identify and Quantify the Road Impacts

- The first step in the preparation of any mitigation plan should be an assessment of the road impacts of concern, i.e. a problem analysis:
  - For the case of mitigation of an existing road, this implies <u>measuring</u> impacts, such as WVC numbers or barrier effects;
  - For the case of a new road, this implies <u>predicting</u> impacts, e.g. based on previously assessed quantitative relations between road impacts and their effects on wildlife or based on predictive models that allow for the estimation of road impacts.
- To plan mitigation measures that aim to reduce road kill due to WVCs, it is recommended to measure (for the case of existing roads) or predict (for the case of new roads):
  - Road kill numbers;
  - Spatial and temporal distribution of road kill;
  - Characteristics of road kill (e.g. species, sex, age, etc.);
  - Ecology and behaviour of species;
  - The (potential) impact of measured/predicted road kill on population dynamics, gene flow, fitness, reproductive success and spatial distribution;
  - The (potential) impact of measured/predicted road kill on the ecosystem.
- To plan mitigation measures that aim to increase road permeability for wildlife, it is recommended to measure (for the case of existing roads) or predict (for the case of new roads):
  - Road-crossing numbers;
  - Spatial and temporal distribution of road-crossings;
  - Characteristics of road-crossings (e.g. species, sex, age, etc.);
  - Ecology and behaviour of species;

    - Characteristics of the population (e.g. size, density, genetic variability, etc.);
    - The (potential) impact of measured/predicted road-crossings on population dynamics, gene flow, fitness, reproductive success and spatial distribution;
    - The (potential) impact of measured/predicted road-crossings on the ecosystem.
- Where possible, both at a strategic and project level, population models should be used to assess impacts on population viability, including:
    - An assessment of which road impact (e.g. road kill versus barrier effects) likely affects the population the most;
    - An assessment to identify where certain road impacts can be expected the most and, hence, mitigation measures will likely have the highest benefits for the population (refer to Box 2-1).

It is recommended to use existing population models, where possible. However, the development of new models may be needed, e.g. depending on the species of concern or desired accuracy.

2.2.2 Identify Clear Goals of Mitigation

- Identify the main driver(s) behind the mitigation:
    - Nature conservation;
    - Animal welfare;
    - Traffic safety;
    - A combination of two or three of these.
- Identify clear goals of mitigation, following the SMART approach (Specific, Measurable, Achievable, Realistic, Time framed):
    - Identify species of concern;
    - Specify which road impact is to be addressed;
    - Quantify the reduction in impact aimed for;
    - Specify the time span over which the reduction is to be achieved.

2.2.3 Involve Stakeholders Early on in the Process and Aim to have the Goals Agreed Upon by all Stakeholders

- Aim for agreement, where feasible, on the goals of mitigation by all stakeholders at the earliest stages of planning, including:
    - Regional and local governments;
    - Managers of natural areas;
    - Private land owners;
    - Non-governmental organizations (NGOs).
- Provide insight to stakeholders on what road impacts are measured or expected and what the mitigation would mean for all involved.
- This approach is essential to prevent objections at later stages that may delay or hinder the full implementation of the plan.

Box 2-1: Example – Use of Population Viability Analysis to explore the need for mitigation

In the Netherlands, priority spots for defragmentation measures, i.e. locations where wildlife crossing structures are most urgently required, were assessed with the help of population viability modelling (Figure 2-1). Firstly, all spots were identified where existing transport corridors (national roads, railroads and canals) impair the viability of wildlife populations. This was undertaken for 10 carefully selected focal species. Each focal species represents a group of wildlife species with similar habitat requirements and dispersal capacities. Population viability was analysed with the expert-based model LARCH (Landscape ecological Analysis and Rules for the Configuration of Habitat) for both the present (with infrastructural barriers) and a hypothetical future where wildlife crossing structures remove all barrier effects. By comparing the two analyses, defragmentation spots were identified at infrastructure sections where population viability is expected to increase considerably due to crossing structures. Secondly, the defragmentation measures were prioritised based on differences in the expected extent to which a mitigation measure would increase population viability.

Source: Van der Grift & Pouwels (2006). Restoring habitat connectivity across transport corridors: Identifying high-priority locations for de-fragmentation with the use of an expert-based model. In: J. Davenport & J.L. Davenport (eds.). The ecology of transportation: managing mobility for the environment: 205-231. Springer, Dordrecht, The Netherlands.

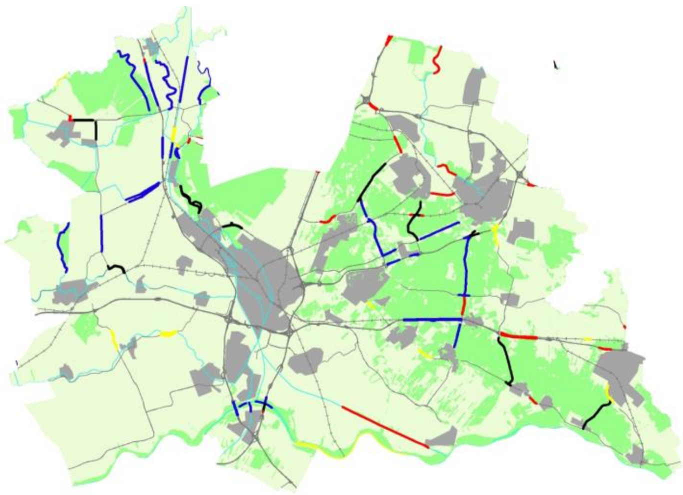

Figure 2-1 Identified defragmentation spots in the Dutch province of Utrecht: low priority (yellow), moderate priority (orange), medium priority (red), above medium priority (blue), and high priority (black). The National Ecological Network (NEN) is shown in green.

2.2.4 Select Road Mitigation Measures for which Effectiveness is Proven

- Only measures should be selected for which it has been proven that they have the potential to reduce the barrier effect of roads and/or road-related wildlife mortalities.
- Recommendable measures, if applied correctly, are:
    - Fencing in combination with wildlife crossing structures;
    - Animal detection systems;
    - Cross-walks;
    - Traffic calming;
    - Speed reduction.
- Potentially effective measures are:
    - Reducing attractiveness of road verges to certain groups of animals;

  - Increasing the attractiveness of areas further away from the road;
  - Virtual 'fences', i.e. devices that emit sound and light signals and are activated by the headlights of passing cars;
  - Modifications of road lighting;
  - Increasing visibility of animals to drivers, e.g. through frequent mowing of the vegetation in the zone adjacent to the road surface;
  - In-vehicle warnings, e.g. through the navigation system;
- Not recommendable measures are:
  - Wildlife mirrors and reflectors;
  - Olfactory repellents;
  - Acoustic deterrents;
  - Wildlife crossing structures <u>without</u> fencing.
- Standard wildlife signs are ineffective in reducing WVCs; however, in some countries their placement is required to provide legal cover.
- In the selection of an appropriate measure, the species of concern needs to be taken into account. For example, while fencing in combination with wildlife crossing structures can be applied for a large variety of species, animal detection systems can only be used for large mammals.
- In the selection of an appropriate measure, the local situation needs to be taken into consideration. For example, reducing the attractiveness of road verges to the animals cannot be applied everywhere because of the possible natural value of the road verge. Note that the measure does not necessarily mean that verges are turned into "deserts"; it may also mean taking out specific plants or shrubs (e.g. with berries) to prevent large herbivores from lingering in the verge, or cleaning up carcasses to prevent carnivores from being attracted to the roadside.
- To be sure that mitigation measures are effective, thorough evaluations of the effectiveness of road mitigation measures should be carried out before the measures are widely applied (refer to Box 2-2 and Chapter 6).
- If scientific support for effectiveness is lacking, application of the measures – even on the basis of 'there is no harm in trying' – is advised against, because:
  - It is a waste of financial resources;
  - It may result in the unjustified impression amongst stakeholders that the problem has been solved and further measures are not needed (refer to Box 2-3).

Box 2-2: Meta-analysis Road kill

Rytwinski et al. reviewed the effectiveness of road mitigation measures in reducing road kill among terrestrial fauna using a meta-analytical approach. The study showed that, overall, mitigation measures (all types) reduce road kill (all taxa) by 40% compared to controls. Fences, with or without crossing structures, reduce road kill (all taxa) by 54%. No detectable effect on road kill was found for crossing structures without fencing. Within taxa, vast differences may occur between mitigation measures. For example, the combination of fencing and crossing structures led to an 83% reduction in road kill of large mammals, compared to a 57% reduction for animal detection systems and only 1% reduction for wildlife reflectors.

Source: Rytwinski et al. (2016). How Effective is Road Mitigation at Reducing Road kill? A Meta-Analysis. PLoS ONE 11(11): e0166941.

Box 2-3: Economy versus Effectiveness

Economic considerations strongly influence the selection of mitigation measures. Comparatively inexpensive measures are commonly employed by road agencies despite there being little evidence concerning their effectiveness. For example, warning signs are implemented across the world to reduce large animal collisions with vehicles (Figure 2-2), yet many transportation and natural resource agencies report they do not know whether this measure is effective. In contrast, measures that are thought to be more effective – i.e. wildlife fencing, crossing structures, and animal detection systems for large mammals – may not be implemented due to high costs and low public support. Where cost, rather than effectiveness, drives decision making, mitigation effectiveness may be compromised.

Figure 2-2 Standard wildlife warning signs are one of the most common types of road mitigation; however, without sufficient evidence of effectiveness. Photographs: E.A. van der Grift

2.2.5 Combining Fences with Wildlife Crossing Structures is Best Practice

If wildlife fencing is designed, implemented and maintained correctly, the road becomes an almost total barrier to wildlife. This may be problematic for species that have large home ranges, or for species that need to be able to migrate between habitat patches on both sides of a road in order to have a viable population locally in the region. This problem especially affects species that live in highly fragmented landscapes. Fences without crossing structures may also be an incentive for the animals to breach the fence. Therefore, it is best practice to always combine wildlife fencing with safe crossing opportunities for wildlife to ensure connectivity between habitats/ecosystems.

Planning Fencing

Where road kill poses a safety or an ecological concern, fencing remains the most effective mitigation measure to date, but should always be used in conjunction with wildlife crossing structures. Although a 100% road kill reduction is rarely reached through fencing, it has been proven to be essential in reducing road kill, particularly for large mammals.

In the case of fencing, it is recommended to:

- Select a fence type that addresses the requirements of all target species.
    - There is no one-size-fits-all approach in fencing; each target species should be considered in decisions on fence type, including:
        - Fence design;
        - Fence height;
        - Fence material;

        - Mesh size.
    - Special features should be included to account for the climbing or burrowing ability of animals, such as:
        - Top extensions that face away from the road;
        - Smooth vertical surface, to prevent animals from climbing over;
        - Buried fence base or skirt.
- Always construct fences on both sides of the road, with the fence ends opposite each other.

Box 2-4: Example: Short or long fences?

Huijser et al. found that short fences (≤5km road length) had lower and more variable effectiveness in reducing large mammal-vehicle collisions than long fences (>5km) on a North American highway. On average, mitigated road sections that were at least 5km long, reduced collisions with large mammals by approximately 84%, whereas mitigated road sections that were shorter than 5km only reduced these collisions by approximately 53%. Additionally, the effectiveness of mitigated road sections shorter than 5km was extremely variable and hence unpredictable. The researchers conclude that if the primary aim is to improve highway safety for humans by reducing collisions with large ungulates, fence lengths should be at least 5km. The study is highly relevant as currently fence length is often minimized as fences may affect landscape aesthetics, may receive little support from the public and are sometimes considered costly.

Source: Huijser et al. (2016). Effectiveness of short sections of wildlife fencing and crossing structures along highways in reducing wildlife–vehicle collisions and providing safe crossing opportunities for large mammals. Biological Conservation 197: 61-68.

- Ensure that fence length is sufficient (refer to Box 2-4).
    - For the case of existing roads, fencing should be located at:
        - Road stretches where concentrations of road kill ("hotspots") occur;
        - Road stretches where concentrations of road kill are expected, e.g. due to changes in land use or habitat restoration.
    - For the case of planned roads, fencing should be located at:
        - Road stretches where concentrations of wildlife crossings are expected, based on an analysis of:
            - current species distribution;
            - current movement, migration or dispersal patterns;
            - current spatial configuration of suitable habitat.
- Prevent fence end effects, i.e. elevated road kill immediately adjacent to fence ends, through:
    - Constructing fences that go well beyond the road stretch where concentrations of road kill or wildlife crossings occur or are expected;
        - The distance over which fencing should be continued can be based on the mean daily movement distances of the target species or on the diameter of the average home range of the target species.
    - Taking specific measures at the fence end to prevent animals from going around, such as:
        - Fencing perpendicular to the road;
    - Accepting that animals go around and take measures for safe at-grade crossings, such as:

    - Installation of a wildlife detection system that can activate warning signs for drivers.

- Prevent animals from entering the fenced road corridor through modifications at the fence ends, such as:
    - Perpendicular fence from fence end to the paved road surface;
    - Boulder fields between fence end and paved road surface (Figure 2-3);
    - Wildlife guard (Figure 2-3);
    - Electric mat;
    - Electric concrete.

Figure 2-3 Boulder fields at the end of the fence (left) and cattle guards (right) may help prevent animals from entering the road corridor. Photographs: E.A. van der Grift.

- Prevent animals from entering the fenced right-of-way at access roads, through:
    - Gates;
    - Wildlife guard;
    - Electric mat;
    - Electric concrete;
    - Wildlife crossing structure underneath the access road.
- Include measures that allow animals to escape the fenced right-of-way, such as:
    - One-way gate;
    - Wildlife jump-out;
    - Climbing poles on the road side;
    - Tree stumps or branches stacked up against the fence on the road side;
    - Lowered fence with top extension that faces away from the road.
- If possible, avoid any type of fencing in the median, including Jersey barriers, if the roadway is not fenced, as this may increase road kill numbers. If fencing in the median is unavoidable, this should always be combined with fencing in both road verges and the installation of wildlife crossing structures.

Fencing may not always be feasible or desirable, especially in regards to road kill on local roads or when appropriate wildlife crossing structures are absent. In these cases, other mitigation options could be explored, such as animal detection systems, traffic calming or reducing traffic speed.

Planning Crossing Structures

Wildlife crossing structures remain best practice where the barrier effect is impacting populations or fencing is needed. Although a 100% restoration of landscape connectivity is rarely achieved, crossing structures have been proven to provide safe crossing opportunities for a variety of species.

For the case of installing wildlife crossing structures, it is recommended to:

- Install a crossing structure that addresses the requirements of all target species, including:
    - The type of crossing structure (overpass, underpass);
    - The design of the crossing structure (e.g. dimensions, material, furnishing, screening);
    - The positioning of the crossing structure in the landscape;
    - Feasible fencing/guiding structures.
- Make use of available information on the acceptance and use of different types and designs of structures by the target species, as well as the conditions these species prefer in the direct surroundings of the measures, such as:
    - Distance to traditional movement paths;
    - Distance to cover;
    - Distance to riparian corridors;
    - Distance to human settlements.
- If no crossing structure can be identified that facilitates all target species in terms of type/design or if different target species require an alternative positioning of the crossing structure in the landscape, multiple (types of) crossing structures should be installed.
- Assess the desired number of crossing structures for each target species, through:

  $$L/D - 1$$

  in which:
  L = length of the road stretch that needs to be mitigated;
  D = maximum distance between two crossing structures.

- The maximum distance between two crossing structures (D) should be based on an empirical assessment of the mean distance covered by the target species along a fence (refer to Boxes 2-5 and 2-6).
- If such assessments are missing, the distance can be based on the size of the target species' home range (HR), i.e. the area used by an animal during its day to day activities, through:
    - Maximum distance between structures = $\sqrt{HR}$ if the crossing structures need to provide daily access to foraging resources for all members of a population;
    - Maximum distance between structures = $7 * \sqrt{HR}$ if the crossing structures need to facilitate occasional dispersal.

Box 2-5: Example: Tunnels for toads

One of the largest known common toad (*Bufo bufo*) populations in the Netherlands is bisected by a two-lane road. In the past, high numbers of toads were killed by traffic during spring migration, as the animals had to cross the road to migrate from their wintering habitat (south of the road) to their breeding ponds (north of the road). Until 2010, volunteers erected temporary drift fences and pitfall traps to catch the migrating animals and transported them manually across the road. In 2010, the temporary measures were replaced by two amphibian tunnels (Figure 2-4) and permanent drift fences along a 1km road stretch. Research showed that, on average, only 31% of the toads used the tunnels. The others ended up on the road (1%) or quit following the drift fence before a tunnel was reached (68%). The average distance covered by the toads along the drift fences was approximately 60m. Therefore, it was recommended to increase the number of tunnels as the current tunnel density did not create sufficient road permeability for toads.

Source: Ottburg & Van der Grift (in prep.) Effectiveness of road mitigation measures for a common toad (*Bufo bufo*) population in the Netherlands.

Figure 2-4 Amphibian tunnel and drift fences to help toads safely across the road. Photograph: E.A. van der Grift

Box 2-6: Example: Spacing of crossing structures for moose

In Norway, fences are built along highways with high traffic volume and high speed limits to avoid AVCs. Often, crossing structures are built to provide animals with the opportunity to cross these fenced roads. These can be structures designed for wildlife, multiple purposes or traffic. Rolandsen et al. studied how many and what kind of structures are needed for moose (*Alces alces*) to reach pre-set goals for mitigation. For this purpose, they analysed the movements of 55 moose that had been fitted out with Global Positioning System (GPS)-collars (Figure 2-5). The study suggests that moose use wildlife crossing structures with a higher probability than crossing an unfenced road with high traffic volume. For multi-use structures, however, no significantly higher probability is found for using a structure as compared to crossing an unfenced road with high traffic volume. When the distance to the wildlife crossing structures increases, this reduces the likelihood of moose choosing to use the structure. For wildlife crossing structures, the results suggest that building a structure every 1.4km would outweigh the barrier effect of the fence; moose use such spaced crossing structures with the same probability as crossing an unfenced road with high traffic volume.

Source: Rolandsen et al. (in prep). You shall pass! A mechanistic evaluation of mitigation efforts in road ecology.

Figure 2-5 Female moose marked with GPS collar and ear tags. Photograph: O. Roer

- Explore the need for and feasibility of human co-use of the crossing structure (e.g. pedestrians, cyclists, horse riders, skiers, etc.), through:
    - An assessment of potential impacts of human co-use on use by the target species;
    - Identification of potential modifications in the design of the crossing structure that will mitigate these impacts, such as:
        - Widening of the structure;
        - A clearly demarcated recreational zone (e.g. trail);
        - Fencing, earth berms or planting (screening) that separate the recreational zone from the wildlife zone.

Wildlife crossing structures may not always be feasible or the most appropriate mitigation measure, e.g. in restoring habitat connectivity across low-speed/low-traffic-volume roads. In such cases, other mitigation options could be explored, such as cross-walks, animal detection systems, traffic calming or reducing traffic speed; however, these are usually less effective.

2.2.6 Select Mitigation Measures that have Proven to be Sustainable

- Mitigation measures require frequent inspection and maintenance; otherwise failure will occur a few years after installation (refer to Box 2-7).
- To prevent frequent failures, emphasis should be placed on the construction of more robust fences and wildlife crossing structures (Figure 2-7).
- In this respect, it is recommended to:
  - Install amphibian fences made of concrete or steel rather than of plastic;
  - Install bridges or culverts that include dry parts of the river bank rather than bridges or culverts in which a dry ledge or shelf is installed;
  - Install large wildlife over- or underpasses that will not be easily blocked-up or flooded as compared to small wildlife tunnels.
- Higher construction costs of more sustainable measures are balanced by lower costs of maintenance and a reduced risk of failure.

Box 2-7: Example: Mitigation for reptiles – does it work in the long term?

Mean yearly road kill numbers of reptiles decreased by 67% on a 2km road stretch, bordering Fochteloërveen Nature Park (the Netherlands), after mitigation measures (tunnels and fences) were installed in 2003 (Figure 2-6). These means were calculated over three years immediately prior to mitigation (1999–2002) and three years immediately after mitigation (2004–2006). The accomplished road kill reduction, however, fully disappeared again in the years 2007–2009. Defects in fences and tunnels were identified as the main cause.

Source: Mulder (2010). Reptile and amphibian road kill on roads in and along the Frisian part of Fochteloërveen 1999-2009. WARF 13 (13): 12-25.

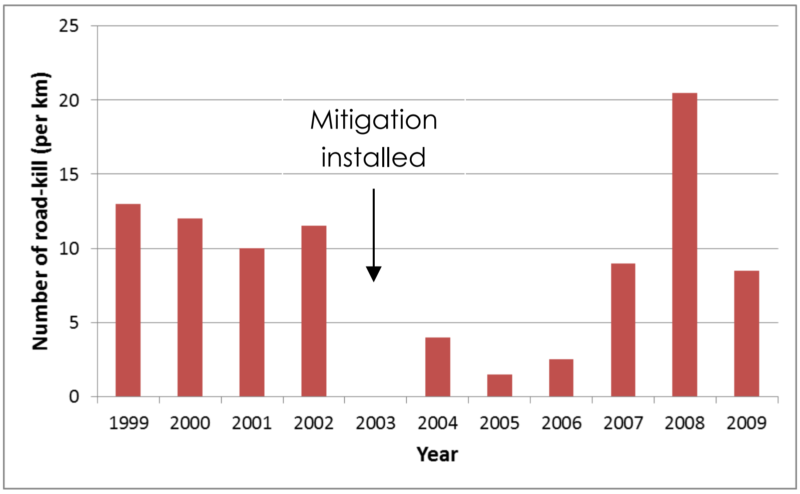

Figure 2-6 Road kill numbers of reptiles on a 2km road stretch, before and after mitigation measures – tunnels and drift fences – were installed.

Figure 2-7 Synthetic amphibian fences (left) tend to fail a few years after installation. Concrete barriers (right) can be seen as a more robust and sustainable alternative. Photographs: E.A. van der Grift.

2.2.7 Explore the Economic Benefits of Road Mitigation

In some species, especially large mammals, mitigation against accidents or habitat fragmentation can have a clear economic dimension. Deer-vehicle collisions in Europe have a significant societal cost, partly due to the loss of hunting and recreational value attributed to these species, but mainly because of the risk of material damage, human injuries and fatalities they entail. Also, barrier effects on wildlife and consequent isolation of local populations can have significant economic consequences to, for example, agriculture, forestry, and wildlife management. With a more accurate estimation of these costs, e.g. through cost-benefit analysis (CBA) and cost-effectiveness analysis (CEA) (refer to Box 2-8), the cost/benefit of effective mitigation can be quantified. Therefore, it is recommended to undertake CBA and CEA for all wildlife mitigation measures. As a result, it will be easier to justify investments in road mitigation for wildlife in general. This will have a positive spill-over effect on biodiversity protection, as many smaller species may also benefit from measures employed for larger wildlife.

Box 2-8: Applying CBA and CEA

CBA is a systematic approach to the estimation of the strengths and weaknesses of alternative activities for a business. The technique is used to determine which options provide the best approach in terms of benefits from time and cost savings. The transport sector applies CBA to evaluate whether an investment in measures to improve, for example, traffic flow and safety, is economically worthwhile. While costs for an investment may be relatively easy to assess, potential benefits are often more complex and long term. By default, CBAs tend towards an underestimation of benefits. CBA outcomes are expressed as the ratio of monetary costs and benefits and result in a single number that translates to how well a project alternative may pay off.

In comparison, CEAs generally compare the relative costs and outcomes among several actions. CEAs do not answer the question about whether or not a measure should be taken or an investment should be made, but give guidance in the selection of the most efficient measure. The advantage over CBA is that expected benefits do not need to be monetized but instead can be expressed in qualitative or quantitative terms that can provide a direct link to policy objectives and political targets. Market prices play a role in this analysis, but are only one factor amongst others, subordinated under the political agenda. As such, CEA can play an important role as an enforcement mechanism, helping to identify the cheapest way to accomplish a certain goal. As costs and benefits are incommensurate, they can neither be added nor subtracted to obtain a single criterion measure. Typically, a CEA is therefore expressed as a ratio where the denominator is the gain in a quantifiable measure of success (e.g. number of lives saved or increased viability of populations) and the numerator is the economic cost associated with this gain. The ratio can take two forms: CE ratio = Cost/Effect (e.g. Euros spent per life saved) and EC ratio = Effect/Cost (e.g. lives saved per Euros spent). Both ratios offer a powerful means for the ranking of alternatives in a decision process.

CEA requires political target setting, preferably based on a multi-stakeholder, multi-criteria analysis. An example for such targets is the HD with its binding regulations for governmental and private actors to maintain or restore a FCS for threatened species. Similar strategic goals may exist for, perhaps, the reduction of human fatalities in road traffic or the reduction of the costs of human injuries in AVCs. However, where such political directives are lacking or are less precise, for example, concerning the protection/management of common wildlife species and their ecosystem services, CEA falls short and economic rules are applied. CEA is thus not an alternative but rather a complement to CBA.

CEDR Call 2013: Roads and Wildlife Documents

Further information on the topics discussed in this chapter can be found in SAFEROAD Technical Reports 3, 4 and 7 and SAFEROAD Scientific paper 5. Details on these reports and a few other key references can be found at the back of the manual.

Chapter 3. Mitigation Measures for Bats

Summary

Bats may fly across roads but they often do so at traffic height, which puts them at risk of vehicle collision. Roads may also degrade and destroy habitats and act as barriers. A variety of measures has been implemented on roads across Europe that reduces their impact on bats, e.g. wildlife overpasses, tunnels, roost sites and habitat management. The effectiveness of most of the measures is uncertain or varies between bat species, but potentially suitable interventions are available. In this chapter, we present pros and cons and uncertainties for mitigation measures for bats. If methods are carefully chosen, designed and subsequently monitored, more accurate and consolidated recommendations for scientifically-sound mitigation strategies for bats can be provided in the future.

3.1 Bats and Roads

Roads can have a detrimental effect on bats. Contrary to common belief, bats are hit by vehicles as they often cross transport infrastructure at low height. Furthermore, road development may destroy important habitats. As bat populations are very susceptible to increased mortality rates and environmental changes, measures are often implemented on roads to reduce or off-set their potential negative impact on bats. This chapter describes, assesses and provides recommendations on the different mitigation measures for bats.

Table 3-1 Assessment of bat mitigation measures and their potential effectiveness for bat species with different flight characteristics.

1/ Good evidence of use or effectiveness. Recommended measure if constructed correctly (green).
2/ A potentially effective measure. Further development and documentation is needed (yellow).
3/ Studies indicate use by some species, but more research is needed (orange).
4/ Ineffective measure or studies have shown very ambiguous results. Not recommendable (red).

		Flight characteristics		
Mitigation method		**In or near clutter and structures**	**Open airspace**	**Notes**
Fauna passages				
Wildlife overpasses		1	1	
Modified bridges	Green verges	1	1	
	Panels	3	n/a	
Bat gantries	Open structures	4	4	
	Closed structures	3	3	
Hop-overs		3	3	Species dependent
Viaducts		1	2	Size dependent
Tunnels and culverts		2	4	Size dependent
Diversion and guidance				
Hedgerows		2	3	
Barriers		2	3	
Artificial lighting	Deterrence	3	3	Species dependent
	Adaptation of spectrum	3	3	
	Restriction of spillage	2	2	
Audible warning		3	3	Species dependent
Speed reduction		3	3	
Ecological mitigations				
Bat boxes		4	4	
Bat houses		2	2	Very variable success
Relocate tree trunks		3	3	Species dependent
Artificial holes in trees		3	3	Only long term
Tree retention		2	2	Only long term
Habitat improvements		2	2	Only long term

3.1.1 Road Impact

Road traffic may result in direct mortality and reduce the ecological functionality of landscapes for bats. Bats have long life spans and usually only produce one offspring per year, which makes bat populations very susceptible to increased mortality rates. The low reproductive rate also limits bats' ability to recover if populations have been depleted. Bats use resources that are widely dispersed in the landscape. They often commute 5–10km, some species even further, and may cross several roads each night. The locations of roost sites and foraging habitats vary during the year. Therefore, a well-connected, complex habitat network must be maintained to protect viable populations.

The different threats from roads occur at different time scales. Roost site destruction and habitat loss during construction will have immediate impact, while noise and light pollution and road mortalities will be constant threats once the road has opened to traffic. The effects of each individual factor might be small, but their cumulative impact can be significant. However, the effects on population status may take several years to detect. The cumulative effects of roads and the time lag between the impact and detectability of population declines should be considered when assessing road impacts and the effectiveness of mitigation strategies.

3.1.2 Bat Conservation and Mitigation

All European bat species are protected under the Bonn Convention, the Bern Convention and the EUROBATS Agreement. Furthermore, in the EU, all bats are strictly protected by the Habitats Directive.

Various measures have been implemented on roads in many countries to reduce road mortality risk and increase road permeability, or to compensate for habitat degradation and losses. Some fauna passages are designed and constructed specifically for bats, but bats will also use passages designed for other wildlife species and multifunctional passages if the passages are suitable and located optimally, relative to bat commuting routes and habitats.

Bats have been observed to use the majority of measures as intended. However, the effectiveness of most measures has not been adequately evaluated. Recent studies have indicated that some mitigation structures are only used by a minor proportion of bats. Overall, there is little documentation to indicate that the currently advised measures are adequate to mitigate the road effects at a site-specific level or on population or landscape scales. Appropriately systematic pre-construction surveys and post-construction monitoring of bats on mitigated sites and at landscape and population scale are needed to assess, document and develop more effective bat mitigation strategies.

Due to the limited knowledge on the effectiveness of bat mitigation measures, a precautionary approach should be applied when planning roads and bat mitigation schemes. Special consideration should be given when infrastructures are planned in areas with rare species, small vulnerable populations, or species with a fragmented distribution.

3.1.3 Species-specific Considerations

All bat species can be affected by roads, but the risk differs between species depending on their echolocation characteristics, manoeuvrability, and flight pattern. The larger, narrow-winged species usually hunt and commute in the open airspace above traffic height, while the more manoeuvrable species often fly near vegetation and surfaces. These latter "clutter-adapted" species cross open stretches, e.g. roads, at low heights. Bats are also at risk when foraging along hedgerows and forest edges, close to roads.

The behaviour and flight pattern of bat species influence their use of mitigation measures, e.g. small underpasses can be effective for low-flying species, but ineffective for species that commute and forage in the open airspace. Consequently, a detailed knowledge of species presence is crucial for an effective mitigation scheme. Within each bat species there is also a large natural behavioural "plasticity" which must be considered when monitoring and planning mitigation strategies.

Functional Groups of European Bat Species

A. Extremely manoeuvrable bats, which often fly within foliage or close to vegetation, surfaces and structures. When commuting, they often follow linear and longitudinal landscape elements. Low flying (typically < 2m) when commuting over open gaps.

B. Very manoeuvrable bats that most often fly near vegetation and surfaces, but may occasionally hunt within the foliage. When commuting, they often follow linear and longitudinal landscape elements. Low-medium flying in commuting flight over open stretches (typically < 5m).

C. Bats with medium manoeuvrability. They often hunt and commute along vegetation or structures, but rarely close to or within the vegetation. They may also fly in open areas. Typically commuting over open stretches at low to medium heights (typically 2 –10m).

D. Bats with medium manoeuvrability. They hunt and commute away from vegetation and structures in a variety of flight heights with more straightened flight patterns. Commuting over open stretches tends to occur at medium heights (2–10m).

E. Less manoeuvrable bats that most often fly high and in the open airspace, away from vegetation and other structures. These bats generally commute over open stretches at medium heights or higher (10m and often higher). However, they may sometimes fly quite low, e.g. when hunting insects over warm (road) surfaces, or when they emerge from a roost site.

Table 3-2 Provisional categorisation of European bat species in functional groups based on their typical flight behaviour and height. Brackets indicate that knowledge on the species' flight behaviour is limited.

		In or near clutter and surfaces			Open airspace	
Latin name	**Common name**	**A**	**B**	**C**	**D**	**E**
Rousettus aegyptiacus	Egyptian fruit bat				(X)	
Rhinolophus hipposideros	Lesser horseshoe bat	X				
Rhinolophus ferrumequinum	Greater horseshoe bat		X			
Rhinolophus euryale	Mediterranean horseshoe bat		X			
Rhinolophus mehelyi	Mehely's horseshoe bat		X			
Rhinolophus blasii	Blasius's horseshoe bat		(X)			
Myotis daubentonii	Daubenton's bat		X			
Myotis dasycneme	Pond bat			X		
Myotis capaccinii	Long-fingered bat			X		
Myotis brandtii	Brandt's bat		X			
Myotis mystacinus	Whiskered bat		X			
Myotis aurascens	Steppe whiskered bat		(X)			
Myotis alcathoe	Alcathoe bat		X			
Myotis nipalensis	Asiatic Whiskered bat		(X)			
Myotis nattereri	Natterer's bat	X				
Myotis escalerai	Iberian Natterer's bat	X				
Myotis emarginatus	Geoffroy's bat	X				
Myotis bechsteinii	Bechstein's bat	X				
Myotis myotis	Greater mouse-eared bat			X		
Myotis blythii	Lesser mouse-eared bat			X		
Myotis punicus	Maghreb Mouse-eared bat			(X)		
Nyctalus noctula	Common noctule					X
Nyctalus lasiopterus	Greater noctule					X
Nyctalus leisleri	Leisler's bat					X
Nyctalus azoreum	Azores noctule					(X)
Pipistrellus pipistrellus	Common pipistrelle			X		
Pipistrellus pygmaeus	Soprano pipistrelle			X		
Pipistrellus hanaki	Hanak's Pipistrelle			(X)		
Pipistrellus nathusii	Nathusius's pipistrelle			X		
Pipistrellus kuhlii	Kuhl's pipistrelle			X		
Pipistrellus maderensis	Madeira pipistrelle			(X)		
Hypsugo savii	Savi's pipistrelle				X	
Vespertilio murinus	Parti-coloured bat					X
Eptesicus serotinus	Serotine bat				X	
Eptesicus nilssonii	Northern bat				X	
Eptesicus isabellinus	Isabelline serotine				X	
Eptesicus bottae	Botta's serotine				X	
Barbastella barbastellus	Barbastelle				X	
Plecotus auritus	Brown long-eared bat	X				
Plecotus macrobullaris	Alpine long-eared bat	X				
Plecotus sardus	Sardinian long-eared bat	(X)				
Plecotus austriacus	Grey long-eared bat	X				
Plecotus kolombatovici	Balkan long-eared bat	(X)				
Plecotus teneriffae	Canary long-eared bat	(X)				
Miniopterus schreibersii	Schreiber's bent-winged bat				X	
Tadarida teniotis	European free-tailed bat					X

3.1.4 Bat Surveys and Monitoring

A comprehensive pre-construction survey is essential to select an effective mitigation strategy for all species that might be affected by a road scheme. Post-construction studies and monitoring are crucial to document that the mitigation measures have reached their targets, and to ensure that the functionality of the measures is maintained.

Pre-Construction Surveys

The aims of pre-construction surveys are:

- To register all bat species which are likely to be affected by a road scheme;
- To find intersections of bat flight paths with all the proposed road trajectories and to study bats' behaviour at these sites; and
- To identify important foraging habitats and roost sites in the project area.

The pre-construction survey should apply robust, quantitative and standardised methods (e.g. field techniques, survey sites, survey timing and periods) to provide data on bat occurrence and activity at crossing sites against which post- construction monitoring results can be compared. Due to the seasonal variation in bat behaviour, several survey sessions from spring to autumn are needed to record species present, bat foraging habitats and activity at potential crossing sites.

Special effort must be paid to locate sites where the road trajectories sever linear landscape elements that act as commuting routes for bats, e.g. hedgerows, treelines, stone walls, forests, rivers and streams. Bats also use many different roost sites through the year. Buildings, underground sites, and large trees that may constitute bat summer roosts (maternity roosts, intermediate or mating roosts) and winter roosts (hibernacula) should be inspected thoroughly.

Post-Construction Studies and Monitoring

The post-construction studies and monitoring programmes should aim:

- To evaluate the effectiveness of mitigation measures and identify if modifications or maintenance actions are needed; and
- To evaluate the impact of the road and mitigation schemes on landscape and population scale.

The methodological approach in the post-monitoring programme should be robust, replicable and quantitative. The monitoring protocol should ensure that results are comparable to pre-construction survey data. To assess the effectiveness of mitigation structures, appropriate reference sites should also be monitored for comparison.

3.2 Bat Mitigation Measures

Structures should be constructed to reduce traffic mortality risk and increase road permeability for bats at sites where roads intersect bat commuting routes. Several interventions have been implemented on roads to mitigate the impacts on bat populations. The effectiveness of the different mitigation types may depend on the species composition and the topography at the site. Thus, the mitigation strategy at a site must be carefully selected and each measure carefully designed.

3.2.1 Wildlife Overpasses

General Description and Objective

A wildlife overpass (Figure 3-1) is a vegetated overbridge constructed to maintain road permeability for the fauna. Wildlife overpasses can provide safe crossing structures for most bat species, regardless of their flight patterns. Bats readily use overpasses built for larger wildlife species. For bats, the use of wildlife overpasses is dependent on the vegetation cover and connectivity to adjacent bat habitats and commuting routes.

The trees and shrubs across the overpass should provide a continuous guidance structure, and protection from noise and light due to traffic below. Noise and light deflecting screens should be installed on the outer edges of the overpass to further reduce disturbance. On large passages, earth banks on the outer edges may also provide guidance and noise protection. A dense vegetation is particularly important for woodland bat species, which otherwise can be reluctant to cross large roads.

If human activity is low during the night, human use of multifunctional overpasses, e.g. small roads, agricultural and forest tracks, probably does not influence usage by bats.

Figure 3-1 Wildlife overpasses can function as fauna passages for all bat species. Dense, diverse, woody vegetation on the overpass is important for usage by bats. Photograph by E. van der Grift.

Key Points

- The overpasses should be planted with trees and shrubs. The vegetation should form an unbroken guidance structure with higher structural and species diversity across the passage;
- The vegetation on the overpass should connect to bat habitats in the surrounding landscape to guide commuting bats to the overpass;
- Local deciduous trees and shrubs should be used;
- Planted vegetation takes years to mature into an effective guidance structure for commuting bats. Vegetation should be planted as early as possible to allow the bats to habituate to the structures. Planting of 3–4 m high trees or taller and fast-growing species are advised;
- Noise and light deflecting screens should be installed along each side of the overpass;
- Fences and screens must be tightly connected to fences along the road to guide woodland bat species to the passage (Figure 3-2);

- Access to the overpasses should not be hindered by areas with artificial lighting, e.g. large roads, railways and buildings; and
- Joint use of the overpasses should only be allowed if the vegetation on the overpass and the approaches is maintained and human traffic is minimal during the night.

Maintenance

Even small gaps in hedgerows and fences guiding the bats towards the overpass may divert them away from it and on to the road. These guidance structures should be regularly inspected to ensure their functionality.

The vegetation on the overpass and vegetation linking the overpass to adjacent bat habitats and flight paths should be managed in accordance with the target species' preferences.

Figure 3-2 Fences and screens along the road and across the passage must be tightly connected to prevent bats from diverting on to the road. Photograph by SWILD & NACHTaktiv.

3.2.2 Modified Bridges

General Description and Objective

Conventional overbridges for local roads, agricultural and forest tracks, and pedestrian paths are used incidentally by bats to cross larger roads. Modifications to overbridges may enhance the bridges' suitability as crossing structures for bats. The modified overbridges cannot replace purpose-built fauna passages, but may provide valuable additional safe crossing sites.

The most effective modification to overbridges is the addition of green verges with shrubs and trees on the bridge (Figure 3-3). Preferably, the road should be placed towards the outer edge of the overpass to maximize the width of the green corridor on the bridge. The width of the verges should be sufficiently large and the soil-cover deep enough to support growth of shrubs and small trees (Figure 3-4). Green verges can be designed on new bridges or retrofitted on existing bridges, if the road width is reduced.

A simpler modification to existing and new bridges is the installation of panels on the sides (Figure 3-5). The panels are installed to reduce the noise and light disturbance from the road below. The panels may also give a better acoustic reflection to guide the bats. Dense railings may serve a similar function but cannot protect the bats from the disturbance due to traffic below. The effectiveness of dense railings or mesh fences as guidance structures is unknown.

Figure 3-3 A newly constructed overbridge with an agricultural access track and planted with two hedgerows to form a flight corridor for bats across the A14 in Germany. Photograph by Landesstraßenaubehörde Sachsen-Anhalt.

Figure 3-4 The hedgerows planted in the green verges should form an unbroken guidance structure over the bridges. Photograph by SWILD & NACHTaktiv.

Figure 3-5 Retrofitted panels to the railings on an overbridge and a tightly fitted fence have increased the number of *Rhinolophus* bats using the bridge as a safe crossing structure. Photograph by L. Arthur.

Key Points

If positioned on a commuting route, modified overbridges, fitted with green verges, have good potential as mitigating structures for a wide range of bat species. Fitting panels to bridges is less costly, but the method is probably not as effective as green verges. Retrofitted panels and dense railings are to be regarded as experimental installations that should be carefully studied and adjusted if necessary.

- The treeline and hedgerow planted in the green verges should form an unbroken guidance structure over the bridge;
- The vegetation or panels on the modified bridge should be tightly connected with hedgerows and treelines to bat habitats in the surrounding landscape;
- Local deciduous trees and shrubs should be used;
- The vegetation should be planted as early as possible during construction. Planting of 3–4m high or taller trees and fast-growing species is advised;
- Overbridges with green verges should be fitted with noise and light deflective screens to reduce disturbance from the traffic below;
- Panels used to modify overbridges should be sufficiently high to shield bats from noise and light (>2m); and
- Night time traffic intensity on the modified bridges should be low to minimise collision risk on the bridge, and the structures should be unlit.

Maintenance

Even small gaps in hedgerows and fences guiding the bats towards the overpass may divert the bats away from it. These guidance structures should be regularly inspected to ensure their functionality.

The vegetation on the green verges and in hedgerows linking the overpass to adjacent bat habitats and flight paths should be managed to match the target species' preferences.

3.2.3 Bat Gantries

General Description and Objective

A bat gantry is a simple structure spanning a road (Figure 3-6). Gantries aim to guide bats across the road above the traffic to reduce road mortality rates and maintain landscape connectivity.

The gantries could be considered at sites where a road severs a well-defined commuting route. Gantries are suitable at roads that are built level with the surrounding terrain or in cuttings. To enhance the use of gantries, guidance structures such as shrubs and trees should link the bat gantry and the adjacent landscape elements used by bats as commuting routes.

Bat gantries are typically constructed with steel wires, ropes, nets or metal lattice constructions, spanning the road. Other gantries are constructed as more closed structures that may resemble small bridges.

Figure 3-6 A closed-structure gantry might shield the bats slightly from traffic noise and light disturbance. The gantries must be linked to adjacent landscape elements (such as hedgerows) used by bats as a flight route. Adjacent to the newly constructed gantry shown, the vegetation has not yet developed. Photograph by M. Elmeros.

Key Points

Simple wire and wire mesh gantries have been documented as ineffective. Other open-structured designs, e.g. lattice structures, cannot be recommended either. Wires with large spheres installed at short distances have been tested as a temporary measure. The large spheres with multiple reflective surfaces may act as acoustic reflectors. It has shown some potential, but the method should be more rigorously tested to assess its effectiveness. Bats have been observed using gantries with more closed-structure designs, but further testing is needed to document their effectiveness. Points worth noting for future experimental installations of gantries are:

- Bat gantries must be located exactly on an existing flight path;
- The gantry should be constructed so that the commuting bats do not need to change their flight height to follow the structure across the road;
- The gantry must be well connected to adjacent bat flight paths with hedgerows and trees to encourage the bats to use the structures; and
- The gantry and adjacent commuting routes should not be lit.

3.2.4 Hop-overs

General Description and Objective

A hop-over consists of tall vegetation on the verges on either side of a road. The tall vegetation close to the road is envisaged to encourage the bats to maintain or increase their flight height to cross the road at a safe height above the traffic. Preferably, the trees should overhang the road to create a continuous canopy cover over the road. A dense thicket or barrier screens (Figure 3-7) could be installed on the road verges to force bats to climb above traffic height before crossing the road. Ramps or embankments along the road in combination with the trees and screens may also encourage the bats to increase their flight height.

The effectiveness of hop-overs depends on species-specific flight behaviour. Thus, the detailed structure of hop-overs depends on the target species and landscape characteristics at a site. If dense vegetation near the road cannot be established due to traffic safety concerns, species that are commuting at medium heights near the vegetation (e.g. *Pipistrellus* bats) might be brought up to safer heights by removing undergrowth and lower branches of the trees whilst retaining a closed crown layer. However, clutter-adapted species may decrease their flight height if undergrowth and lower branches are removed. Hop-overs cannot be used for highly clutter-adapted, manoeuvrable species such as *Rhinolophus*, *Plecotus* and some *Myotis* species. These species may fly through relatively dense vegetation. If screens are installed, these bats may fly along the screens only to cross the road at low height at the end of the screens, or if the bats cross the first screen they may descend to low height between the screens. Hop-overs may also increase traffic mortality risk if bats forage over the road section lined by trees and shrubs.

Key Points

Hop-overs have some potential for reducing bat-vehicle collision risk for some species (Table 3-2 Groups B and C) on small roads. The effectiveness varies between sites for the same species. Hop-overs should be used only on an experimental basis. Installations should be monitored to ensure that they are effective.

- Knowledge of the species composition and flight behaviour at a site is essential to decide on the best design of hop-overs;
- Species with different manoeuvrability are likely to be present at any hop-over site. The potential advantages and disadvantages for each species must be carefully considered;
- Caution is required if attempting to use hop-overs for manoeuvrable species, which may fly between gaps in vegetation or along screens;
- Hop-overs should not be used for highly clutter-adapted species (Table 3-2 Group A). Hop-overs may increase mortality risk for these species;
- On road stretches built on embankments or low bridges, screens should be considered as hop-overs for medium and high flying species (Table 3-2 Groups D and E); and
- Hop-overs cannot be recommended for wide roads as the distance between the tall vegetation or screens on the verges becomes too large and bats descend between them. Attempts to maintain the bats' flight height with supplementary screens or poles on the central reservation have not been successful.

Location and Design

- Trees and hedgerows close to the road should be preserved during road construction;
- The hedgerow and treeline should encourage the bats to gradually increase their flight height as they approach the hop-over;
- Planting at hop-overs should be undertaken at an early stage in the construction phase to allow the vegetation to develop before the road is opened to traffic;
- Planting of 3–4 m high or taller trees and fast-growing species is advised. Trees and shrubs of local provenance should be used; and
- A minimum height of 5m for hop-overs is advised.

Maintenance

Trees and shrubs in a hop-over require regular maintenance to maintain their functionality.

Figure 3-7 Screens or dense vegetation on road verges may encourage some bats to increase their flight height before crossing the road. However, if the distance between the screens or tall vegetation is too long, the bats may descend over the road. Photograph by M. Elmeros.

3.2.5 Viaducts

General Description and Objective

Viaducts are usually not constructed to mitigate road impacts on wildlife and the environment, but due to the span and clearance, they can function well as passage structures for many wildlife species, including bats. The dimensions of viaducts vary extensively from short, low bridges across small river valleys, to longer bridge structures across wetlands, to high structures over canyons in mountainous areas.

Viaducts may cause little disturbance to the vegetation under and adjacent to the structure, and preserve existing habitats and wildlife corridors under the viaduct, e.g. water courses and hedgerows that are used as flyways by many bats species (Figure 3-8). Viaducts are preferable to roads on embankments with tunnels and culverts. Generally, multifunctional use of viaducts does not affect their effectiveness as bat passages if human traffic and disturbance during the night is limited.

Figure 3-8 Viaducts and river bridges may preserve vegetation structure and habitats used by bats as guidance structures on commuting routes. Photograph by M. Elmeros.

Key Points
The use of viaducts is size and species dependent. Spacious bridges with a high clearance and span provide good opportunities for a wider range of bat species. Low river bridges are only suitable as crossing structures for clutter-adapted species.

- Trees and hedgerows under the viaduct bridges should be preserved in their natural condition or planted to maintain guidance landscape structures for bats;
- Rivers and watercourses, including the river bank, should be maintained in their natural states under the bridges;
- The canopies of trees in hedgerows and forests adjacent to the bridge should not extend above the level of the road as this may bring medium and high flying species into conflict with traffic on the road;
- Barrier screens/fences should be considered on roads on embankments and low bridges, level with landscape structures used by commuting bats, e.g. hedgerows and forest edges;
- Access to viaducts and river bridges should not be hindered by areas with artificial lighting, other roads, buildings, and other human activities that cause disturbance;
- Minor roads, cyclists and pedestrian paths under river bridges and small viaducts should be unlit. If lighting is essential for traffic safety, light intensity and light spillages away from the road surface should be minimal; and
- Under river bridges, the water surface should always be unlit, as many species that commute and forage on waterways show strong avoidance behaviour to light.

3.2.6 Tunnels and Culverts

General Description and Objective
Culverts and tunnels constructed to facilitate passages for medium and large sized animals are also used by bats. Bats may also use tunnels that have been constructed for purposes other than wildlife such as pedestrian and cycle paths and minor roads. The dimensions – particularly the height – are significant for the effectiveness of tunnels and culverts as bat passages. These underpasses are primarily suitable for low-flying bat species.

The underpasses should be located and designed to conform to local vegetation and topography, and the bats' habitat use and commuting routes. The vegetation near the entrance should connect with existing hedgerows and other landscape features that function as flight paths for bats. Generally, culverts are often more effective than tunnels, possibly because the waterways function as commuting routes for many species. Bats' use of multifunctional tunnels and culverts is reduced by artificial lighting in the underpasses or near the entrances. Restricting or modifying the lighting in and around the underpasses could increase their use by bats.

Key Points
Tunnels and culverts can be effective mitigation measures for low-flying, clutter adapted bat species. The effectiveness of tunnels and culverts varies markedly between sites, depending on the dimensions and presence of guidance structures up to the passages.

- The design of tunnels and culverts should be carefully considered with reference to all the species present at the site, their flight behaviour and commuting routes;
- Culverts and tunnels for bats should always be as large as possible. Tentative minimum estimates for the height (*H*) and width (*W*) of tunnels and culverts for the functional groups of bats are:

Group A:	*H* > 2m, *W* > 2m
Group B:	*H* > 2m, *W* > 2m over water *H* > 4m, *W* > 4m over land
Group C:	*H* > 4.5m, *W* > 5m
Group D:	*H* > 4.5m, *W* > 5m. Effectiveness is very questionable
Group E:	Not a recommendable mitigation method for these species

- Bats may use smaller underpasses, but these are less effective; and
- Human traffic and disturbance in multifunctional tunnels and culverts should be minimal at night time.

Location and Design

- The tunnels and culverts should be situated in existing bat commuting routes;
- The underpasses should be designed and orientated so that the commuting bats do not need to change their flight height or direction to fly through the structure;
- Tunnels and culverts must be well connected to adjacent bat habitats and commuting routes (Figure 3-9 and Figure 3-10);
- Watercourses and drainage in culverts should be maintained in their natural states as much as possible;
- Barrier screens on the road verges above the underpass can reduce noise and light disturbance in the commuting route up to it. Screens and fences can also hinder access to the road for low-flying bats that attempt to cross over the road and function as a hop-over for other bat species;
- Vertical surfaces around the entrances to the underpasses may guide the bats into the underpass;
- Access to the tunnels and culverts should not be hindered by dense vegetation or areas with artificial lighting, other roads, buildings, etc.;
- Roads and paths in joint-use tunnels and culverts should be unlit (Figure 3-10). If lighting is essential for traffic safety, light intensity and light spillage away from the road surface should be restricted; and
- The water surface in culverts should always be unlit, as many species that commute and forage on the waterways show strong avoidance behaviour to lighting.

Figure 3-9 Hedgerows may guide commuting bats into the underpasses. Tall fences on the road above the underpass enhance the effectiveness of the passage for low-flying species and may function as a hop-over for species with medium and high flight behaviour. Photograph by SWILD & NACHTaktiv.

Figure 3-10 Bats may use multifunctional tunnels and culverts if there is little human traffic during the night. The underpass should preferably be unlit, and the waterway should always be maintained as a dark corridor. Photograph by M. Elmeros.

3.3 Other Measures to Reduce Barrier Effect and Mortality

There are other methods that may reduce the impact of roads on bats, e.g. reducing light and noise pollution, deterring bats away from roads and diverting bats to safe crossing sites. Measures that deter or divert bats may increase the barrier effect of roads. Therefore, they should only be used in combination with fauna passages for bats.

3.3.1 Artificial Lighting

General Description and Objective

Street lighting may degrade foraging habitat for bats in the vicinity of roads, increase the barrier effect of roads and cause bats to abandon roost sites. In particular, low-flying clutter-adapted species show strong avoidance behaviour to light. Other species seem to be less sensitive and often exploit insect aggregations around street lights. However, this behaviour may increase the risk of vehicle collisions. The effects of light may also vary with light intensity and spectral content. Both traditional high-pressure sodium lights and white light-emitting diode (LED)-lights deter light-sensitive species, even at low intensity.

Several approaches to the management of artificial lighting have been tested: deterrence with light, modification of light spectrum of street lighting, reduced light intensity and light spillage, and dynamic lighting systems. However, documentation of their effectiveness has not been published. If employed, these measures should be monitored to evaluate their potential as mitigation measures. Overall, no light should be assumed to be better than any of the solutions to reduce light disturbance.

Light Deterrence

Strong white lights installed on road verges have been employed to deter bats away from hazardous crossing sites. The effectiveness of the method has not been documented. If light deterrence is planned, the effectiveness and the potential collateral increase in the barrier effect must to be considered and subsequently monitored. Lights on road sections next to fauna passages could potentially enhance the usage of the passage as it will present itself as a distinct dark corridor. However, it is crucial to prevent light spillage into the fauna passage.

- Light deterrence is most likely to be successful for the most photosensitive bats; and
- The secondary effect of artificial lighting on other species, e.g. increased mortality risk for species foraging on insects near street lights, should be carefully considered.

Adaptation of Light Spectrum

Amber coloured narrowband LED street lighting should be less visible for bats and hence more tolerable than traditional wideband street lighting. Street lighting with narrowband amber coloured light may reduce the impact of light pollution in the surroundings and the barrier effect of the lit road section (Figure 3-11). To what extent this intervention has a positive effect on bats' use of commuting corridors and habitats surrounding amber-lit road sections, has not been evaluated.

Insects are attracted to lights with a strong ultraviolet (UV) component. Street lights with a low UV component or UV-filters could reduce the mortality risk for bats. However, the potential effectiveness of adaptations of the spectral content of the lighting on bat mortality risk has not been documented.

Figure 3-11 Amber coloured street lighting may minimise the light disturbance of a bat flight path. Furthermore, the lamps on this path in the Netherlands are controlled by motion sensors, and only switch on when there are bicycles or pedestrians on the road. Photograph by V. Loehr.

Minimise Light Pollution

Simple methods to reduce light pollution include reduction of light intensity, installation of lights on short poles and directional lighting or hoods directing light downwards on to the road surface only (Figure 3-12).

Managing the period with artificial lighting is also an option to reduce the light disturbance of bats. Dynamic lighting systems controlled by motion sensors may restrict light disturbance to periods when traffic is present on the road.

Part-night lightning has also been proposed as an option to mitigate road impact on bats. To be effective, part-night lighting schemes should maintain dark conditions during the peak hours of bat activity, i.e. at dusk and the first hours into the night and before dawn.

Management of lighting in joint-use overpasses and underpasses is important for their use as crossing structures for bats. Preferably, the structures should be unlit, but if lighting is necessary for safety reasons, the lit area should be restricted and a dark corridor through the passages should be maintained. The watercourse in culverts and under river bridges should always be protected from artificial lighting.

Figure 3-12 Lighting on this bicycle bridge in the Netherlands has been installed in the railing to reduce the light spillage into the surroundings and maintain a dark zone along the bridge to encourage the bats to use it as an overpass. Photograph by V. Loehr.

3.3.2 Noise

General Description and Objective

Traffic noise may reduce bats' foraging efficiency near roads. Strong sonic and ultrasonic noise can cause an avoidance response by bats and intensify the barrier effect of roads. Noise has been tested as a deterrent at hazardous sites to reduce mortality. Conversely, noise abatement near important foraging habitats and roost sites could reduce the impacts of roads on bats.

Minimise Noise Pollution

Noise pollution could be reduced with special noise abatement road pavements or noise barriers. These measures should be considered near important bat foraging and roosting sites and near fauna passages to enhance their effectiveness. Noise abatement is a relative low-cost intervention that intuitively mitigates the impact of traffic noise on bats, but the effectiveness of noise reduction has not been evaluated.

Noise Deterrence

Noise avoidance behaviour of bats has been explored as a method to deter bats from roads when a vehicle is approaching. The experimental audible warning system comprised short sections of asphalt which generates near-ultrasonic noise when a vehicle passes (Figure 3-13). Variables such as length of the specially coated stretch, the distance to the bat crossing site and vehicle speed determine the time provided for the bats to avoid the approaching vehicle.

If effective, the audible warning system could be installed on roads in lowland flat terrain where the topography is unsuitable for underpasses or overpasses, or on road sections with no defined commuting routes, e.g. in forests or very open foraging habitats. The system only deters the bats when collision risk is imminent, so the barrier effect is minimal. However, high-frequency sounds attenuate rapidly which may limit the system's effectiveness and applicability on high-speed roads. Species-specific variations in avoidance behaviour, the effect of vehicle speed and habituation to the noise must be studied further to determine the potential of noise deterrence for bats.

Figure 3-13 An experimental audible warning system has been installed on the regional road in France. When cars pass the patches with special asphalt (light patch under the car in the picture), a high frequency sound is generated to deter bats. Photograph by M. Elmeros.

3.3.3 Speed Reduction

General Description and Objective

Vehicle speed is positively correlated with collision risk for many vertebrates. A few studies have also indicated that speed and mortality numbers are correlated. Speed reduction would be a simple method to reduce the mortality risk for bats but the effectiveness must be assessed. Speed reduction should reduce mortality risk for most bat species, but the effectiveness would probably be species-specific and depend on their manoeuvrability and flight speed.

If effective, speed reduction can be implemented on roads built at level with the surrounding terrain and on road sections with no distinctive landscape features and bat crossing sites, e.g. in forests. Reduced speed limits could be restricted to the hours from sunset to sunrise. Other methods include installation of physical traffic calming structures, e.g. speed bumps and chicanes.

3.3.4 Diversion and Guidance

General Description and Objective

Many bat species, when commuting, follow linear and longitudinal landscape elements such as hedgerows, treelines, streams, stone walls and forest edges. Creating such landscape features could divert bats towards safe crossing sites (Figure 3-14). Hedgerows and treelines planted between fauna passages and existing commuting routes and habitats may create a funnelling effect and increase the effectiveness of the passages.

Key Points

- Diversion and guidance with hedgerows, treelines and screens are most likely to be effective for species commuting at low and medium heights (Table 3-2 Groups A, B, and C);
- Hedgerows or screens intended to guide bats should be well connected to existing flight paths and fauna passages;

- Planted vegetation takes years to mature into an effective guidance structure for commuting bats. Consequently, the vegetation should be planted as early as possible. Planting of 3–4m high trees or taller and fast-growing native species are advised (Figure 3-15);
- Hedgerows and treelines could be supplemented by screens or mesh fences to increase their functionality until the vegetation has matured;
- Screens and fences intended to prevent bats from crossing roads should be a minimum of 5m high to increase the probability of deterring bats from crossing the fence, or to lift the bats that do cross the fence up above traffic height (Figure 3-16);
- Screens and fences should be much longer than the width of the commuting route. Short fences are probably ineffective as the bats just circumvent the barrier; and
- Preferably, the screens and fences should lead to safe crossing sites. If this is not possible, bat activity should be carefully monitored where the screen ends.

Figure 3-14 Hedgerows take years to develop and should be planted as early as possible. The illustrations show a corridor established to guide bats to an underpass 1 year (left) and 7 years (right) after it was planted. Photograph by SWILD & NACHTaktiv.

Figure 3-15 Hedgerows and treelines should be planted as early in the construction phase as possible. Planting of large trees may advance the development of a guidance structure. Photograph by Landesstraßenaubehörde Sachsen-Anhalt.

Figure 3-16 High fences are needed to discourage bat access to the road and guide them safely across road above traffic height. The illustrated fences are installed near underpasses on the state road S170n in Germany. Photograph by SWILD & NACHTaktiv.

3.4 Ecological Mitigation

Inevitably, the negative impacts on bats and their habitats cannot be completely avoided, despite precautionary planning in some projects. Ecological mitigation is then implemented to compensate the impact at landscape or population scale. General habitat improvement and enhanced roosting conditions may replace destroyed and degraded habitats and roost sites. Ecological mitigation may enhance population sizes and their overall resilience to road impacts.

3.4.1 Roost Site Management

Road developments may destroy trees and buildings used by bats as roost sites. Most bats show high fidelity to roost sites, and the destruction of breeding and hibernation sites can pose a significant threat to local bat populations. It is difficult to recreate suitable microclimatic conditions in alternative roosts structures, and it may take years for the bats to locate and accept the new sites.

Actions to provide new accommodation or enhancement of existing roost sites include bat boxes, construction or modifications of buildings, bridges and underground sites, translocation of tree trunks with roosts or cavities, artificial holes in trees and tree retention (Figure 3-17). These interventions are potentially beneficial as long-term compensatory actions. However, the effectiveness and scale of the interventions needed to offset roost site losses and habitat degradation is unknown. Thus, a precautionary approach is advised and more research on the value of roost site and habitat management is needed.

Bat Boxes

Bat boxes have been widely used as a conservation intervention as well as for research and monitoring purposes. Installing bat boxes in trees and buildings is a quick, low-cost method to attempt to replace destroyed roost sites. There is a huge variety of models, but all boxes are primarily used as temporary roost sites. Maternity roosts have been recorded for some species but that is the exemption, and it typically takes several years before boxes are occupied.

Key Points

Bat boxes cannot be recommended for ecological mitigation as their occupation rates are low and their use as maternity roosts is uncertain.

- If bat boxes are installed, monitoring should always be conducted to determine if they achieve their purpose;
- Bat boxes must be installed well in advance of removal of existing potential roost sites;
- Bat boxes may need annual inspection to remove bird or wasp nests, and to clean out bat faeces;
- Wooden boxes typically need to be replaced every 3–5 years; and
- If boxes are installed near infrastructure, e.g. on bridge abutments, the boxes should be installed so that vehicle collision risk is minimal. Occupation rates of bat boxes are correlated with distance to major roads.

Tree Trunk Translocation

Translocation of tree trunks with bat roosts has been tested as a method to preserve roost sites in trees that had to be removed. The tree with the roost is carefully cut down, and the trunk or a section containing the cavity is mounted on a nearby tree. Relocating trunks with roosts and potential roost sites is preferable to bat boxes as the bats may recognise the access point to the roost and the microclimate inside the cavity could be more suitable than in bat boxes.

The tree trunk will gradually dry out after the relocation, resulting in cracks in the trunk that may expose the roost cavity. Decay of the dead wood also limits the persistence of this intervention.

Key Points

- The relocated tree trunk should be mounted on the nearest suitable tree;
- The trunk should be positioned so that the access point has the same height and orientation as originally;
- Protective rubber straps between the banding and the tree trunks may reduce the impact on the live tree;
- If bats are present in the roost at the time of the translocation, the exit hole(s) should be temporarily blocked and the trunk must be kept vertical throughout the procedure; and
- Played-back bat calls may lure the bats to the relocated roosts, and result in a more rapid occupancy, particularly for species which use eavesdropping when locating new roost sites, e.g. noctules.

Figure 3-17 Translocation of tree trunks with roost or cavities may function better than bat boxes. Protection of large trees in forests near transport infrastructure may enhance long-term roost site availability. Photographs by H.J. Baagøe and M. Elmeros.

Bat Houses, Bridges and Underground Sites

Some bat species roost in buildings, bridges and artificial underground sites, such as tunnels and ice cellars. Construction of new roost structures or improvement of existing ones can compensate for destroyed roost sites. Careful management of internal microclimate (e.g. temperature and humidity) and access routes (e.g. to reduce predation risk and light disturbance) can improve roost site quality and increase the maternity colony size.

Small numbers of bats may roost in crevices in both old and modern bridges, and large maternity roosts and hibernacula are sometimes found in the girders, piers and abutments of large bridges. The occurrence of bat roost sites should be considered when renovating bridges. Roost sites in bridges have successfully been preserved or improved during maintenance works. New roost sites could be integrated into the design of new bridges. Underground chambers and tunnels could be constructed as artificial hibernacula in the earthwork of bridges and wildlife overpasses.

Preservation and renovation of existing roost site structures is always advantageous to new installations. Adaptations and improvements of existing buildings and bridges with roosts may have immediate effects. New purpose-built buildings, bridges and underground roost sites are potentially beneficial as long-term compensation actions.

Enhancing Natural Roosts in Trees

Arboricultural and forestry management often lead to a loss of tree roosts for bats, and large, old trees are rare in many forests. Protection of single broadleaved trees or forest stands with a high potential for natural cavities, may enhance the long-term availability of natural roost sites in woods. Natural cavities in trees develop very slowly. Cutting slits, drilling holes or enlarging natural hollows in trees may advance the development of potential roost sites.

Tree retention and the development of cavities will be beneficial for bats as a long-term management action only, and the effectiveness, temporal and spatial scale needed to compensate for destroyed roost sites is unknown.

3.4.2 Habitat Improvement and Creation

Habitat improvement and the creation of new natural habitats may balance the effects of destruction and degradation of feeding areas and landscape connectivity. Such actions for bats may include the enhancement or creation of ponds and wetlands, planting of hedgerows and woodlands, and expansion of natural grassland habitats.

Bat-friendly habitat management may include simple actions such as allowing plants to flower before cutting and the planting of flowering shrubs and trees that attracts many insects throughout the summer season. Improved habitats should be well connected with existing bat habitats and flight paths. If located optimally, habitat improvements may increase the overall landscape connectivity for bats.

The effectiveness of habitat improvement and the scale needed to offset the road impact is largely unexplored; therefore, a precautionary approach is advised. Enhanced and newly created habitat will take years to develop into high quality bat habitat. Habitat enhancements and creation should be developed and in place well in advance of the destruction or degradation of the original habitats. Long-term monitoring and a management plan are essential to maintain favourable habitat quality of the enhanced habitats.

CEDR Call 2013: Roads and Wildlife Documents
Further information on bat mitigation discussed in this chapter can be found in SafeBatPaths Technical Reports 1, 4 and 7. Details of these reports and other key references can be found at the back of the Manual.

Chapter 4. Procurement and Performance Indicators

Summary

This chapter outlines approaches to the procurement of road mitigation and methods to achieve effective measurable outcomes that facilitate wildlife crossings. The various contract types shape how the ecological aspects will be addressed.

- Regardless of the proposed contract type, the assessment of suitability of the contractor should, in relation to ecology, be a pass/fail criterion;
- In order to assist the contractor, and to ensure consistency, the language used in the procurement of mitigation measures should be standardised;
- The development and use of performance indicators to judge the products and services delivered by contractors can help ensure that the road authority gets maximum delivery from procurement; and
- Follow-up studies to establish the performance of a contract are vital to certify delivery and can also be used to establish best practice.

4.1 Procurement Approaches

The EU Public Procurement Directive 2014/24/EU sets out the legal framework for public procurement which applies when an NRA seeks to acquire supplies, services or works (e.g. civil engineering for linear infrastructure). The EU procurement regime is not static and is subject to change, based on evolving European and National Case Law. Consequently, there is no fixed "model" describing what exactly an NRA in Europe does or how to procure contracts for transport infrastructure. There are five types of permitted procurement competition, as listed in Box 4-1.

Box 4-1: EU Procurement Types of Procurement Competition

- Open;
- Restricted;
- Competitive Procedure with Negotiation;
- Competitive Dialogue; and
- Innovation Partnership.

4.1.1 Overview of Pan-European Models

Suitability Assessment

As part of procurement competition, Suitability Assessments establish the experience of the Contractor and can include Quality Assessments to measure the Contractor's proposed approach to the project, which may include specific measures for dealing with ecological protection and enhancement.

The ecological capability of a Contractor is only one of many factors to be considered in suitability assessment and will have a minor influence, if addressed through a qualitative evaluation. This factor is best addressed as a Pass/Fail requirement, similar to that used for Health & Safety capability. Examples of specific capability requirements are:

- Provision of a qualified ecologist with minimum stated years of experience; and
- Evidence of a certain number of completed contracts with wildlife mitigation measures, as confirmed through Certificates of Satisfactory Completion.

Procurement Models

There are generally four different types of contracting strategy for the construction of road schemes across Europe (refer to Table 4-1). Specific issues in relation to each strategy, where the NRA is assumed to fulfil the role of Employer, are provided in Table 4-2.

Table 4-1 Contracting strategies and body responsible for each stage

Contract Type/Name	Body responsible for project stage			
	Planning	**Design**	**Construction**	**Maintenance**
Traditional (Employer Designed)	Employer	Employer	Contractor	Employer
Design and Build (D&B)	Employer	Contractor	Contractor	Employer
Design, Build and Maintain (DBM)	Employer	Contractor	Contractor	Contractor
Early Contactor Involvement (ECI)	Contractor	Contractor	Contractor	Contractor/Employer

Table 4-2 Issues with types of contract

Contract Type/Name	Issues specific to type of contract	Wildlife related issues
Employer Designed (ED) 'Traditional'	Advantage that certain continuity is ensured. A failing of this form of contract is its vulnerability to a shortfall in resource commitment beyond construction.	Responsibility for wildlife protections rests with the NRA and requires full suite of expert ecological services for the design and monitoring of wildlife protections over the project life.
D&B[25]	A D&B partnership can reduce time, save money, provide stronger guarantees and allocate additional project risk to the private sector.	The NRA determines wildlife measure performance requirements. Monitoring may be undertaken by the Contractor for the initial performance period prior to handing it over to the NRA.
DBM[26]	Benefits are similar to the D&B, with risk allocated to the private sector expanded to include maintenance.	Appropriate ecological expertise is needed for proper transfer to the next stages. The NRA has an ecological supervision role in monitoring the compliance at all stages including appropriate actions during the operational phase in response to Contractor monitoring.
Design, Build, Finance & Maintain (DBFM)	The responsibilities for each stage are bundled together and transferred to private sector partners.	
ECI[27]	Designed to achieve value for money, alleviate strain on industry and best utilise market capacity. The Contractor, working with the NRA on completing the detailed design stage, ensures that the Contractor will be able to move onto site at short notice.	The Contractor plans, designs and constructs, with an option to maintain/operate. If the Contractor does not maintain, then the NRA role is similar to D&B. Otherwise, the NRA must ensure that targets are achieved.

[25] A2 Shore Road (Northern Ireland)
[26] N19g road project from Kasterlee to Geel in the province of Antwerp (Belgium)
[27] A6 Randalstown to Castledawson Dualling (Northern Ireland)

Contract Type/Name	Issues specific to type of contract	Wildlife related issues
Maintenance Contract	Contractor undertakes the maintenance and the NRA is responsible for ensuring the works are being undertaken. International best practice appears to favour the procurement of Maintenance Works in outcome based contracts.	Wildlife measures are maintained by a Contractor with particular targets for management of the wildlife infrastructure amongst other duties. The NRA is required to provide an ecological supervision role to monitor compliance.

For most small to medium scale road construction projects, procurement will continue to be mainly by the Traditional ED or D&B procurement options. In these circumstances, the NRA must assign a continuous effort in terms of resources and expertise to provide the necessary level of attention to wildlife provisions throughout the lifetime of a road asset. This is necessary to avoid the pitfalls that have occurred in the past where wildlife issues may have been largely neglected beyond the planning and construction stages.

Box 4-2: Key Procurement Issues

A. Delivery of commitments for wildlife mitigation measures needs to be validated through a robust engagement of suitable ecological expertise at each step in the process from planning, through design and construction.

B. Formal arrangements for Maintenance are required with provision for regular inspection and evaluation of mitigation measures to ensure that they continue to perform in line with the commitments made at the planning stage. This process requires suitable ecological expertise both for the Maintaining Organisation and in the NRA for suitable overall supervision of such activity across the full road network.

Table 4-3 Responsibility Matrix: Provisions for environmental measures according to works procurement process

	Responsible Parties in each Procurement Process Type				
Activity	***Traditional Contract (ED)***	***D&B Contract***	***DBM Contract***	***ECI Contract***	***Maintenance Contracts***
Environmental Assessment: Ecological, Hydro-Geological, Air Quality, etc.	Employer		Employer & Contractor		Employer
Identify Mitigation Measures	Employer Designer		Contractor Designer		Employer
Design Mitigation Measures	Employer Designer	Contractor Designer	Contractor Designer	Contractor Designer	Employer Designer
Certify Designs - Check	Checker	Checker	Checker	Checker	Checker
Install Mitigation	Contractor	Contractor	Contractor	Contractor	n/a
Certify Installation	Employer Designer	Contractor Designer	Contractor Designer	Contractor Designer	n/a
Ecological Performance Audit – Annual for 5 Year Maintenance Period	Employer Designer	Contractor Designer	Contractor Designer	Contractor Designer	Contractor
Rectify Problems	Contractor	Contractor	Contractor	Contractor	Contractor
Supervision	Employer	Contractor Designer	Contractor Designer	Contractor Designer	Employer
Auditing	Independent	Independent	Independent	Independent	Independent
Management	Employer - Specialist Ecologist				

4.2 Standardisation in Procurement Terminology

The use of consistent and similar language in devising mitigation specifications in procurement is important. Standardisation throughout procurement contracts avoids potential confusion due to inconsistent nomenclature across NRAs and mitigation studies.

- Specifications must be specific and unambiguous. If quantitative requirements or thresholds are used in the specifications, metrics to be used must be clearly stated. If any terminology is included, it should be well explained; and
- The characteristics of each mitigation structure must also be clearly described: structure dimensions (length, width, height); cross-sectional shape (e.g. round, rectangular); intended function (drainage, wildlife passage); and mode of construction and materials (e.g. pre-fabricated concrete box culvert).

4.3 New Types of Procurement

The shift to new types of contract demands new procurement procedures in which functional specifications increasingly replace design specifications. While the traditional contracts were based on a detailed design of the mitigation works, new types of contracts are based on a set of specifications that describe the functional requirements that should be met during the construction and maintenance phases of a road mitigation project. A procurement process in which functional specifications are used should be continuously evaluated to assess whether the functional requirements are clear, complete and matching with the overall goal of the road mitigation.

Green Public Procurement (GPP)

GPP is a process whereby public authorities seek to procure goods, services and works with a reduced environmental impact throughout their life-cycle. A tendering procedure is considered "green" if it complies with "core" GPP criteria; notably award criteria must:

- Not confer an unrestricted freedom of choice (objectivity and verifiability);
- Ensure the possibility of effective competition (artificial foreclosure); and
- Be advertised in advance.

The procurement directives require that EU GPP criteria are not mandatory. As public authorities, NRAs are specifically empowered to include environmental and social requirements in their conditions for the performance of contracts (refer to Article 26 of Directive 2004/18/EC). Contract performance clauses can address environmental considerations that relate to the contract execution and can:

- Specify services/works to be performed that minimise environmental impact;
- Link penalties and incentives under the contract to environmental performance;
- Indicate responsibility for compliance and reporting; and
- Stipulate that subcontractors are held responsible for environmental aspects of work.

Application of an Outcome-based Model

Procurement of effective road mitigation measures requires a clear definition of success. Outcome-based procurement has the potential to achieve better environmental outcomes over standard environmental requirements incorporated into EIA. Outcome-based mitigation measures of a DBFM Public Private Partnership (PPP) contract, where the contractor is given specific targets with financial incentives, may be a way of not only ensuring that the measure is provided but, by requiring the Contractor to prove the functionality and/or effectiveness of the measure, they are also incentivised to undertake extensive monitoring. Due to these constraints, new juridical frameworks may need to be applied.

Functions for Wildlife Crossing Structures

In procurement documents, the NRA will identify all functions that are relevant to the project. Functional specifications for wildlife linkages (e.g. wildlife overpasses, tunnels, crosswalks, bat hop-overs, but also to wildlife fences, habitat restoration, and other landscaping measures that accompany the crossing structures) can be applied in those documents for a variety of structures, both existing and future ones, such as viaducts, bridges, tunnels and culverts[28].

Table 4-4 Main functions that relate to wildlife linkages

Function	Description
Connecting habitat	To maintain or restore wildlife linkages between habitat on both sides of the road.
Offering habitat	To offer habitat in which sufficient food, cover and breeding areas occur that enable the target species to use the wildlife linkage.
Offering guiding structures	To help the target species to find and use the wildlife linkage.
Protecting from disturbance	To limit anthropogenic disturbances that may prevent the use of the wildlife linkage by the target species.

Quality Management

The NRA can implement a certified quality management system (e.g. ISO 9001) where the Contractor has to be able to prove that works meet all quality standards. During the different stages of procurement and project execution, contractors can be provided with a clear view of what is expected, such as:

- Results of surveys of flora and fauna in the project area;
- A presentation on ecology at formal information meetings during the tendering process;
- Informal meetings between ecologists of both the road agency and contractors; and
- The provision of a comprehensive handbook on road mitigation measures, including many examples of wildlife crossing structures[29].

Verifiability

The project can use qualitative assessments to verify if specifications are being met. The proposed design is evaluated by experts and judged whether ecological functionality can be expected or not. If award criteria relate to factors which cannot be verified by the contracting authority, it will be difficult to demonstrate that they have been applied objectively. This results in a need to consider in advance what means of proof tenderers can offer under each award criterion and how this will be evaluated.

4.4 Performance Indicators

This section should be read in conjunction with Chapter 6 (Performance Evaluation of Road Mitigation Measures) that addresses many related issues.

[28] Rijkswaterstaat (2016) Specification Eco-passage (Basisspecificatie Ecopassage)
[29] Wansink et al. (2013) Handbook wildlife measures at transport corridors.

To ensure successful outcome-based procurement, sound performance indicators are needed. It is necessary to check both the function of a mitigation measure and its effectiveness at the population viability level. The performance of a mitigation structure has to be evaluated by using some kind of ecological/biological indicator or metric that reflects its quality. A good set of indicators provides unbiased guidance for the planning and operation of infrastructure and mitigation measures. The quality of any indicator is dependent on underlying data, which has to be collected beforehand. In turn, the availability of data will influence the choice of the indicator.

Box 4-3: Requirements for a Good Key Performance Indicator (KPI)

Indicators for wildlife mitigation projects should satisfy the following:

- Indicators should be easy to measure, compare and reproduce.
- Indicators to be measured have to take the EIS into account.
- It is important to establish a baseline beforehand, on which the indicator(s) will be modelled. This necessitates the availability of sufficient base data.
- The indicators should already be considered during the procurement process.
- Indicators should reliably show if a mitigation structure is functioning as planned.
- In the specific case of mitigation structures such as wildlife bridges, the indicator(s) used should be able to document "negative" outcomes as well, e.g. when a structure is not used by the target species.
- The indicators used should include a "positive" element, i.e. preferably include an incentive that reliably leads to the outcome planned. This could be, for example, an economic benefit for the contractor when performing well rather than just a penalty for poor performance.
- Indicators have to consider that different species may use measures differently. This might necessitate the use of an alternative indicator.

If the required "outcome" cannot be measured, then performance cannot be determined or subsequently managed and another appropriate procurement model should be used.

4.4.1 Defining Specifications

Regulations have a strong emphasis on population-level indicators as the ultimate goals and these should be reflected in the procurement specification. With the exception of the EIA Directive, all nature conservation legislation and regulations refer to **population viability** as one of the end goals (refer to Table 4-5). In addition, the Birds Directive (BD) and the Bern Convention implicitly emphasise the importance of **population size** in view of, not only species conservation, but also economic and recreational requirements. The Environmental Liability Directive (ELD) also refers to population size, as well as two other measures that relate to wildlife populations.

Table 4-5 Defining Indicators from EU environmental and transport legislation

Indicator	Environmental regulations						Transport regulations	
	HD	BD	ELD	EIA	BONN	BERN	MITA	RISM
Related to populations								
Population viability	X	X	X	-	X	X	-	-
Population size	-	X	X	-	-	X	-	-
Population density	-	-	X	-	-	-	-	-
Capacity for propagation	-	-	X	-	-	-	-	-
Related to species distribution								
Actual distribution (occupancy in relation to road)	X	-	-	-	X	-	-	-
Historic distribution (comparative occupancy)	-	-	-	-	X	-	-	-
Related to species abundance								
Actual abundance	-	-	-	-	X	-	-	-
Historic abundance	-	-	-	-	X	-	-	-
Related to habitat								
Habitat availability (landscape level, connectivity)	X	X	-	-	X	-	-	-
Habitat quality (suitability)	X	X	-	-	-	-	-	-
Related to road barriers								
Wildlife movements (frequency of use)	X	-	-	-	-	-	X	-
Migration routes	-	-	-	-	X	-	-	-
Related to WVCs								
Wildlife mortality (road kill – no. of individuals / % of baseline population)	X	-	-	-	-	-	X	-
Road safety (no. of incidents per species)	-	-	-	-	-	-	X	X

Legend: X = indicator is mentioned in the document. - = indicator is not mentioned in the document. HD = Habitats Directive; BD = Birds Directive; ELD = Environmental Liability Directive; EIA = Environmental Impact Assessment Directive; BONN = Convention on the Conservation of Migratory Species of Wild Animals ("Bonn Convention"); BERN = Convention on the Conservation of European Wildlife and Natural Habitats ("Bern Convention"); MITA = European Agreement on Main International Traffic Arteries; RISM = Directive on Road Infrastructure Safety Management.

4.5 Linking Specifications to Indicators

Audits and checks, as part of the quality management of the procurement process, can use qualitative assessments to verify if specifications submitted by the contractor are achieved.

- Proposed design can be evaluated by experts and judged whether ecological functionality can be expected or not;
- Specifications can be linked to multiple focal species as applicable to the project;
- Known responses of wildlife species to linkages can be used to assess whether the proposed design structure dimensions are appropriate for the target species;
- Specifications should be linked to the entire road barrier to be mitigated and not confined to a single structure;
- It is preferable that specifications are linked directly to the indicators used in regulations and policies;
- Evidence that the barrier effects on population persistence have been sufficiently mitigated is essential for compliance with nature conservation legalisation and policy frameworks;
- It is vital to assess the rate of use of wildlife crossing structures and compare these rates with baseline data on between-population movements in the pre-mitigation or even pre-road construction situation[30];
- The number of animals killed through collisions with vehicles is an issue of human safety as well as an indicator of the efficacy of mitigation measures aimed at reducing road kill and securing species population viability; and
- The effectiveness of mitigation measures should not rely solely on measuring the rate of road kill as a proxy for crossing-structure success but should use multiple and population level indicators, incorporated into mitigation procurement, whenever possible and relevant.

4.5.1 Limited Net Loss versus NNL

NNL is achieved where the post-mitigation situation for the targeted species and goals is identical to the pre-road construction situation. In a scenario where mitigation specifications are selected, incorporating a limited net loss target level, it should be carefully determined how much loss, relative to pre-road conditions, is acceptable. If a target level is difficult to ascertain or is overly complex, precautionary principles should be followed, i.e. NNL should be selected as the target level.

4.5.2 Guidelines for Defining Outcome-Based Specifications

- **Specify Goals for Mitigation**: Goals for mitigation should be clearly described prior to procurement of road mitigation;
- **Specify Target Level**: A target level will depend on the local situation, including the local conservation status of a species, but may also be suggested by legislation and policy;
- **Develop Clear and Objective Specifications**: Road mitigation objectives, and consequently the specifications for mitigation works, should be SMART. The early integration of performance indicators into procurement arrangements to complement mitigation goals and targets is extremely important; and

30 Lesbarreres & Fahrig (2012) Measures to reduce population fragmentation by roads: what has worked and how do we know.

- **Integrate Input from Spatial Planning and Zoning**: The use of clear, robust and specific evaluation criteria by Contracting Authorities can help to reduce procurement challenges from Contractors. To avoid conflicts of interest, an independent assessor should evaluate the road mitigation works on the basis of the provided performance indicators in procurement contracts.

4.5.3 Potential Pros and Cons of Outcome-Based Model

Ecology is a key aspect of the tender Quality Assessment of outcome-based procurement and, as a result, all tenderers, need to submit high quality ecological plans. The DBM approach can allow the NRA to demand that the Contractor be thorough and achieve optimal results through innovation[31].

- Outcome-based objectives can achieve better environmental outcomes over standard environmental requirements, incorporated into the EIAR/EIS[32]; and
- Outcome-based mitigation measures of a DBFM (PPP) contract, where the contractor is given specific targets with financial incentives, may be a way of not only ensuring that the measure is provided but by requiring the Contractor to prove the use of the measure by the target species, they are also incentivised to undertake extensive monitoring. This also requires the NRA to monitor and validate the results.

Outcome-based specifications have however certain disadvantages and risks when compared with the more traditional procurement approaches in certain scenarios:

- New knowledge on road mitigation effectiveness can become an asset of private contractors and consequently may not be freely available to all stakeholders if not regulated. This may result in a loss of valuable data that could be used by future private contractors or to inform other projects; and
- For the approach to work well, there is a requirement for evidence based decision making. This can be based on KPIs. However, if KPIs are not accurate indicators of the desired outcomes, full responsibility for positive delivery of mitigation goals may not be imposed on the contractor.

If outcome-based procurement is used, well designed studies are required to validate the expected outcomes which can present challenges (refer to Chapter 6); notably:

- Costs are likely to be considerably higher compared to traditional procurement approaches;
- Outcome-based studies need to establish detailed baseline or reference standards that may not be economically viable or feasible; and
- Appropriate time-spans for evaluation studies may be uncertain, with implications for resources and reduced confidence that objectives will be met.

Currently outcome-based contracts are still in development and further testing in practice is needed to prove the links between performance indicators and long-term goals. Further optimisation of their application in road mitigation projects is required before this approach can be widely implemented throughout the EU.

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[31] A12 Widening Scheme DBM Contract (Netherlands)
[32] EC (2015) Green (Public) Procurement

4.6 Follow-Up Studies

Follow-up studies are the only way to evaluate the effectiveness of mitigation measures and constitute the most effective way to gain knowledge and improve best practice. Follow-up studies should be included as an integral part when procuring a contract and performed or supervised by experienced ecologists, who ideally are permanently employed to ensure:

- A continuation of competence throughout the lifecycle of the project up to and including the maintenance phase;
- The build-up of local knowledge; and
- The development of performance indicators, which will be locally applicable.

4.6.1 Data Management

The Aarhus Convention commits the public authorities in the EU Member States to publish all environmental information. Follow-up data should be correctly collated in a unified database system to facilitate access on request. The NRA should provide guidance on file format, compatible with standard database systems.

4.7 Main Points

With the involvement of ecological experts and financial incentives, NRAs can ensure a long-term strategy, a continued project commitment to ecological performance, and a considerable reduction of administrative expenses. A failure (i.e. not meeting the targets) through misunderstanding or misuse of KPIs or other generalised indicators, can thus be avoided.

- Ecological expertise of all parties involved in project delivery is essential for the successful implementation of environmental measures from the preparation of contract documents through to the monitoring of road operations. The NRA requires access to suitable ecological expertise to enable it to fulfil its duties properly;
- The increased use of Quality Assessment, including ecological requirements, in procurement, would provide environmental advantages. However, as this is only a small part of the assessment process, there is no guarantee that it can have a decisive influence on the appointment process, and it is doubtful if that would be appropriate in the overall project management process;
- Construction and Operation Contracts that incorporate a Maintenance function with appropriate monitoring, may be preferred as this ensures that there is a process for problems to be resolved;
- Contracts which engage the Contractor before the Planning Stage and that carry through to Operation and Maintenance, could be particularly successful for wildlife protection as they provide continuity and monitoring throughout the entire process, but there are not enough completed projects to provide confirmation of this;
- Maintenance Only Contracts have potential to be particularly effective for the satisfactory management of existing infrastructure to achieve ecological outcomes and may be used to improve the quality and functionality of wildlife measures;
- Outcome-based procurements are costly and time-consuming due to the time and resources required to validate the expected outcomes. Costs are therefore likely to be considerably higher compared to traditional procurement approaches. In addition, appropriate time-spans for evaluation studies may be uncertain, with implications on resources for project planning;

- Follow-up studies need to be an integral part of all mitigation projects;
- Follow-up studies should be performed or supervised by accredited and technically competent experts (in line with standards of the EIA Directive), who ideally are permanently employed to ensure:
  - a continuation of competence throughout the lifecycle of the project up to and including the maintenance phase; and
  - the build-up of local knowledge.
- Outcome-based mitigation measures of a DBFM (PPP) contract where the contractor is given specific targets with financial incentives, may be a way of not only ensuring that the measure is provided but, by requiring the Contractor to prove the use of the measure by the target species, they are also incentivised to undertake extensive monitoring.

CEDR Call 2013: Roads and Wildlife Documents

Further information on the topics discussed in this chapter can be found in SAFEROAD Technical Report 2 and Harmony Deliverable Reports E part A and E part B. Details on these reports and other key references can be found at the back of the Manual.

Chapter 5. Maintenance

Summary

- Planning road maintenance needs to take place at various levels from network level down to the individual component level;
- No matter the level, guidelines need to be specific to the project context and also be open to adaptation to the varying conditions of climate, wildlife and road use;
- Maintenance personnel need ongoing thorough training in order to carry out any maintenance plan and deal with the specialist activities, such as:
    - Dealing with invasive species;
    - Removal of animal carcasses.
- The scope and complexity of the interaction between roads with wildlife means that multiple stakeholders have valuable input and opinion to offer. Building relationships with these parties can make maintenance more effective and efficient; and
- Whatever practices are used to carry out road maintenance, it is important that best practice is identified, adopted and shared.

5.1 Introduction

The application of road-wildlife maintenance guidelines can help to achieve several goals as follows:

- Reduce the risk of road traffic accidents involving animals;
- Reduce wildlife mortality caused by traffic, but also by other factors such as collisions with fences or screens, animals trapped in kerbs or ditches, etc.;
- Enhance habitats for wildlife on road verges, ponds, or any other landscaped areas; and
- Enhance the role of wildlife crossings as connections between natural habitats and protected areas, thereby reinforcing European Green Infrastructure.

The diversity of landscape, climate conditions, ecosystems and wildlife in Europe makes it challenging to provide detailed prescriptions that can be applied throughout the continent. These recommendations must be seen as general indications on topics that should be addressed. They need to be adapted to the conditions of each country or region (road network, environment, jurisdiction and economy), and specific standards must be defined for each one. The guidelines presented in this chapter emerge from detailed discussions with road ecology practitioners and best practice identified by experts.

Box 5-1: Target Species

The term "target" indicates that the mitigation measure is initially designed and made for these animal species. That does not say that other species can or do not use or are affected by this facility. It is recommended that during inspection and maintenance, attention is given to evidence of use by species other than the target. This information could be used to adjust the maintenance and/or design of the mitigation measure in the future.

5.2 Develop an Adaptive Road Wildlife Maintenance Plan

Conditions of ecosystems, habitats and species may vary greatly over time, due to variations in environment conditions, human activities and climate change. Human activities and land use on roadsides, which could strongly influence the effectiveness of road-wildlife maintenance practices, may also change. Maintenance plans must be able to adapt to these changing conditions. Appropriate application of such road-wildlife maintenance practices will provide a framework to develop successful adaptive strategies (refer to Figure 5-1).

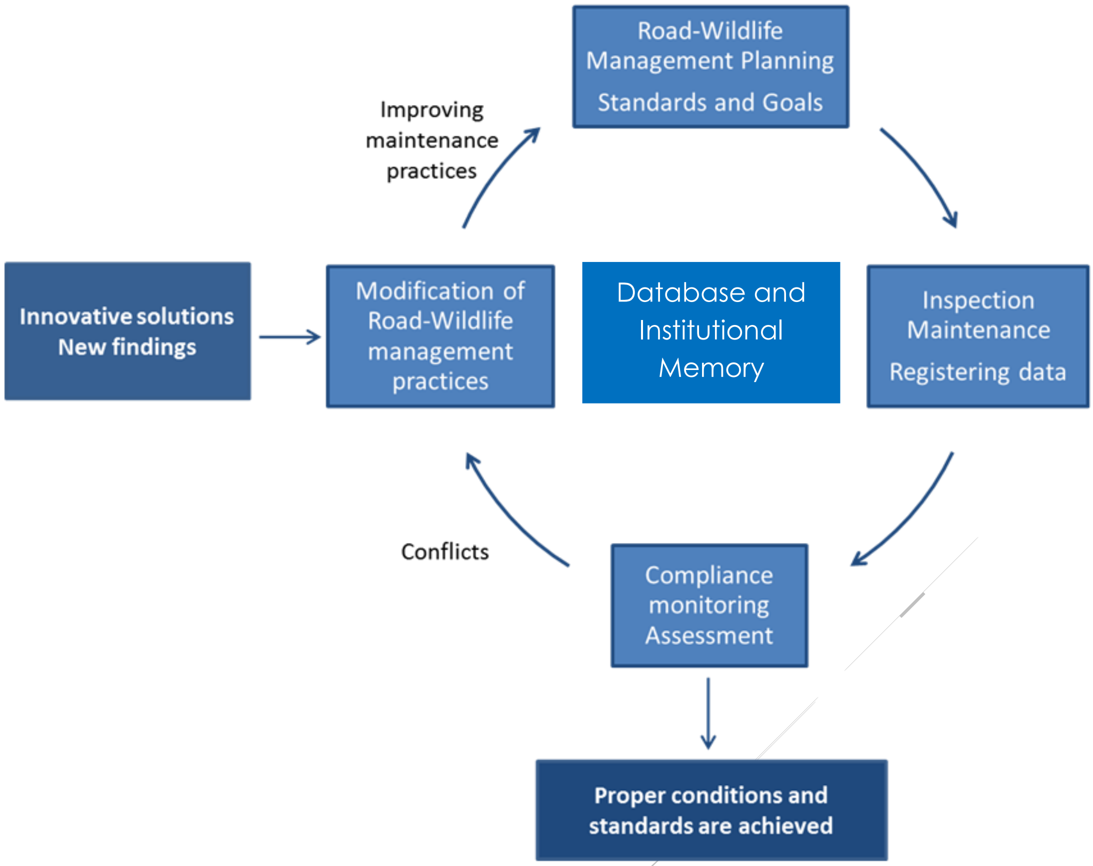


Figure 5-1 Adaptive road-wildlife maintenance strategy.

5.3 Develop an Adaptive Maintenance Plan for each Road Element

The following are guidelines for maintenance planning of mitigation measures:

- Draft a Maintenance Plan for the area/road of concern, taking account of each measure (refer to Box 5-2 for an example);
- Provide a database with details, including location, of each mitigation measure to be maintained;
- Use information from experts who specified the mitigation measures to ensure that details, such as target species, are incorporated;
- Describe the standards to be met and road safety and operational requirements;
- Draft a list of maintenance actions specific to each type of mitigation measure;
- Specific maintenance plans may need to be drafted for particular structures such as large wildlife overpasses;
- Draft a list of maintenance actions for any measure or species-specific requirement (refer to Figure 5-3);
- Identify the location of particular points on the measure to be inspected and maintained;
- Schedule inspections, accounting for target species, inspection frequency, seasonal weather and habitat (refer to guideline in Section 5.5);
- Revisit and modify the maintenance plan according to maintenance results, changes in species distribution, increases in AVCs, etc.; and
- Provide procedures for updating maintenance tasks.

Step 1
- **Define** which road elements included in the Road Maintenance Guideline require guidelines related to wildlife topics.

Step 2
- **Identify** topics that could require additional maintenance guideline documents (wildlife crossings and road side green areas management are recommended).

Step 3
- **Develop** a cooperation platform: stakeholders that could contribute to definition, applicaton or monitoring of the maintenance practices and who may be involved in developing guidelines.

Step 4
- **Draft** general structure of the maintenance strategy and specific guidelines for all road elements.

Step 5
- **Establish** and implement training of technical staff and field crews for road maintenance.

Step 6
- **Apply** the inspection and maintenance guidelines.

Step 7
- **Monitor** and report the results. Define future improvements and new innovative practices to be applied.

Step 8
- **Modify** the plans and actions according to what has been learned in the past and to adapt to changes.

Figure 5-2 Process for developing an adaptive maintenance strategy.

Box 5-2: Example Guidelines for Maintenance Planning of Ponds and other elements of Drainage System

- Draft a maintenance plan based on the identification of drainage elements that can play a role as habitats for wildlife. Identify drainage elements that are hazardous and where fauna access must be avoided if no optimisation is possible;
- Maintenance practices must be defined primarily to maintain the function of drainage. Water, road and wildlife experts must work together to design a successful drainage system maintenance plan;
- Provide information about aquatic habitats beside the roads and identify sections of road where appropriate maintenance of retention ponds, ditches and other drainage system elements could be managed to enhance habitats for aquatic fauna species;
- The maintenance plan should:
  - Be adapted to the site and consider wildlife species that are actually present and species that could use the habitats provided, according to local species requirements;
  - Perform pond and ditch maintenance to avoid harming animals that are living there, and to improve habitats for invertebrates, fish, amphibians, otters and other aquatic or semi-aquatic species;
  - Identify potential risks for road safety and animal mortality;
  - Evaluate the opportunity to modify some features of ponds or ditches to allow the habitat to host endangered species;
  - Define proper procedures for drainage systems, according to the fauna living in these areas.

Amphibian Pond

Ponds should not be too deep so that the water can be rapidly heated by the sun, but deep enough (or with deeper parts):

- to provide sufficient water in the summer for the development of larvae and,
- so as not to completely freeze in winter.

Planting for shade is allowed, but care should be taken that enough sunlight can reach the pond to warm the water sufficiently. In addition, there should be no tall vegetation (bushes or trees) within about 20 metres of the water's edge. Falling leaves will eventually fill the pond. A pond has to be part of a network of amphibian habitats, and therefore, a connection to this network is of great importance.

What to check?	What to do?
Optimal water depth: 0.8 – 1.2 m	Phased dredging, so that a part of the pond will remain intact and damage is reduced as much as possible: • in clay and peat areas, once every 4-5 years; • in very fine sandy areas, once every 7 years; • in sandy areas, once every 10 to 20 years.
At least 50% open water	Cleaning (mowing), but leave some of the vegetation; remove excess dead plant material away from the pond.
Enough incoming sunlight	Curb shading by pruning and felling.
Gradually sloping shore	Level the shore by removing soil.
Well connected to existing corridors and habitat in the surrounding area	Use planting to make or restore the connection.
Disturbance	Take steps to ensure limited access of people.
Litter	Remove litter.

Inspection scheme

j	f	m	a	m	j	j	a	s	o	n	d

Conduct the work between mid-August and mid-October.

Target species
Frogs, toads and salamanders. Ponds can also offer a place to drink or forage for other animals, such as mammals, birds and insects.

Figure 5-3 Example of measure-specific inspection and maintenance actions from the Netherlands[33].

5.4 Develop Green Area Maintenance Plans

Road verges and other landscaped areas as well as ponds and other aquatic habitats associated with drainage systems, require the development of guidelines for maintenance to enhance wildlife habitats and reduce hazards of road mortality. Such plans should be developed in conjunction with all other road maintenance planning.

[33] Further examples in den Ouden and Piepers (2008) (in Dutch) translated to English in Harmony Deliverable G part B

Creating and maintaining a natural verge that supports biodiversity or species of conservation concern is challenging as:

- The vegetation at a zone immediately adjacent to the roadway should be kept short by mowing on a regular basis;
- Attractive habitat for target species or for biodiversity in general should be created behind the zone of shorter vegetation. However, this only applies in regions where the road passes through "ecological deserts", i.e. landscapes that are unattractive to wildlife;
- The more diverse a verge is in plant species, vegetation structure, relief and non-vegetated patches, the more species it can accommodate;
- It is important that wildlife has the ability to escape from these pieces of land and this should be taken into consideration at the design stage of these measures; and
- Lack of maintenance results in no transition zone which leads to an increased risk of AVCs.

No strategy is perfect, e.g. in order to provide a better line of sight for both driver and wildlife, it is recommended to keep the vegetation in verges adjacent to the road short but this does not promote biodiversity and in fact leads to more road kill among butterflies. Table 5-1 highlights some of the various factors to consider and the objectives to have in mind in relation to the maintenance of verges and other green areas. Some general considerations are:

- The timing and the intensity of maintenance are both important;
- Maintenance methods and timing should allow for the biology, e.g. migration seasons of animals; and
- Spatial and environmental differences should be taken into account when deciding on the methods of maintaining different road sections.

Table 5-1 Possible road verge and other green area maintenance objectives and actions

	Road Safety	Grassland Biodiversity	Butterflies	Other Terrestrial Invertebrates	Birds	Bats	Mammals	Amphibians
Open verge Closest to the Road	A hard surface or frequent close mowing provides a better line of sight for driver and wildlife, directly reducing road kill.	Mow between late September and early May and, where practical, maintain as narrow an open strip as possible.			Enhanced line-of-sight reduces the number of carcasses attracting scavenging birds, hence further reducing road kill.	Unfavourable foraging habitats near road reduces road kill risk.	Frequent close mowing allows a better line of sight for both animals and drivers and reduces road kill.	Timing of mowing must avoid key periods of amphibian migration.
Verge Mowing Practice	May be necessary to mow narrow strip near the road more often that twice a year for safety reasons in certain locations.	Grassland management should be by cutting or mowing. For verges requiring two cuts, do it prior to flowering and after seeding. Removal of roadside cutting will avoid soil enrichment. Sow native and appropriate seed mixes where there is low chance of natural regeneration.	Only part of the site should be mown in any one year, rotating year on year. Mowing of butterfly habitat should be avoided during June and late September as this would remove the host vegetation on which butterflies lay their eggs. Maintain a mosaic of mown and unmown areas.	Cutting time has major impact. Mowing twice a year (for medium/high production verges), with removal of cuttings, provides the best feeding for flower-visiting insects. Avoid the use of flails; rotary cutters are preferable. Early or late mowing can benefit obligate myrmecophilic species.	Avoid mowing during bird breeding season where ground nesting birds on the verge may be impacted. Mowing regimes should not encourage raptors to hunt along the road verge unless foraging habitats are provided behind continuous screens.	Mowing regime should not encourage bats to hunt along the road verge unless foraging habitat are provided behind continuous screens.	Lower intensity regime provides greater refuge for small mammals.	
Scrub Encroachment	Scrub may require cutting back for public safety and to maintain drainage function.	Cutting back will be required on a rotational basis to prevent shading out of wildflowers. Cuttings should be removed. Control of invasive scrub growth will depend on species and soil structure.	Rotation of control (5–20 years) will depend on desired mosaic of connecting corridors, clearings and glades.		Establishing scrub/hedgerow may provide a refuge for breeding birds. However, immediately adjacent to the road surface (<5m), scrubs and hedgerows should be avoided to prevent road kill. Avoid cutting back during bird breeding season, delay cutting of fruit bearing trees as late as possible. At locations where birds are known to cross the road, e.g. during daily flight to and from foraging areas, well-developed scrub vegetation and/or hedgerows (>3m high) on both sides of the road may obstruct low-level flight and, hence, reduce the risk for collisions.	Cut back scrubs and hedgerows to reduce road kill risk for bats commuting and foraging along the vegetation structures. At designated bat crossing sites, achieve and maintain high scrub and hedgerows (>5m high) on both sides close to the road to obstruct low-level flight.	Scrub and hedgerow can provide refuge and corridors for larger fauna.	Hedgerows connected with ponds help amphibians move through the landscape.
Hedgerows	Hedgerow may require cutting back for public safety or road amenities/ services access.	Hedgerows are associated with higher plant richness at landscape scale.	Maintain areas of longer grass for hedgerow species. Appropriate cutting of hedgerow one side per year to avoid impacts on species that lay eggs on one-year-old growth.	Hedgerows are associated with higher arachnid richness on road verges.				
Grazing	Grazing not advised on busy roads.	Grazing is practiced in the road corridor in some countries using temporary electric fencing and herders. Appropriate grazing regimes (desired sward height) will depend on particular species to be managed. Also possible on compensation land.						

5.5 Develop a Schedule for Inspection

The timing and frequency of inspection is dependent on a number of factors. Figure 5-4 shows a table translated from a Dutch handbook which provides guidance on when elements of road mitigation measures should be inspected for the local conditions there. Such an inspection timetable should be developed by each contracting authority for specific regions or roads. Details that need to be considered are specific to:

- The element of concern;
- The target species:
  - If inspection for use is required, then there is nothing to be gained during periods of hibernation or periods when the target species has migrated away;
- The climate:
  - Scheduling inspections for January, as an example, for a country as a whole may not make sense for countries where winter snows differ greatly between north and south;
- The timing and frequency of other inspections:
  - The maintenance of mitigation elements in combination with road maintenance, would shape the schedule of inspections;
  - After verge cutting, elements need to be inspected in case of damage by machinery.
- Inspection triggers:
  - Instances of AVC may indicate the need for inspections of nearby mitigation measures to ensure that structural issues are not a factor;
  - Non AVC traffic accidents involving a mitigation measure, or near one, may damage it and initiate an inspection.

Measure / Facility/ Utility	Section	Month for inspection											
Amphibian pond	Pool	j	f	m	a	m	j	j	a	s	o	n	d
Amphibian screen / guide wall	Screen / Guide Wall	j	f	m	a	m	j	j	a	s	o	n	d
	Walkway	j	f	m	a	m	j	j	a	s	o	n	d
Amphibian underpass	Tunnel (entrance & tube)	j	f	m	a	m	j	j	a	s	o	n	d
Bat dwelling	Stay / Dwelling	j	f	m	a	m	j	j	a	s	o	n	d
Bridge with path underneath	Ongoing bank	j	f	m	a	m	j	j	a	s	o	n	d
Ecoduct, green bridge	Landing Strip Run & Slope	j	f	m	a	m	j	j	a	s	o	n	d
	Sound & sight screen	j	f	m	a	m	j	j	a	s	o	n	d
	Drinking pool	j	f	m	a	m	j	j	a	s	o	n	d
Fence, electric	Wire / Fence	j	f	m	a	m	j	j	a	s	o	n	d
Fence, large mammals	Poles, mesh & wire work	j	f	m	a	m	j	j	a	s	o	n	d
	Cattle grid	j	f	m	a	m	j	j	a	s	o	n	d
	Return facility (mound)	j	f	m	a	m	j	j	a	s	o	n	d
	Gates	j	f	m	a	m	j	j	a	s	o	n	d
	Wild Boar Gate	j	f	m	a	m	j	j	a	s	o	n	d
Fence, small mammals	Poles, mesh & wire work	j	f	m	a	m	j	j	a	s	o	n	d
	Return hatch	j	f	m	a	m	j	j	a	s	o	n	d
	Return facility (mound)	j	f	m	a	m	j	j	a	s	o	n	d
	Gates	j	f	m	a	m	j	j	a	s	o	n	d
Gangway / dam	Gangway / dam	j	f	m	a	m	j	j	a	s	o	n	d
Guiding vegetation	Plants	j	f	m	a	m	j	j	a	s	o	n	d
Large bridge or viaduct	Underpass	j	f	m	a	m	j	j	a	s	o	n	d
Large fauna underpass	Tunnel (entrance & tube)	j	f	m	a	m	j	j	a	s	o	n	d
Ledge under bridge or in culvert	Ledge / shelf	j	f	m	a	m	j	j	a	s	o	n	d
Ramparts	Planting	j	f	m	a	m	j	j	a	s	o	n	d
Sand martins nesting site	Wall	j	f	m	a	m	j	j	a	s	o	n	d
Small fauna underpass/badger tunnel	Tunnel (entrance & tube)	j	f	m	a	m	j	j	a	s	o	n	d
	Manhole	j	f	m	a	m	j	j	a	s	o	n	d
	Gravel pit	j	f	m	a	m	j	j	a	s	o	n	d
	Lighting shaft	j	f	m	a	m	j	j	a	s	o	n	d
Stub wall (tree stumps)	Tree stumps (Stub wall)	j	f	m	a	m	j	j	a	s	o	n	d
Tunnel/viaduct (with underpass)	Walkway	j	f	m	a	m	j	j	a	s	o	n	d
Viaduct (with wildlife overpass	Walkway	j	f	m	a	m	j	j	a	s	o	n	d
	Sound & sight screen	j	f	m	a	m	j	j	a	s	o	n	d

Figure 5-4 Example of inspection timetable[34]: A dark green box indicates that a complete inspection should be carried out. A light green box indicates that only inspection for vandalism and litter is needed.

5.6 Develop Training Management Plans

The incorporation of wildlife experts into maintenance staff, and regular training of maintenance crews, ensures that they have the knowledge needed to undertake tasks and record relevant wildlife events, such as road casualties, or detect IAS. Ecological facts and maintenance guidelines are strongly site-dependent so training should be adapted to each road context. To perform a proper training programme:

- Define purpose and goals;

[34] den Ouden and Piepers (2008) (in Dutch) translated to English in Harmony Deliverable G, part B

- Develop a training curriculum that is suitable for all staff (team leaders, technicians and field crews);
- Identify topics and staff needs, and schedule regular training seminars that include field trips, when possible, to update knowledge;
- Meetings and field visits must be organised in a participative way to gather information from field crews and technical maintenance staff and learn from them. Listening to practitioners should be an important component of training sessions and will also be useful to focus training on more controversial aspects;
- Trainers must combine teaching skills, expert wildlife knowledge and a comprehensive knowledge of the roads where maintenance tasks are applied; and
- Provide specific training materials: sheets, field guides to identify target species, and other elements must be drafted to adapt the general contents as much as possible to each road maintenance plan. Website-based applications could also be envisaged as a useful tool for updating contents and use in the field.

When roads are privately operated, maintenance crews should provide evidence of a certain level of expertise in ecological issues.

Box 5-3: Best Training Practices

- Regular meetings at the onset of, and sometimes during, a contract (standard five years), at which NRA biologists and plant experts discuss maintenance issues with practitioners. Meetings have a training component, are participative, and enable learning from practitioners. General environmental education is aimed at project leaders and maintenance operators regionally.
- In 2015, the Swedish Transport Administration (STA) provided general environmental education for all project leaders in maintenance nationally (approximately 200 persons). This type of education will now also be aimed at project leaders and operators regionally, within the LIFE project ReMiBar (Remediation of migratory barriers in Nordic/fennoscandian watercourses).

5.7 IAS Management Plan

Roads provide excellent conduits of IAS and can be inadvertently spread through maintenance actions, facilitating further infestation throughout the road network. Early detection and removal of IAS is a necessary maintenance practice and legal obligation where IAS are of Union concern as listed in EU Regulation 2016/1141.

IAS control in maintenance planning depends firstly on accurate identification of species. This may require special training. Field teams must be provided with:

- A field guide of IAS; and
- Instructions for an "early awareness" detection system.

The purpose of the Management Plan is to prevent further spread of IAS within and outside of the road network subject to maintenance planning. As part of the Management Plan, different methods can be used for each species. The main options for plant IAS include:

- Chemical control;
- Excavation and burying or disposal to licensed landfill/incinerator;

- Bunding and treatment; and
- Soil screening.

There are a number of issues which will affect the management strategy, including the following:

- Accessibility and space available;
- Transboundary (local planning authority) issues;
- Proximity to environmentally sensitive areas, watercourses and drains; and
- Proximity to areas used by the general public and/or defined vulnerable groups.

In the course of devising and implementing the most effective eradication methods, the IAS Management Plan must comply with all legislation regulating the treatment and management of IAS. In addition:

- To comply with sustainable use of pesticides legislation, the application of herbicide should only be undertaken by registered professional users;
- Only a suitably certified pesticide advisor should approve procedures prior to IAS maintenance commencing; and
- All professional users should demonstrate correct use, ensuring only authorised products are used and all treatments are catalogued and documented pursuant to the requirement of relevant plant protection products legislation.

After treatment has taken place, it is important that monitoring takes place. Beginning approximately 6–8 weeks after treatment, it may need to last for years afterwards, depending on species.

5.8 Plan How to Deal with Removal of Animal Carcasses

Removing carcasses of road killed animals and carrying out inspections and repairs at the locations where AVCs have occurred, are frequent tasks of road maintenance crews.

Box 5-4: Conflict Diagnosis and Thresholds

AVC data can be used to identify need, inform design, and evaluate the effectiveness of mitigation measures. Thresholds in the number of road casualties, above which mitigation measures are required, are rarely applied at this time. In Spain, road managers apply a threshold on the number of ungulate-vehicle collisions (UVC) along a road section leading to its classification as a "UVC priority road section" and to the application of mitigation measures. Thresholds are also applied in other countries to require the installation of warning signs.

For best results, the accuracy of the data is important, with three aspects in particular to be addressed:

- Correct identification of species, including age and sex;
- Precise marking of location; and
- Comprehensive description of road section and mitigation measures in place.

Other data to be registered include the date and time of collision, and the date and time of carcass removal and inspection. The use of this information to improve mitigation measures may clearly benefit wildlife conservation, increase the economic efficiency of investments in mitigation measures and reduce the economic and social costs of accidents. Moreover, AVC analyses by road and wildlife experts allow new mitigation measures to be designed, and existing ones to be re-located or improved.

Procedures to deal with AVC and the resulting carcasses need to be included in the training plan. Individuals need to know how to:

- Use clothing and equipment to ensure hygienic conditions;
- Identify species;
- Recognise the aspects of the road that need to be reported;
- Correctly register incidents;
- Use special equipment that may be required in the removal of large carcasses; and
- Dispose of the carcass according to each country's regulations and policies.

The procedures that are put in place to deal with carcasses resulting from AVC need to also be applied in instances where casualties are discovered in regular maintenance patrols. The following are maintenance planning guidelines for the removal of animal carcasses:

- Draft accurate procedures for road mortality and AVCs;
- Provide procedures and appropriate devices and databases for accurately recording carcasses collected by field patrols, and road traffic accidents involving wildlife;
- Define carcass management procedures;
- Establish regular analyses of the data collected, and correct identification of clusters of road mortality ("hotspots") using standardised thresholds;
- Provide frequency thresholds of road casualties to identify road sections that will require the design and application of proper mitigation measures. Large AVCs and endangered species road mortality thresholds must be provided;
- Cooperation between road and wildlife experts is needed to implement appropriate procedures, evaluate the data that is collected, and design appropriate mitigation measures, according to each conflict road section; and
- Cooperation with parties such as drivers, NGOs, police, researchers and hunters is needed to maximise the instances reported and efficiency of removal.

5.9 Develop Cooperation with Other Stakeholders

Cooperation platforms at national, regional or local level are useful to coordinate actions with other stakeholders involved in wildlife topics. Such cooperation ensures that all parties understand who is responsible for the maintenance and can help improve the actions taken. The main stakeholders and the topics of concern are:

- Environmental administrations;
- Water administrations;
- Land-planning administrations;
- Traffic administrations;
- Local administrations;
- Researchers;
- Owners of adjacent land;
- Farmers and forest managers;
- Nature conservation organisations;
- Hunter associations; and
- Volunteer networks.

Box 5-5: Best Cooperation Practice

- Cooperation of NGOs on the maintenance of compensatory measures (Spain, Germany and Belgium);
- Specific agreements signed with organizations other than road authorities (e.g. water agencies and municipalities) to commit them to the responsibility of maintaining compensatory measures in private or public lands outside of the road area (Spain);
- Maintenance of measures transferred to the nature conservation agency that owns the territory next to the road (the Netherlands);
- Inventories of fauna passages, accessible in a web-based or Google Earth-based database, are being completed in several countries (Sweden, Norway and Catalonia-Spain), as a basis for better maintenance;
- In Norway, the National Road Database (NRDB) lists all environmental measures (including an inventory of fauna passages and other environmental measures). In order to be included in maintenance contracts, the existing measures have to be included in the NRDB.

5.10 Develop and Share Institutional Memory

An "institutional memory" at the NRA level needs to be established so that knowledge can be retained when personnel change. While it is necessary to keep track of data on each mitigation measure (location, age, etc.), it is just as important to keep track of maintenance techniques and methods. Accurate inventories of mitigation measures and databases (based on web applications where possible) must be developed to integrate all data related to wildlife as follows:

- Data should be recorded in a standardised manner, which must be established in the road-wildlife maintenance plan, to allow correct analysis and assessment;

- If a contractor is employed to carry out maintenance, detailed records should be kept by the authority to ensure that knowledge/experience is gained by the NRA and used in future work;
- Knowledge/experience should be disseminated through road authorities and various contractors;
- Knowledge/experience should be used to inform future contracts; and
- Comprehensive reports that provide an understanding of the causes of failures, of re-design practices, and of changes in road maintenance strategies or practice is the final crucial step.

Regular coordination meetings between all stakeholders based on assessment reports, will allow compliance monitoring to be coordinated with other environmental monitoring, carried out by environment agencies or other stakeholders. Forums should be organised to share information about conflicts and to find solutions. Where maintenance is carried out in shorter term contracts (five years), the need for recording of best practice is heightened.

Box 5-6: You Cannot Inspect What You Cannot Find

Small mitigation measures, such as tunnels for amphibians, reptiles or medium-sized mammals, are difficult to find in the field. This is especially the case when they are infrequently maintained or partially covered by vegetation. Also, it has happened that the road owner sometimes is not aware of the existence of these small mitigation measures or for what purpose or target species they were built. This can happen when the mitigation measure was constructed before the current staff responsible for maintenance were employed. All mitigation measures should be registered in a database, including location coordinates, the target species and the function it should fulfil, immediately after their construction.

CEDR Call 2013: Roads and Wildlife Documents

Further information on the topics discussed in this chapter can be found in SAFEROAD Technical Report 5 and Harmony Deliverable Reports F and G. Details on these reports and other key references can be found at the back of the Manual.

Chapter 6. Performance Evaluation of Road Mitigation Measures

Summary

This chapter provides a framework to assist with the evaluation of road mitigation performance. After addressing the questions *why should we evaluate*, *when should we evaluate* and *what to do if resources are insufficient for a full evaluation*, a set of guidelines is presented for the preparation of a scientifically-sound plan to evaluate whether the desired outcome for road mitigation has been achieved or not: (1) Identify the target species and goals of mitigation; (2) Select appropriate performance indicators; (3) Use reference values and controls; (4) Select appropriate survey methods; (5) Select an appropriate spatial scale for data collection; (6) Time data collection carefully; (7) Take sufficient time for performance evaluations; (8) Use a sampling frequency that provides sufficient data; and (9) Measure explanatory variables.

Twelve practical recommendations are provided for the implementation of the presented guidelines: (1) Make the preparation of an evaluation plan for planned road mitigation measures an inseparable part of the legal processes that must be followed during the road planning and procurement stages; (2) Form an independent advisory board; (3) Develop a strategy for systematic assessments of baseline conditions and reference standards; (4) Arrange close collaboration between ecologists and those who plan, design, construct and manage the road; (5) Facilitate greater involvement of ecologists within road agencies in the procurement process of road mitigation works; (6) Involve all stakeholders in the preparation of the performance evaluation; (7) Secure all necessary resources for the evaluation of road mitigation performance in advance; (8) Contract an independent contractor to evaluate road mitigation performance; (9) Document both research methods, results and conclusions systematically; (10) Analyse and report all data in a timely manner to ensure that existing structures can be modified within an adaptive framework and the design of future mitigation measures can be improved; (11) Arrange peer review of reports and aim for publication in scientific journals to improve the quality and rigour of the scientific methods as well as improve access to the findings; and (12) Make the outcome of all evaluations, including research reports and raw data, widely available through an open access database.

6.1 Introduction

Across Europe, thousands of crossing structures and tens of thousands of kilometres of wildlife fencing have been constructed to reduce the number of collisions between vehicles and wildlife and simultaneously allow the animals to move through the landscape. Do such mitigation measures work? Are they effective in reducing road impacts? To answer these questions, the performance of existing and future road mitigation measures has to be carefully evaluated. However, what is the best way to do this? Which performance indicators should be selected? What would be the best study design to assess whether the desired outcome is achieved? And how can we be assured that the measured outcome is not biased by factors that do not directly relate to the road mitigation works? In this chapter, a framework is provided that aims to assist with the evaluation of road mitigation performance (refer to Figure 6-1).

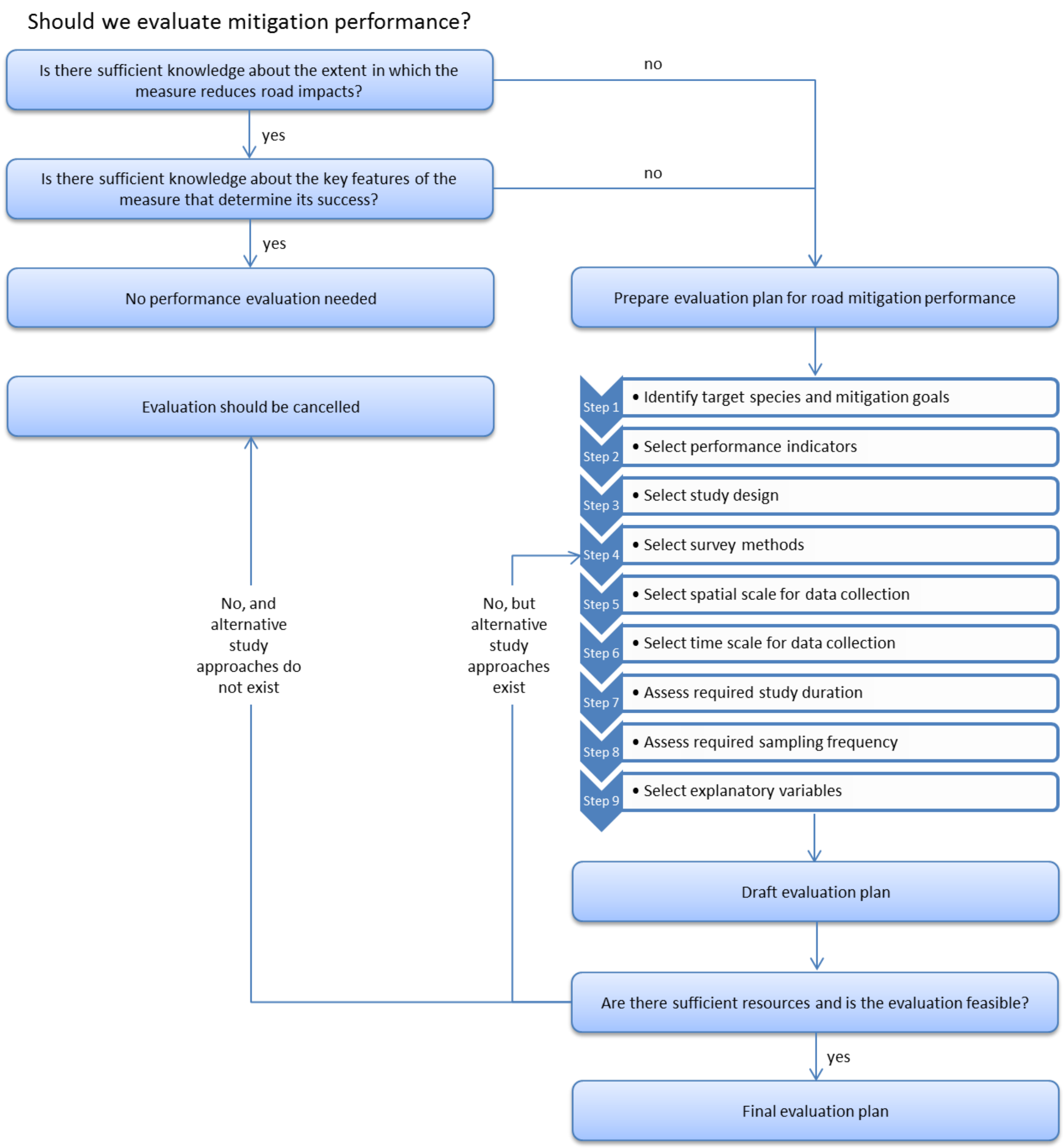


Figure 6-1 Flowchart to decide whether performance evaluations should be carried out, in case that such performance is not obligatory or part of an outcome-based procurement approach.

Road mitigation performance should be evaluated to:

- Assess whether measures implemented result in the reductions aimed for in road impacts;
- Increase our knowledge base on what mitigations work and what do not; and
- Increase our knowledge base on what features of the mitigation works are vital for its success and in what way the effectiveness of measures can be optimized.

Without such evaluations there are risks of untested and ineffective mitigation measures, thus wasting money and threatening wildlife populations. No mitigation measure should be widely implemented before it is tested and its performance is assessed (refer to Figure 6-1).

6.2 When should Evaluations be Performed?

Road mitigation performance evaluations should be conducted when there is insufficient knowledge about:

- The extent in which a mitigation measure reduces road impacts for the target species; and
- The key features of a mitigation measure that determine its success.

Furthermore, performance evaluations are indispensable if an outcome-based procurement approach is used to assess whether implemented measures are functioning in conformance with provided specifications.

6.3 What if Resources are Missing for a Full Performance Evaluation?

- If resources are not adequate for a full performance evaluation, the evaluation should be cancelled. It is better to carry out a few well-designed and correctly executed studies than numerous poorly designed studies;
- Only scientifically rigorous studies will contribute new knowledge and insights on the extent to which mitigation reduces road impacts; and
- Only full performance evaluations can be used in an outcome-based procurement approach.

6.4 Guidelines for Performance Evaluations

These guidelines are not intended to be a step by step guidance for all mitigation evaluations. Decisions on, for example, study design, sampling scheme or survey methods, are highly dependent on the goals for mitigation, target species, local situation, etc. The guidelines are a checklist to address all relevant issues in the preparation of a scientifically-sound plan to evaluate whether the desired outcome for road mitigation has been achieved or not.

6.4.1 Identify the Target Species and Goals of Mitigation

The starting point for any evaluation of road mitigation measures should be the target species and goals of mitigation:

- The target species list should indicate:
  - Species for which road impacts have been assessed or are expected;
  - Specific species and not species groups, such as 'small mammals' or 'amphibians', because species within such groups may require a different approach.
- The goals of mitigation should indicate, for <u>each</u> target species:

- What road impacts need to be addressed;
- Clear and measurable thresholds for each road impact that need to be addressed;
- The time period within each year that the mitigation works should be in operation;
- The time period over which the performance should be assessed to decide whether the goals are being met.

6.4.2 Select Appropriate Performance Indicators

Performance indicators should be selected that:

1. Are most closely related to the desired outcome; and
2. Are directly derived from the goals of mitigation.

Examples:

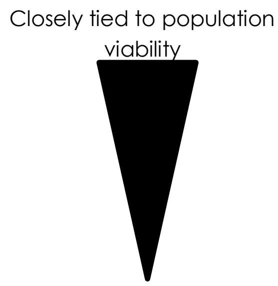
- If "*a reduction in road kill of target species X by 90%*" is the goal, road kill numbers is obviously the performance indicator to use (but it should be borne in mind that some measures to address road kill may damage connectivity); and
- If "*at least 90% of the between-population movements of target species X should be restored*" is the goal, movement numbers should be the performance indicator.

In some cases, multiple performance indicators may suit and a choice has to be made (refer to Box 6-1).

Box 6-1: Performance Indicators and Population Viability

Goals of mitigation may refer to the maintenance or restoration of population viability. For example, a mitigation goal could be '*to ensure that the survival probability of the population after road construction is not affected when compared with the pre-road situation*'. As population viability cannot be directly measured in the field, it is necessary to measure attributes of the population that reflect or influence the likelihood of population persistence. Options for performance indicators are, in this case:

1. Trend in population size or density
2. Number of road kill
3. Reproductive success
4. Age structure
5. Sex-ratio
6. Between-population movements
7. Genetic differentiation or genetic variability



Of these, the trend over time in the size or density of the population is the most informative indicator and should be selected if possible. If this is not possible, less direct attributes may be measured, such as road kill number, reproductive success, etc. However, conclusions about road mitigation performance will be harder to make as these attributes are less closely tied to population viability.

6.4.3 Make use of Reference Values and Controls

The study design should include the collection of data on reference values, such as:

- Baseline conditions, which refer to:

- The local conditions before road construction (in the case of a new road);
- The local conditions before mitigation (in the case of an existing road).
- Reference standards, which refer to:
  - The conditions at reference sites;
  - Standards generated with model simulations (refer to Box 6-2);
  - Standards that have been derived from regulations or policies.

Such reference values are essential to assess the extent to which road impacts have been mitigated and hence the extent to which the goals of mitigation are achieved.

Box 6-2: Road Mitigation Calculator

Model simulations may be of assistance to evaluate reference standards for road mitigation measures. For example, if wildlife crossing structures are planned, the question may arise: *How many animal movements should be facilitated by the crossing structures per year to guarantee the survival of the population* (refer to Figure 6-2)? Essentially, each performance evaluation requires a clear definition of success.

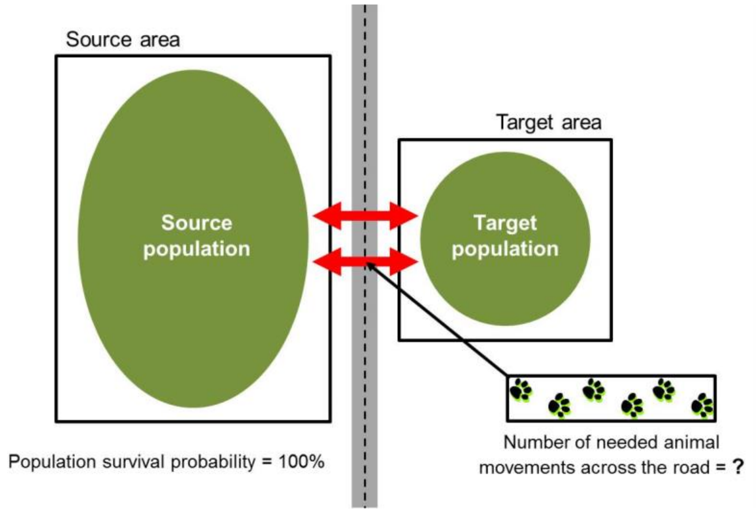


Figure 6-2 Illustration of relationship between source population, target population and number of needed animal crossings

Models in which population dynamics are simulated, however, are not widely available and are often complex to use. For this reason the Road Mitigation Calculator was developed (refer to roadmitigationcalculator.eu). This web tool is not a model itself but provides quick access to model simulations for a few scenarios that are frequently encountered in road projects. It provides an answer to the previous question about desired crossing numbers, taking into account the size of the populations on each side of the road. In addition, the tool can be used to estimate the survival probability of a population, given the number of animal movements that have been registered at a crossing structure. The output of the tool should be seen as indicative; however, it may still be a helpful tool to assess whether a mitigation plan or installed mitigation measure is likely to do what it is expected to.

The optimal study design for evaluating road mitigation performance includes the collection of data:

1. Before road construction or mitigation;
2. After road construction or mitigation;

3. At the road sites where mitigation is installed (mitigation sites); and
4. At road sites without mitigation (control sites).

Such a study design is referred to as a *Before-After-Control-Impact* (i.e. BACI) design. Collecting data at control sites ensures that measured changes can be attributed to the mitigation.

If no suitable control sites can be found, one should:

- Use a *Before-After* (i.e. BA) design in which measurements are carried out at the mitigation sites, before and after road construction or before and after the construction of the mitigation; and
- Measure explanatory variables (refer also to Section 6.4.9), which may partly cancel out the consequences of not having control sites.

6.4.4 Select Appropriate Survey Methods

- The survey method should be based on the selected performance indicator and target species (refer to Tables 6-1 and 6-2);
- If more than one survey method is available, the one that is most accurate, informative and efficient should be selected;
- Testing methods prior to the evaluation is recommended to select the best technique and the optimal way to apply it;
- If multiple target species should be surveyed, survey methods that monitor multiple species simultaneously are recommended because they provide more information for similar effort and cost;
- Where possible, more than one survey technique should be used, as methods may provide different insights (refer to Box 6-3); and
- Consistent use of the same methods and personnel over time is important to reduce bias and provide comparable results.

Box 6-3: Genetic Techniques

The application of genetic techniques in road mitigation studies is relatively new. They often provide complementary insights to the more conventional survey techniques and seem to be of particular value in assessing the population-level effects of roads. Through genetic techniques, it is possible, among other things, to identify:

- Species of road kill;
- The origin of individuals that arrive at a crossing structure;
- Characteristics (e.g. sex) of individuals that arrive at a crossing structure;
- How many individuals of a species use a crossing structure;
- Frequency of use of crossing structures by specific individuals;
- Movement routes through the landscape by specific individuals;
- Level of exchange of individuals between populations;
- The extent to which dispersal leads to gene flow;
- Health of a population.

Genetic sampling can be costly and time-consuming if species have to be captured, but low-cost methods exist, such as the use of hair traps and collecting road kill, faeces, feathers or shed skin. Genetic sampling can also be easily coupled with other already-occurring surveys.

Table 6-1 Potential survey method(s) for each performance indicator, categorised over the three main drivers of road mitigation: human safety, animal welfare, and wildlife conservation. The list provides some examples of frequently used survey methods and is not intended to be complete.[35]

Performance indicator	Potential survey methods
Human safety	
• Number of humans killed or injured due to WVC or due to collision avoidance	• Accident statistics, police reports, questionnaires
• Insurance money spent on material/other damage due to WVC	• Insurance statistics, questionnaires
• Number of hospitalizations due to WVC	• Accident statistics, police reports, questionnaires
• Number of WVC with species that potentially impact human safety, regardless of whether they resulted in human injury or death	• Road surveys, police reports, hunter reports
Animal welfare	
• Number of animals killed or injured while crossing roads	• Road surveys, police reports, hunter reports, public wildlife reporting systems
• Number of animals killed or with ill-health due to isolation from needed resources because of the barrier effect of roads	• Field surveys, biological sampling through, e.g. hunting or live-capture
Wildlife conservation	
• Trend in population size/density	• Capture-mark-recapture, point/transect counts or calling surveys, pellet counts, nest/den counts, tracking arrays, e.g. photograph/video cameras, track pads
• Number of animals killed	• Road surveys, radio tracking, road kill statistics
• Reproductive success	• Counts of eggs/young
• Age structure	• Capture, direct observation
• Sex ratio	• Capture, direct observation
• Between-population movements	• Capture-mark-recapture, radio-tracking, direct observation, tracking arrays
• Genetic differentiation	• Invasive DNA sampling after capture, non-invasive DNA sampling, e.g. through hair traps, scat collection, antler/skin collection
• Genetic variability	• Invasive DNA sampling after capture, non-invasive DNA sampling

[35] Adapted from: Van der Grift et al. (2013). Evaluating the effectiveness of road mitigation measures. Biodiversity and Conservation 22 (2): 425-448.

Table 6-2 The suitability of commonly used survey methods for each species group. ** = highly suitable; * = suitable; 0 = registration of species group, but not able to identify species; - = not suitable; ? = unknown[36].

Survey method	Species group										
	Large mammals	Medium-sized mammals	Small mammals	Bats	Non-flying birds	Flying birds	Reptiles	Amphibians	Non-flying insects	Flying insects	Other invertebrates
Track bed (coarse sand)	**	**	0/-[a]	-	**	-	0/-[a]	-	-	-	-
Track bed (fine sand)	**	**	0	-	**	-	0	0	-	-	-
Track plate	-	**	0	-	-	-	0	0	-	-	-
Snow tracking	*	*	-	-	-	-	-	-	-	-	-
Photographic/Video camera	**	**	*/-[b]	-	**	?	?	*[c]	-	-	-
Infrared trail monitor	0	0	0	0	0	-	-	-	-	-	-
Artificial shelters	-	-	*	-	-	-	**	**	*	-	*
Bat detector	-	-	-	**	-	-	-	-	**	**	-
Survey of animals by direct observations (sight or acoustics)	-	-	-	*	-	**	**	**	**	**	-
Survey of animal signs (e.g. browsing, droppings, nests)	*	*	*	-	*	*	-	-	*	*	-
Hair trap – Hair identification	*	*	*	-	-	-	-	-	-	-	-
Hair trap – DNA analysis	*	*	*	-	-	-	-	-	-	-	-
Capture-mark-recapture	-	*/-[b]	**	-	-	-	**	**	**	**	*
Capture-mark-monitor (e.g. Passive Integrated Transponder (PIT) tag, ear tag)	*	*	*	-	*	-	*	*	*/-[b]	*/-[b]	-
Capture-tracking (e.g. radio or GPS/satellite tracking)	*	*	-	*	*	-	*/-[b]	*/-[b]	-	-	-
Capture-release (e.g. live-trap, pitfall trap, mist net)	-	-	**	**	*	-	*	**	**	**	**
Capture-kill (e.g. pitfall trap, light trap)	-	-	-	-	-	-	-	-	**	*	*

[a] Registration, but not at species level, for only some species within this species group.
[b] Suitable for only some species within this species group.
[c] If used in small wildlife underpasses.

[36] Adapted from: Van der Grift & Van der Ree (2015). Guidelines for evaluating use of wildlife crossing structures. In: R. van der Ree, D.J. Smith & C. Grilo (eds.). Handbook of Road Ecology, First Edition: 119-128. John Wiley & Sons, Ltd., West Sussex, UK.

6.4.5 Select an Appropriate Spatial Scale for Data Collection

The spatial scale for data collection should be based on:

- The spatial scale of the road effect being mitigated; for example, impacts of WVCs need to be sampled on and near the road while barrier effects usually need to be sampled over a larger area surrounding the road;
- The performance indicator selected; for example, if demographic or genetic features of the population are used as performance indicators, data collection should take place over a large area surrounding the mitigation site as the mitigation effects will diffuse from the local area adjacent to the road and indirectly affect the broader population over time;
- The species of concern; for example, data collection for species with small home ranges and limited dispersal capacity can be done on a smaller spatial scale than for species with large home ranges and high dispersal capacities; and
- The local situation; for example, topography, land use and available habitat types influence the delineation of the study area.

If fencing is included in the mitigation works, fence end sites (i.e. the road stretches beyond the fences) should be included in the evaluation to avoid over- or underestimation of the effects of mitigation.

6.4.6 Time Data Collection Carefully

Data collection should be timed on the basis of:

- The goals for mitigation;
- The life cycle of the target species, especially if predictable periods of presence/absence or inactivity can be identified; and
- The time when an effect is expected.

6.4.7 Allocate Sufficient Time for Performance Evaluations

Data collection should preferably take place for the full period in which the performance indicator is relevant. An alternative approach may be to sample only for a part of that period, e.g. if resources are limited. However, most wildlife species show different activity and movement patterns throughout the year. Hence, a shorter sampling period may result in over- or underestimating mitigation effects, or the target species may be missed altogether. The duration of data collection should allow for a sufficient statistical basis to determine whether the mitigation results in a significant change in the performance indicator of concern.

Consequently, the required study duration should be assessed on the basis of the:

- Characteristics of the studied species;
- Chosen performance indicator and aimed for effect size;
- Chosen study design and number of study sites; and
- Number of data points that are expected to be collected in each year or sample.

It is recommended to conduct power analyses to determine appropriate study duration for each of the performance indicators of interest, based on the aimed for effect size and desired power.

To allow for inclusion in quantitative reviews (meta-analyses), a minimum study duration of four years for BA studies, and a minimum of either four years or four sites for BACI studies are recommended.

6.4.8 Use a Sampling Frequency that Provides Sufficient Data

- The frequency of sampling should allow for rigorous estimates of the performance indicator, i.e. make sure the sampling scheme will result in sufficient data for statistical analyses; and
- Pilot studies may be needed to assess the optimal sampling frequency in which sampling effort is minimized without jeopardizing accuracy.

6.4.9 Measure Explanatory Variables

Variables that may affect mitigation performance, other than the performance indicators of interest, should also be measured to:

- Improve interpretation of the results; and
- Allow for stronger inferences concerning the causes of observed differences.

It is recommended to document spatial and/or temporal variability in:

- Features of the road and traffic, including:
  - road width;
  - whether the road is in a cut or elevated on fill;
  - presence and type of pavement;
  - presence and type of street lights;
  - presence and type of fences;
  - presence and type of noise screens;
  - presence and type of median strip;
  - presence and type of road verges;
  - type and frequency of road management;
  - traffic volume;
  - traffic speed.
- Features of the road mitigation works, including:
  - the design and size of the mitigation structure(s);
  - the type and quality of habitats;
  - the type and frequency of management;
  - the type and frequency of defects;
  - the presence and frequency of use by non-target species;
  - the presence and frequency of use by humans;
  - the presence and frequency of use by domestic animals and livestock.
- Features of the surrounding landscape, including:
  - altitude;
  - topography;
  - land use;
  - type and amount of vegetation;
  - the occurrence of important landscape elements, such as hedgerows or ponds.
- Weather conditions during data collection, including, where relevant:
  - temperature;
  - cloud cover;
  - precipitation;
  - snow cover depth;
  - wind speed.

6.5 Implementing the Guidelines

This section presents two examples based on two hypothetical road mitigation projects to illustrate how the guidelines provided can be applied.

6.5.1 Example 1: Toad on the Road

A local road crosses toad habitat and separates their land habitat from their breeding ponds. Hence, the toads have to cross the road twice per year, during spring migration and when they return to their land habitat after breeding. Each year, especially in spring, many toads are killed on a 1km road stretch due to traffic. The population size is still considerable but shows a negative trend. To prevent the deaths of toads on the road and a further decrease of population numbers, the road agency initiated a road mitigation project. The ambition is to install a number of crossing structures (Figure 6-3) that should bring the toads safely across the road and keep the population healthy.

Figure 6-3 Amphibian tunnels (left) are frequently installed to help toads safely across roads during spring migration (right). Photographs: E.A. van der Grift (left) and F. Ottburg (right).

The following goals for mitigation were selected by the road agency:

1. The mitigation measures shall allow at least 90% of the migrating toads to get across the road safely.
2. The mitigation measures shall ensure that no more than 5% of the migrating toads will be killed in traffic.
3. The mitigation measures shall ensure that the survival probability of the toad population is >99%, calculated over a 100 year period.

Based on these goals, the contractor installs amphibian fences over the full road length (1km) where migrating toads – dead or alive – have been detected and constructs five amphibian tunnels, evenly distributed within this road stretch that should allow the toads to cross safely. To evaluate the performance of these mitigation measures, the following approach could be proposed:

Performance indicators: Selection of four performance indicators that reflect the goals of mitigation:

- *Percentage successful crossings*; calculated on the basis of a comparison between the number of toads that try to cross the road and the number of toads that actually cross through tunnels.

- *Percentage unsuccessful crossings* (road kill); calculated on the basis of a comparison between the number of toads that try to cross the road and the number of toads that, despite the mitigation, still end up as road kill on the pavement.
- *Percentage road kill reduction*; calculated on the basis of a comparison of road kill numbers before and after the mitigation works were installed.
- *Change in trend in population size*; derived from a comparison of pre- and post-mitigation population counts.

Reference values: The first two performance indicators use the number of toads that try to cross the road as a reference value. The third and fourth performance indicators make use of reference values derived from measurements of baseline conditions, i.e. the number of road kill and trend in population size before the mitigation works were installed.

Controls: Control sites cannot be identified as the road mitigation covers the full road length over which migrating toads, and road kill, have been observed.

Survey methods:

- To assess the percentage successful crossings, a capture-mark-recapture survey method is selected; toads that approach the road are captured and provided with a unique marking, e.g. through fitting coloured rubber bands around their legs, attaching numbered stickers on their back or injecting PITs. Toads that pass through the tunnels are recaptured with the help of a pitfall trap at the end of each tunnel. The unique marking allows the calculation of the percentage of approaching toads that make it across;
- To assess the percentage of unsuccessful crossings and percentage road kill reduction, road kill surveys are conducted;
- To assess changes in population size trends, two survey methods are selected: counts of females that approach the road during spring migration and counts of egg-strings in the breeding ponds during the reproduction period; and
- To assess whether the desired survival probability of the population will be achieved, long-term survival probability will be estimated on the basis of successful and unsuccessful crossing numbers, with the help of a population model (refer also to Box 6-2). The empirical population counts will serve as input to validate the model.

Spatial scale: The study site includes the mitigated road stretch, two 100m unmitigated road stretches beyond the fence-ends, the land habitat zone adjacent to the road where the toads approach, and the breeding habitat (ponds) on the opposite side of the road where the toads reproduce.

Timing: Post-mitigation data collection will start in the first year after installation of the mitigation works. The timing of data collection in each study year is linked to the start and end of the spring migration as well as the start and end of the post-breeding migrations in the opposite direction.

Study duration: Data collection before the mitigation works are installed is at least two years to estimate the percentage road kill reduction, and at least three years to estimate the change in population size trend. The duration of data collection after the mitigation works are installed is five years. Through power analysis, it was assessed that this will be sufficient for adequate statistical power.

Sampling frequency: The necessary surveys to assess successful and unsuccessful crossings and road kill reduction are conducted on a daily basis over the period that the migrations occur. The necessary surveys to assess changes in population size trends are carried out respectively on a daily basis (counts of females) and a weekly basis (counts of egg-strings) over the spring migration and reproduction period.

Explanatory variables: All spatial and/or temporal variability in (i) features of the road and traffic; (ii) features of the road mitigation works, including possible defects; (iii) features of the surrounding landscape; and (iv) weather conditions are documented.

6.5.2 Example 2: Moose on the Loose

A highway crosses moose habitat. Suitable feeding areas occur on both sides of the highway and hence moose are crossing the road frequently. Over the past five years, ten moose-vehicle collisions occurred on average each year on a 4km stretch of the highway; hereafter referred to as the 'hotspot'. All collisions resulted in the death of the animal, but only a few caused human injuries and one collision resulted in a human fatality. The populations on both sides of the road are sufficiently large and not seriously affected by the number of traffic-related animal deaths. Moose movements across the highway also occur elsewhere, however, and rarely result in accidents outside the collision hotspot due to differences in road design and the presence of bridges and tunnels that moose use for safe passage. To increase road safety, the road administration initiates a mitigation project. The ambition is to implement measures that will keep the moose off the road and reduce the number of collisions (Figure 6-4).

Figure 6-4 To keep moose off the road (left), wildlife fences are installed (right). Photographs: N. Luks (left) and A. Seiler (right).

The following goals of mitigation were selected by the road agency:

1. The mitigation measures shall reduce the number of moose-vehicle collisions at the collision hotspot by at least 80%, compared to the mean number of collisions at that spot over the previous five years.
2. The mitigation measures at the hotspot shall not cause an increase in the number of moose-vehicle collisions on adjacent highway stretches without mitigation, compared to the mean number of collisions on these stretches over the previous five years.

Based on these specifications, the contractor installs wildlife fences that keep moose off the road over the full road length of the collision hotspot. To evaluate the performance of these mitigation measures, the following approach could be proposed:

Performance indicators: The percentage moose-vehicle collision reduction is selected as the performance indicator, calculated on the basis of a comparison of collision numbers before and after the mitigation works were installed.

Reference values: The performance indicator makes use of reference values derived from measurements of baseline conditions, i.e. the number of road kill before the mitigation works were installed.

Controls: As controls, two known hotspots – 3km in length – at other roads in the same region but not in the immediate vicinity to the targeted hotspot are selected. These are monitored with respect to traffic volume, moose-vehicle collisions and hunting statistics as indicators of moose population densities. Relative changes in mean collision frequencies are used as an index that compares with the observed relative change on the target road.

Survey methods: The percentage collision reduction is found from police reported incidents and from reports made by hunters who have visited the accident sites.

Spatial scale: The study site includes the mitigated road stretch (4km) and 1km un-mitigated road stretches beyond the fence-ends, 1km road stretches along connecting or intersecting private roads and the two 3km control sites.

Timing: Post-mitigation data collection will start in the first year after installation of the mitigation works. Data will be collected year-round.

Study duration: The duration of data collection is five years before and five years after the mitigation works are installed. Through power analysis, it was assessed that this will be sufficient for adequate statistical power.

Sampling frequency: The necessary data collection to assess collision reductions is performed on an annual basis for the duration of the study.

Explanatory variables: On both the target road and the control roads, all spatial and/or temporal variability is documented in: (i) features of the road and traffic; (ii) features of the road mitigation works, including possible defects; (iii) features of the surrounding landscape; (iv) hunting statistics, and (v) snow cover.

6.6 Recommendations

The following recommendations may assist road authorities in implementing the presented guidelines for evaluating road mitigation performance:

Before the start of the project:

- Make the preparation of an evaluation plan for planned road mitigation measures an inseparable part of the legal processes that must be followed during the road planning and procurement stages.
- Form an independent advisory board, consisting of experienced road ecologists, to assist the road agency in:
    - preparing goals of mitigation;
    - planning and conducting evaluations that meet current best practice standards

    - ensuring that acquired knowledge and best-practices will be available to all stakeholders.
- Develop a strategy for systematic assessments of baseline conditions and reference standards.

During the planning phase of the project:

- Arrange close collaboration between ecologists and those who plan, design, construct and manage the road.
- Facilitate ecologists within road agencies becoming more involved in the procurement process of road mitigation works, including:
    - writing clear goals of mitigation;
    - organising the collection of baseline information;
    - judging evaluation plans proposed by contractors.
- Involve all stakeholders in the preparation of the performance evaluation, such as NGOs, nature managers and private land owners.
- Secure all necessary resources for the evaluation of road mitigation performance in advance.

During the implementation phase of the project:

- Appoint an independent contractor to evaluate road mitigation performance; do not put both the design/construction and evaluation of the mitigation measures (whether the objectives are being met) into one contract.
- Document research methods, results and conclusions systematically, thus allowing for:
    - quick reference;
    - correct comparisons between projects;
    - use in meta-analysis (refer to Box 6-4).
- Analyse and report all data in a timely manner to ensure that existing structures can be modified within an adaptive framework and the design of future mitigation measures can be improved.
- Arrange peer review of reports and aim for publication in scientific journals to improve the quality and rigour of the scientific methods as well as improve access to the findings.

After the project has been finished:

- Make the outcome of all evaluations, including research reports and raw data, widely available through an open access database.

Box 6-4: Meta-analysis

To facilitate inclusion in meta-analyses, the following recommendations apply for the reporting of future studies:

- Provide raw data in an appendix or data archiving site;
- Report data for each year before, during and after implementation/modification of the mitigation measure, and for each control and impact site separately;
- Record data separately for each species or species group, wherever possible;
- Include detailed information on sample sizes and sampling scheme, e.g. timing, frequency and duration of monitoring;
- Include detailed information on the survey methods used;
- Report the spatial accuracy of data, and whether and how far data were collected beyond fence-ends;
- Include summary statistics (e.g. means and associated variances) from which an effect size can be calculated;
- Include test statistic(s) (e.g. *t*-values and *df* from a *t*-test comparing impact and control sites) and the exact *p*-values;
- Include information on the study sites, i.e. features of the landscape, features of the road, features of traffic, features of the mitigation measures; and
- Include information on the overall project such as the level of mitigation maintenance, project costs, etc.

Source: Rytwinski et al. (2016). How Effective is Road Mitigation at Reducing Road kill? A Meta-Analysis. PLoS ONE 11(11): e0166941.

CEDR Call 2013: Roads and Wildlife Documents

Further information on the topics discussed in this chapter can be found in SAFEROAD Technical Report 6 and SafeBatPath Report 7 as well as SafeRoad Scientific Paper 6 and the SAFEROAD Final Report. Details on these reports and a few other key references can be found at the back of the Manual.

CEDR Call 2013: Roads and Wildlife Documents

Harmony

Deliverable Report B: Corrigan, B., Mac Gearailt S., Leahy, C., Carey C., 2016, Final Report, Harmony project Deliverable B.

Deliverable Report C: Ni Choine, M., Gavin S., Wansink, D., 2014, Environmental Legislation and Guidelines, Harmony project Deliverable C.

Deliverable Report D: Gavin S., Corrigan, B., Carey C., Ni Choine, M., Wansink, D., 2015, Recommendations on Appraisal Process & Report on Consultations, Harmony project Deliverable D.

Deliverable Reports E: Tschan, G., Ó Catháin, E., Corrigan, B., Carey C., Mac Gearailt S., 2016, Report on Procurement, Follow-up and Performance Indicators, Harmony project Deliverable E part A.

Tschan, G., Ó Catháin, E., Corrigan, B., Carey C., 2016, Handbook on procurement and follow-up (incl. performance indicators), Harmony project Deliverable E part B.

Deliverable Report F: 2016, Preliminary Maintenance Report Part A: Ecological functions of roads, Harmony project Deliverable F.

Deliverable Reports G: Wansink, D., Tukker, A., Weiperth, A. Puky, M., Gal, B., 2016, Cost-effective maintenance to support the ecological functions of roads, Harmony project Deliverable G part A.

Carey C., OBrien, E., Wansink, D., Corrigan, B, 2016, Maintenance Handbook, Harmony project Deliverable G part B.

SafeBatPaths

SafeBatPaths Technical Report 1: Christensen, M., Fjederholt, E.T., Baagøe, H.J. & Elmeros, M. 2016. Hop-overs and their effects on flight heights and patterns of commuting bats – a field experiment - SafeBatPaths Technical Report.

SafeBatPaths Technical Report 2: Dekker, J., Berthinussen, A., Ransmayr, E., Bontadina, F., Marnell, F., Apoznański, G., Matthews, J., Altringham, J.D., Ujvári, M.L., Phelan, S.-J., Roué, S., Kokurewicz, T., Hüttmeir, U., Loehr, V., Reiss-Enz, F., Fjederholt, E.T., Baagøe, H.J., Garin, I., Møller, J.D., Dalby. L,, Christensen, M. & Elmeros, M. 2016. Future research needs for the mitigation of the effects of roads on bats - SafeBatPaths Technical Report.

SafeBatPaths Technical Report 3: Dekker, J., Garin, I., Møller, J.D., Baagøe, H.J., Christensen, M. & Elmeros, M. 2016. Richtlijnen voor het mitigeren van effecten van wegen op vleermuizen - SafeBatPaths Technical Report.

SafeBatPaths Technical Report 4: Elmeros, M., Dekker, J., Baagøe, H.J., Garin, I. & Christensen, M. 2016. Bat mitigation on roads in Europe - an overview - SafeBatPaths Technical Report.

SafeBatPaths Technical Report 5: Elmeros, M., Baagøe, H.J., Dekker, J., Garin, I., Christensen, M. & Møller, J.D. 2016. Bat mitigation measures on roads - a guideline - SafeBatPaths Technical Report.

SafeBatPaths Technical Report 6: Garin, I., Dekker, J., Møller, J.D., Baagøe, H.J., Christensen, M. & Elmeros, M. 2016. Guía para mitigar los atropellos de murciélagos - SafeBatPaths Technical Report.

SafeBatPaths Technical Report 7: Møller, J.D., Dekker, J., Baagøe, H.J., Garin, I., Alberdi, A., Christensen, M. & Elmeros, M. 2016. Effectiveness of mitigating measures for bats - a review - SafeBatPaths Technical Report.

SAFEROAD

Technical report 1: Helldin, J.O., Broekmeyer, M., Campeny R., Kistenkas, F., 2016, Roads and wildlife: Legal requirements and policy targets, SAFEROAD Technical report 1.

Technical report 2: Van der Grift, E.A., Seiler, A., 2016, Guidelines for outcome-based specifications in road mitigation, SAFEROAD Technical report 2.

Technical report 3: Seiler, A., Klein, J., Chapron, G., Van der Grift, E.A., Schippers, P., 2016, Modelling the performance of road mitigation strategies: Population effects of permeability for wildlife, SAFEROAD Technical report 3.

Technical report 4: Seiler, A., Olsson, M., Rosell, C., Van der Grift, E.A., 2016, Cost-efficacy analysis: wildlife and traffic safety, SAFEROAD Technical report 4.

Technical report 5: Rosell, C., Helldin, J.O., Reck, H., Navàs, F., Cama, A., OBrien, E., 2016, Road maintenance guidelines to improve wildlife conservation and traffic safety, SAFEROAD Technical report 5.

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Glossary

Amphibian fencing	A continuous structure, erected alongside infrastructure, designed to prevent amphibians from crossing or directing them to a specific crossing point.
Amphibian tunnel	An enclosed passage or channel, constructed for the purpose of conveying amphibians from one side of an infrastructure to the other.
Animal-Vehicle Collision	Accidents between wildlife and cars, trucks, etc.
Anthropogenic	Generated and maintained, or at least strongly influenced by human activities.
BA study design	Before-After; A study design that is based on measuring Before and After mitigation.
BACI study design	Before-After-Control-Impact; A study design that is based on measuring Before and After mitigation, at Impact (or treatment) sites and Control sites.
Barrier effect	The combined effect of traffic mortality, physical barriers and avoidance, which together reduce the likelihood and success of species crossing infrastructure.
Baseline conditions	The conditions that would pertain in the absence of the proposed project at the time that the project would be constructed/operated/decommissioned. The definition of these baseline conditions should be informed by changes arising from other causes (e.g. other consented developments).
Biodiversity	Refer to "Biological diversity".
Biological diversity	The richness among living organisms including terrestrial, marine and freshwater ecosystems and the ecological complexes of which they are a part. It includes diversity within and between species and within and between ecosystems as well the processes linking ecosystems and species.
Central reservation	The strip running down the centre of a dual carriageway or motorway (sometimes vegetated), which separates traffic flowing in opposite directions.
Clutter-adapted	Adaptation of echolocation calls and flight behaviour, enabling bats to fly and forage in cluttered environments.
Community (biotic)	Assemblage of interacting species, living in a given location at a given time.
Compensatory measure	Measure or action taken to compensate for a residual adverse ecological effect which cannot be satisfactorily mitigated. Refer also to "Mitigation".

Connectivity — The state of structural landscape features being connected, enabling access between places via a continuous route of passage. The physical connections between landscape elements.

Consequence — Refer to "Impact".

Conservation objective — Objective for the conservation of biodiversity (e.g. specific objective within a management plan or broad objectives of policy).

Conservation status — The state of a species or habitat including, for example, extent, abundance, distribution and their trends.

Corridor — Tract of land or water, connecting two or more areas of habitats that aid animal movement across the landscape. Refer also to "Wildlife corridor".

Crossing — Designated or recognised place for people or fauna to cross from one side of an infrastructure to the other.

Culvert — Buried pipe or channel structure that allows a watercourse and/or road drainage to pass under infrastructure.

Cumulative impact/ effect — Additional changes caused by a proposed development in conjunction with other developments or the combined effect of a set of developments taken together.

Dispersal — The process or result of the spreading of organisms from one place to another.

Distribution — The geographical presence of a feature. This can depend on factors such as climate and altitude.

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

Echolocation — Emission of calls to locate and identify objects by listing to the echoes. Used by bats for short-distance navigation and hunting.

Ecological coherence — Ecological coherence is a legally-defined term that lacks any clear conceptual or empirical basis in ecological science. Its definition, assessment and implementation are directly linked to the statutory duties associated with the designation and management of Natura 2000 sites.

Ecological corridor — Landscape structures of various size, shape and vegetative cover that maintain, establish or enhance landscape connectivity. Hedgerows or verges are examples of ecological corridors (natural and artificial) that can act as interconnecting routes, permitting the movement of species across a landscape and increasing the overall extent of habitat available to individuals.

Ecological network — System of ecological corridors (refer to "Ecological corridor"), habitat core areas and their buffer zones which provide the network of habitats needed for the successful protection of biological diversity at the landscape level.

Ecosystem	Dynamic complex of plant, animal and micro-organism communities and their non-living environment, interacting as a functional unit.
Edge (effect)	The portion of an ecosystem near its perimeter, where influences of the surroundings prevent the development of interior environmental conditions.
Effect	Refer to "Impact".
Embankment	Artificial bank (made of packed earth or gravel) such as a mound or dike, constructed above the natural ground surface in a linear form and designed to carry a roadway or railway across a lower lying area.
Enhancement	Improved management of ecological features or provision of new ecological features, resulting in a net benefit to biodiversity, which is unrelated to a negative impact or is "over and above" that required to mitigate/compensate for an impact.
Environmental Impact Assessment	A method and a process by which information about potential environmental effects is collected, assessed and used to inform decision-making. Refer also to "Strategic Environmental Assessment"; also referred to as Environmental Assessment.
Environmental Impact Statement	A document describing the effects of a project on the environment prepared during Environmental Impact Assessment.
Fauna	Animal species.
Fauna passage	Measure installed to enable animals to cross over or under a road, railway or canal without coming into contact with the traffic.
Fence-end	Ending of a wildlife fence.
Flora	Plant or bacterial life.
Follow-up	All activities, such as monitoring or evaluation, used to decide if Environmental Impact Assessment/contract directions have been delivered.
Fragmentation	The breaking up of a habitat, ecosystem or landuse unit into smaller parcels.
Gene flow	The transfer of alleles or genes from one population to another.
Genetic differentiation	The accumulation of differences in allelic frequencies between completely or partially isolated populations due to evolutionary forces such as selection or genetic drift.
Genetic variability	A measure of the tendency of individual genotypes in a population to vary from one another.

Green Infrastructure — A strategically planned network of natural and semi-natural areas with other environmental features designed and managed to deliver a wide range of ecosystem services such as water purification, air quality, space for recreation and climate mitigation and adaptation.

Green Public Procurement — A process whereby public authorities seek to procure goods, services and works with a reduced environmental impact throughout their life-cycle when compared to goods, services and works with the same primary function that would otherwise be procured.

Guide fencing — Fencing built to lead wild animals to a dedicated crossing point.

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

Habitat banking — Habitat banking is a means of ensuring that development offsets its impacts on ecosystem services, where the true costs of development includes the historically zero-costed resources which are lost as a result of development.

Habitat fragmentation — Dissection and reduction of the habitat area available to a given species caused directly by habitat loss (e.g. land-take) or indirectly by habitat isolation (e.g. by barriers preventing movement between neighbouring habitat patches).

Hard shoulder — Refer to "Shoulder".

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

Hibernaculum — Roost site when bats are hibernating during winter.

Highway — Refer to "Road".

Impact — The immediate response of an organism, species or community to an external factor. This response may have an effect on the species that may result in wider consequences at the population, species or community level.

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

Infrastructure — The system of communications and transport services within an area.

Intermediate roost — Temporary sites where bats roost for shorter periods.

Invertebrate — Animals lacking a vertebral column or backbone.

Kerb — Edging (usually concrete) built along highways infrastructure to form part of the gutter.

Landscape The total spatial and visual entity of human living space, integrating the geological, biological and human-made environment. A heterogeneous land area composed of a cluster of interacting ecosystems that create a specific, recognisable pattern.

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

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

Landuse planning Activity aimed at predetermining the future spatial usage of land and water by society.

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

Maternity roost Roost site for females and cubs.

Migration The regular, usually seasonal, movement of all or part of an animal population to and from a given area.

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

Monitoring Regular measurements of a variable of interest over a period of time, usually to assess whether certain thresholds are met or to assess trends in the variable over time.

If crossings of wildlife are measured at a crossing structure, but no clear goals have been set beforehand, e.g. a minimum number of crossings per year, we speak of monitoring because the conclusion cannot be formulated in terms of success but simply provides a description of what has been measured, e.g.: "species X crossed Y times per year".

Motorway Major arterial highway that features: two or more lanes of traffic, moving in each direction, separated by a central reservation; controlled entries and exits; and alignment eliminating steep grades, sharp curves, and other hazards (e.g. grade crossings) and inconveniences to driving.

Natura 2000 Natura 2000 sites are those identified as sites of Community importance under the Habitats Directive 92/43/EEC or classified as Special Protection Areas under the Birds Directive 79/409/EEC. Together, the Special Protection Areas designated by the Member States make up the European network of protected sites.

No net loss To avoid a net loss of biodiversity and ecosystem services, damages resulting from human activities must be balanced by at least equivalent gains.

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

Glossary

Outcome-based Outcome-based specifications define the client's functional requirements for the proposed development.

Overpass Structure (including its approaches) which allows one infrastructure element to pass above another (or other type of obstacle).

Performance evaluation Assessment of the performance of a specific measure or approach, with a clear definition of success.

If crossings of wildlife are measured at a crossing structure, and the measured numbers are compared to a pre-set goal, e.g. a minimum number of crossings per year, we speak of a performance evaluation because the conclusion can be formulated in terms of success, e.g.: "yes, the minimum number of crossings have been reached", or "no, the minimum number of crossings have not been reached".

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

Population viability Ability of a wildlife population to survive.

Power analysis A statistical technique used in the process of designing an experiment or filed survey that provides insight in (1) sample size needed to allow statistical judgments that are accurate and reliable and (2) how likely a statistical test will be to detect effects of a given size in a particular situation.

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

Restoration The process of returning something to an earlier condition or state. Ecological restoration involves a series of measures and activities undertaken to return a degraded ecosystem to its former state.

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

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

Road impact Negative effect of a road.

Road kill The event that an animal is killed on the road.

Road Maintenance Guidelines Documents that provide direction on how roadways should be maintained.

Road network The interconnected system of roads serving an area.

Road Wildlife Guidelines Documents that provide direction on how to consider wildlife elements near to a roadway.

Road-crossing	The event that an animal crosses a road.
Roost site	Breeding and resting sites for bats.
Scoping	The determination of the extent of an assessment for a full Environmental Impact Assessment.
Screening	Determination of whether or not an Environmental Impact Assessment is necessary.
Screening Report	Report containing information to inform Stage 1 of the Appropriate Assessment process.
Shoulder	The linear paved strip at the side of a "motorway" which vehicles are allowed to use during emergencies, and which is used by maintenance vehicles to access works.
Site	A defined place, point or locality in the landscape.
SMART	Specific, Measurable, Achievable, Realistic and Time-framed.
Spatial planning	Refer to "landuse planning".
Strategic Environmental Assessment	The application of the principles of Environmental Impact Assessment (refer to above) to policies, plans and programmes at a regional, national and international level.
Target species	A species that is the subject of a conservation action or the focus of a study.
Taxon (pl. taxa)	Category in the Linnean classification of living organisms, e.g. species.
Terrestrial	Pertaining to land or earth.
Transition Zone	Area of shorter vegetation between road hard shoulder and longer vegetation.
Ultrasound	Sound with a higher frequency than audible for humans.
Underpass	Structure, including its approaches, which allows one route to pass under another route or obstacle.
Verge	The strip of land (often vegetated) beyond the infrastructure surface itself, but within the infrastructure corridor.
Vertebrate	Any animal characterised by a vertebral column, or backbone.
Viaduct	Long elevated bridge, supported on pillars, which carries infrastructure over a valley or other similar low-level landscape area.
Waterway	A navigable body of water.
Weir	Construction in a river or canal designed to hold the water upstream at a certain level.

Wetland	Land or area containing high levels of soil moisture or completely submerged in water for either part or the whole of the year.
Wildlife	All wild animals, plants, fungi and bacteria collectively.
Wildlife corridor	Linear-shaped area or feature of value to wildlife, particularly for facilitating movement across a landscape.
Wildlife crossing point	Designated place for wildlife to cross infrastructure safely, e.g. using a specially-designed overpass, underpass, etc.
Wildlife crossing structure	Refer to "Fauna passage".
Wildlife crosswalk	Location where animals can cross the road safely at grade.
Wildlife fence	Fence designed and erected specifically to prevent animals from gaining access onto infrastructure, or to lead animals to safe crossing points.
Wildlife overpass	Construction built over infrastructure in order to connect the habitats on either side. The surface is, at least partly, covered with soil or other natural material that allows the establishment of vegetation.
Wildlife underpass	Construction built under infrastructure in order to connect the habitats on either side. The surface is, at least partly, covered with soil or other natural material that allows the establishment of vegetation.
Woodland species	Species primarily living in woods.
Zone(s) of Influence	The area(s) over which ecological features may be affected by the biophysical changes caused by the proposed project and associated activities.

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