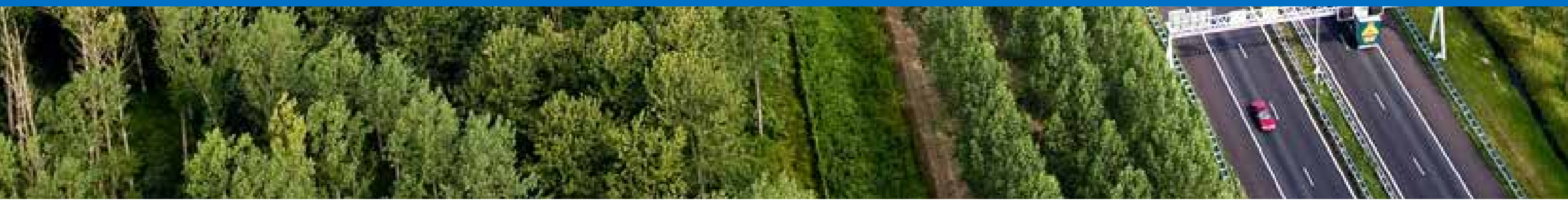
Safe roads for wildlife and people

Final report of the SAFEROAD project



CEDR

Conférence Européenne des Directeurs des Routes

Conference of European Directors of Roads

Saferoad

Contents

Chapter 1

Safe roads for wildlife and people

Roads and traffic exert a variety of direct, indirect and mostly detrimental effects on wildlife. Roads may cause wildlife mortality, inhibit wildlife movements and result in loss of habitat or habitat quality. In most countries across Europe road agencies have acknowledged their responsibility to control these impacts and develop effective road mitigation. However, what is the best strategy to mitigate road impacts on wildlife? What mitigation measures can be seen as most effective? And how should maintenance practices be adapted to prevent impacts? Practitioners involved in road construction and maintenance need clear and practical guidelines to implement cost-efficient mitigation strategies and maintenance practices that aim to reduce road-wildlife conflicts. The SAFEROAD project was started to answer to that need.

The SAFEROAD project was carried out in 2014-2016 as part of the CEDR Transnational Road Research Programme Call 2013: Roads and Wildlife. The funding for the research was provided by the national road administrations of Austria, Denmark, Germany, Ireland, Norway, Sweden, Netherlands and UK.

The aim of the SAFEROAD project was to improve our understanding of how and how effectively different road mitigation strategies work in order to find the best way to reduce the impacts of roads on wildlife and simultaneously enhance traffic safety. The project aimed to generate new scientific knowledge on and insights into methods to help prevent wildlife mortality due to animal-vehicle collisions and assure that the barrier effect of roads is reduced sufficiently to maintain viable wildlife populations. The aim was also to transfer this knowledge into practical guidelines and tools so it can be easily accessed and used by road agencies and other stakeholders.

The research encompassed reviews of scientific and non-scientific publications, explorations of best-practices from across Europe and beyond, re-analyses of existing data through meta-analysis in order to identify road mitigation effects that do not become obvious in the data analysis of a single project, collection and analyses of new empirical data in a variety of case studies and analyses of mitigation effectiveness through population modelling.

The SAFEROAD project team included both scientists and practitioners. Hence, we were able to address the questions of the CEDR research programme scientifically, while never losing sight of the practicality and feasibility of our recommendations. We collaborated with experts outside of our project team, and even outside of Europe to make sure that we collected and used all of the state-of-the-art knowledge and experiences available around the globe. We included stakeholders as well, such as professionals from road agencies and others that deal with the challenges of road-wildlife conflicts, e.g. through workshops and meetings where feedback was provided on research approaches or draft versions of our deliverables.

In this report we summarise all of the findings of the SAFEROAD project. We highlight key messages and develop guidelines and illustrate these with examples or case studies. In addition, we offer recommendations on how to implement the findings in road mitigation practice. Each chapter in this report is based on one or more of the project deliverables. These sources are specified at the end of each chapter. A full list of the SAFEROAD deliverables can be found on page 53.

The SAFEROAD project achieved its objectives and identified mitigation strategies and maintenance practices that are most effective in reducing road-wildlife conflicts. It provides direction for future mitigation works to ensure best-practice mitigation that is both effective and cost-efficient. Hence, we hope the project will help to establish a sustainable green infrastructure across Europe as well as safe roads for both wildlife and people.

Animals that cross the road may result in an unforgettable experience but more often result in hazards for both people and wildlife due to wildlife-vehicle collisions.

Chapter 2

Legal requirements and policy targets for roads and wildlife

How can current environmental policy and legislation be translated into concrete and measurable tasks for road developers? What does regulation actually require? Using a review of legislation and international agreements, court cases and impact assessment cases, we have developed guidelines for the transport sector to better address wildlife barrier effects and mortality to the benefit of both wildlife conservation and road development.

What is the problem?

The European transport sector has an important role in controlling the negative impacts of roads and traffic on nature and wildlife. However, what this responsibility means in terms of requirements for mitigation and compensation is often not clear. EU environmental legislation and policy, transposed into national legislation for EU member states, has set overarching goals for the conservation of biodiversity. Compliance with these legal provisions is a major challenge when designing new roads or operating and upgrading the existing ones in EU member states. Yet these broadly defined regulations have to be translated into measurable tasks for road developers.

Cost-efficient road planning and management requires all relevant manifest political goals to be unambiguous, widely known and taken into consideration. Existing guidance from the EU builds on limited case law and dates back to 2006, hence not taking into account any recent cases. Due to this paucity of case law and limited guidance for consenting authorities on, for example, environmental impact assessment, the required type and level of mitigation cannot be anticipated before a road project is started. This complicates the environmental assessment and mitigation of effects, which may cause costly delays in the planning process.

Questions

- What do current European laws and international agreements state with respect to the barrier and mortality effects of roads on wildlife?
- What is the practical, international (EU) level of how the legal incentives for mitigating barrier and mortality effects are addressed in road development projects?
- Are there any recent developments regarding requirements for mitigation and compensation in road building and maintenance that may affect this practice?
- Are there any unifying and separating patterns between countries regarding the assessing and mitigating barrier and mortality effects?

- What are the main shortcomings of current practice? How can shortcomings in current practice be overcome?

Our approach

For the purpose of this study, we reviewed and analysed:

- EU Directives and other international agreements that we understood to be relevant to European species conservation and that refer to barrier and mortality effects of roads on wildlife. We reviewed the main texts of these documents for passages on fauna, roads, environmental liability and impact assessment. We included available guidelines and additional documents referred to in the main texts in the review;
- recent cases from the EU Court of Justice and from the national Supreme Courts of Spain, Sweden and the Netherlands addressing wildlife barrier effects or mortality, primarily from road projects, but relevant cases on developments other than roads were also included in the analysis;
- recent cases of large road Environmental Impact Statements (EISs) from Spain, Sweden and the Netherlands. We limited the review to cases addressing barrier effects for wildlife or wildlife road-kill.

The search for and selection of case law produced a total of 14 cases for analysis; EISs produced another 14 cases. All court and EIS cases identified were reviewed for legislation, species and effects addressed and the mitigating/ compensating measures prescribed, following a standardised protocol.

Findings

Some international regulations and agreements are of particular relevance in relation to barrier effects for wildlife and wildlife road-kill

The Habitats Directive, the Birds Directive, the Environmental Liability Directive, the EIA Directive, the Bonn Convention, the Bern Convention and the European Agreement on Main International Traffic Arteries all explicitly address the conservation of species and set out conservation objectives and responsibilities, levels of acceptable impact, priority species, principles for derogation and requirements for remedial action, research and monitoring.

Road-kill may be considered prohibited deliberate killing

The Habitats Directive, the Birds Directive and the Bern Convention prohibit the deliberate killing of species of common interest, which includes species listed in the directives, *inter alia* all wild birds. What is deliberate or not is a matter of current discussion, but it is clear from the available guidelines that road-kill does not automatically qualify as non-deliberate.

Road projects must ensure that impacts on species are kept within acceptable levels

The Habitats Directive, the Environmental Liability Directive and the Bonn Convention jointly set an acceptable level of impact on species of common interest; any impact not jeopardising a 'favourable conservation status' and within the natural amplitude of population fluctuations can be considered acceptable. A favourable conservation status requires that population dynamics data indicate that the species maintain itself on a long-term basis and that the range of the species is not reduced. On the other hand, the Birds Directive points at different, possibly more ambitious goals, i.e. maintaining all species at levels needed to provide ecosystem services, expressed as 'ecological, scientific and cultural requirements'. Also national objectives for traffic safety and wildlife management may be more ambitious about the acceptable level of impacts and species for which mitigation is needed.

Ambitious mitigation and impact assessment may be enough to fulfil the provisions regarding protection of species

With regard to the acceptable level of impact, however, recent case law points in a slightly different direction. One important EU case on road impacts on the Iberian lynx and a number of national Supreme Court cases show that it may suffice if an infrastructure developer adopts a high ambition level in mitigation and impact assessment to fulfil the provisions of the EU directives on the protection of species. This implies that, in a development project where the best available mitigation measures are applied and impact assessment is reasonably well conducted, the developer is relieved from the requirement to show that the impacts stay within acceptable levels; the burden of proof then lies with any party opposing the development. Available case law can thus be interpreted so that the requested conservation effort of a project can be described in terms of technical adaptations rather than population status.

Warning signs to alert drivers to the presence of Iberian lynx in southern Spain.

EU member states should conduct population-level monitoring and research on incidental killing of animals

According to the Habitats Directive, EU member states are obliged to establish a system to monitor the incidental killing of animals of community interest and conduct the research necessary to ensure that incidental killing does not significantly impact the species´ conservation status. While the obligation for monitoring is not mentioned in the BD, it apparently does not include birds. The EIA Directive states that a developer of a major road project is required to describe impacts on species, and the Environmental Liability Directive states that this should be done by means of measurable population data such as (i) number of individuals, density or area covered, or (ii) the species' capacity to emigrate or (iii) the species' capacity to naturally recover or immigrate. The impacts should be assessed with reference to baseline conditions and take into account a species´ natural population fluctuations.

Applying the "1% criterion" to the toll from traffic mortality could facilitate impact assessment, but such an application is questionable

Another potential implication for a road developer, although indicated by only one Dutch case, is the possibility to apply the '1% criterion' to traffic mortality. This criterion, developed by the EU ORNIS committee that assists the Commission in the implementation of the Birds Directive, states that any toll of ≤1% of the natural mortality of the population is negligible and therefore acceptable. Whereas applying this criterion to road projects may facilitate the impact assessment, it appears well out of the range of the application initially intended and corroborated by EU court decisions. Hence we question whether the Dutch case can be leading in that respect.

EISs address barrier effects and habitat fragmentation, but generally underemphasise wildlife road-kill

The major road EISs reviewed all explicitly address barrier effects or habitat fragmentation and most of them describe specific fauna passages or adaptations of existing bridges, culverts and tunnels as important mitigation measures. Wildlife road-kill, on the other hand, appears to be generally underemphasised as a conservation issue.

EISs generally fail to quantify the expected effects or differentiate between construction and operation phases

Only a few EISs describe the expected effects in quantified terms, which is necessary to be able to relate to acceptable levels of impact. Also, only a few of the analysed EISs differentiate between effects during the construction phase and the operation phase, which may trigger different requirements for prevention and remedy.

Some country characteristics in impact assessments were observed, but may depend on method bias

In contrast to Swedish EISs, Spanish and Dutch EISs put more emphasis on avoiding animal disturbance. Moreover, Dutch EISs strongly emphasise bat mitigation measures. Requirements for monitoring appear to be particularly meagre in Swedish EISs. We acknowledge, however, that the apparent differences between the countries may depend on method biases.

Guidelines

Guideline 1: Monitor wildlife impacts on population level and long-term, starting before construction

This is both an obligation and in the interest of the infrastructure developer. The requirements to assess impacts with reference to baseline conditions and to take into account a species´ natural population fluctuations imply that the population dynamics of the species in question need to be reasonably well known and that monitoring should start before, preferably well before, the onset of impact. Otherwise, the assessment could become more limiting than what is motivated by conservation goals. Well- conducted monitoring should give a developer adequate room for manoeuvre without jeopardising these goals.

Guideline 2: Improve the assessments of disturbance, mortality and movement corridors, the quantification of impacts and the differentiation of construction and operation phases

To guarantee that environmental legal obligations are achieved, EISs could be improved by better addressing such issues as:

- the effects of human disturbance on wildlife;
- the impact of road mortality on wildlife conservation;
- the continuity of wildlife movements in the landscape (functional movement corridors);
- the difference between impacts during construction and operation phases;
- the expected effect levels (quantified).

Guideline 3: Apply best available mitigation measures – that may facilitate the consenting process

Studying the ecological effects on the population level is both difficult and expensive, and if ambitious mitigation indeed relieves the developer of the responsibility of proving that a proposed development has no significant negative impacts on populations, applying best available mitigation measures may facilitate the impact assessment and the consenting process and therefore be cost-effective.

Source: This chapter is a summary of SAFEROAD deliverable 1.

Outcome-based specifications for road mitigation

New types of contracts in road building often result in constructors not only building but also designing the desired road, including mitigation measures for wildlife. This implies that procurement documents should no longer present detailed prescriptions on the technical design of mitigation measures, but should provide functional descriptions of what the measures should achieve. How to define outcome-based specifications that can guide civil engineers to produce functional road mitigation? How to make sure that these specifications comply with the current EU legal and policy frameworks? And how to implement the use of outcome-based specifications in the procurement process?

What is the problem?

As national road administrations increasingly make use of contract types in which the constructor not only builds but also designs the desired road or road modification, including mitigation measures for wildlife, a new set of procurement specifications is needed. Procurement documents should no longer present detailed technical specifications but provide outcome-based specifications. Outcome-based specifications can be best defined as specifications based on what providers will achieve rather than on what they will do. The reason that more and more governmental agencies are shifting to an outcome-based approach in procurement is the aim to deliver more value within constrained budgets. The approach also means - which is often seen as an advantage - that risk management becomes more a responsibility of the contractor, while simultaneously the contractor gets more control and freedom in carrying out the project.

Furthermore, it is assumed that an outcome-based approach provides a better breeding ground for innovations and increases cost-efficiency over the more traditional contracting models with prescribed products or services.

Outcome-based specifications for the design and construction of road mitigation measures should have a clear link to the predefined objectives of the road project. In their turn, the objectives of a road project will be derived from - national and international - obligations that result from environmental and transport legislation and regulations as well as ambitions elaborated in environmental and transport strategies and policies. Environmental objectives ultimately refer to improving or maintaining population persistence and consequently biodiversity conservation. In this respect, transport objectives refer to improving road safety and avoiding impacts on the natural environment, including wildlife. The challenge in an outcome-based procurement approach is to translate these objectives into clear and measurable functions that can be provided by road mitigation measures.

Questions

- What guidelines can be provided for defining outcome-based specifications that can guide civil engineers in producing functional road mitigation measures that comply with the current EU legal and policy frameworks?
- What are the benefits of using outcome-based specifications and what are the risks?
- How can outcome-based specifications be implemented in the procurement process?

Our approach

We reviewed all relevant EU environmental and transport legislation and policies and identified what they may imply for defining outcomes that road mitigation measures must provide. The focus was on road mitigation measures that aim to increase road safety and reduce road-related wildlife mortality and barrier effects that potentially reduce the survival probability of wildlife populations. Further, we analysed the outcome-based specifications currently used in road mitigation procurement in the Netherlands. We evaluated the extent to which these specifications reflect the requirements of the EU legal and policy frameworks and the potential to link clear and measurable performance indicators to the required outcomes. Using both these analyses and existing guidelines for the evaluation of road mitigation effectiveness, we developed a set of practical guidelines for defining outcome-based specifications for procuring road mitigation measures and recommendations for implementation. To illustrate the use of these guidelines, we elaborated two practical examples.

Findings

EU regulations and policies provide a variety of requirements and ambitions with regard to road projects that may help to define sound road mitigation outcomes

In our review we identified fourteen indicators (see table), all of which provide clues for defining outcome-based specifications for procuring road mitigation measures. Besides these indicators, the review pointed out the importance of the measurability of effects, both from activities that damage the environment and activities that aim to mitigate such damage, as well as the use of baseline conditions or reference standards that allow for quantitative evaluations. Using indicators that directly relate to regulations and policies, adopting a quantitative approach as well as incorporating clear baseline conditions or reference standards in defining outcome-based specifications will all inevitably improve the ability to judge whether or not performance requirements are being met.

The Dutch approach is feasible although there is room for improvement

The Dutch national road administration developed a generic set of functional requirements that can best be seen as a gross list from which particular requirements can be selected that apply to the project at hand. The specifications focus on maintaining or restoring linkages between wildlife ranges at both sides of the road, hence relating to wildlife overpasses, wildlife tunnels, wildlife crosswalks, bat hop-overs, but also to wildlife fences, habitat restoration and other landscaping measures that accompany the crossing structures. The specifications clearly reflect some key requirements and ambitions of the EU legal and policy frameworks; they strongly relate to restoring landscape connectivity, hence, they clearly reflect the indicators ‘habitat availability’, ‘habitat quality’ and ‘wildlife movements’. The emphasis is on restoring range and habitat connections that allow species to move through the landscape in their natural way. Thus, the indicators ‘species distribution’ and ‘migration routes’ are also implicitly addressed.
Improvements may be (i) to include indicators that relate to populations; (ii) to put more emphasis on the impacts that need to be mitigated; (iii) to quantify the requirements; (iv) to use baseline conditions or reference standards. Such improvements will inevitably lead to a higher potential to link the specifications to clear performance indicators. Currently, the

Indicator	Environmental regulations						Transport regulations		EU Policies		
	HD	**BD**	**ELD**	**EIA**	**BONN**	**BERN**	**MITA**	**RISM**	**BS**	**GI**	**SDS**
Related to populations											
Population viability	X	X	X	-	X	X	-	-	X	-	-
Population size	-	X	X	-	-	X	-	-	-	-	-
Population density	-	-	X	-	-	-	-	-	-	-	-
Propagation capacity	-	-	X	-	-	-	-	-	-	-	-
Related to species distribution											
Actual distribution	X	-	-	-	X	-	-	-	X	X	-
Historical distribution	-	-	-	-	X	-	-	-	-	-	-
Related to species abundance											
Actual abundance	-	-	-	-	X	-	-	-	-	-	-
Historical abundance	-	-	-	-	X	-	-	-	-	-	-
Related to habitat											
Habitat availability	X	X	-	-	X	-	-	-	X	X	-
Habitat quality	X	X	-	-	-	-	-	-	X	-	-
Related to road barriers											
Wildlife movements	X	-	-	-	-	-	X	-	X	X	-
Migration routes	-	-	-	-	X	-	-	-	-	-	-
Related to wildlife-vehicle collisions											
Wildlife mortality	X	-	-	-	-	-	X	-	X	-	-
Road safety	-	-	-	-	-	-	X	X	X	-	X

The table shows the indicators extracted from EU environmental and transport regulations and policies, which provide clues for defining outcome-based specifications in road mitigation projects. The table provides an overview of whether a document mentions an indicator (X) or not (-). Legend:

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
BS = EU Biodiversity Strategy
GI = EU Green Infrastructure Strategy
SDS = EU Sustainable Development Strategy

procurement process in which functional specifications are used can be best described as 'learning-by-doing'; projects and procurement procedures are continuously evaluated to assess whether the functional requirements were clear, complete and in line with the overall goal of the road mitigation. This implies that the generic set of functional requirements is permanently under development: as experiences and insights in what does and does not work increase, specifications are modified, added or deleted.

The use of outcome-based specifications may have certain benefits if compared with the more traditional procurement approaches

The use of outcome-based specifications, based on these guidelines, may have value for all stakeholders involved. First, they may better ensure that the overall objective - either related to wildlife conservation or road safety - is being met. Second, they may significantly increase our knowledge base as such specifications will force all involved to gain more knowledge on what does and does not work. Third, they may guarantee a strong link with national and international regulations and policies and better support political and/or societal discussions on the need for and usefulness of road mitigation. And fourth, an outcome-based approach provides room for adaptive management. If road mitigation works, designed and constructed on the basis of the best available knowledge, appear insufficient to reach the desired outcome, corrective measures can be taken.

The use of outcome-based specifications may have certain disadvantages and risks if compared with the more traditional procurement approaches

First, such specifications require better knowledge on mitigation measures and their effects than what we may have today. This implies that contractors may not yet be held fully responsible for a failure and the costs of mitigation works may increase. Second, costs may increase due to the need for studies in which baseline conditions or reference standards are assessed. Third, little is known about appropriate timespans for evaluation studies, which may result in wasting resources or wrong conclusions on whether or not the measures are successful. Fourth, if not well regulated and safeguarded, knowledge on road mitigation effectiveness becomes an asset of private contractors and consequently may not be freely available to all stakeholders. And fifth, an outcome-based approach in road mitigation procurement requires a new juridical framework in which the responsibilities of both the road agency and contractors are clearly delineated.

Guidelines

It is clearly impractical to develop a static set of technical rules for road mitigation works that must always be applied regardless of the actual conditions. Local and regional deviations from the rules may be necessary and render such a static system of design specifications ineffective. Instead, it may be more efficient to define general properties or qualities that should be achieved to produce an outcome that meets the overall goals of mitigation as well as the requirements from environmental legislation and policies. However, what should such outcome-based specifications look like? How can we ensure that such specifications result in the end goals being met? And how can we avoid the set of specifications becoming too extensive, which may reduce its practical application?

Guideline 1: Link the specifications directly to the mitigation goals

No procurement of road mitigation works should be started until the mitigation goals are clearly described. This goes beyond listing target species as it should include a clear description of what road impacts need to be addressed and to what extent these impacts should be mitigated.

Guideline 2: Specify whether or not no-net-loss is the aim

In goals for road mitigation two potential targets can be distinguished: (1) no-net-loss, and (2) limited-net-loss. No-net-loss implies that road impacts will be entirely mitigated, i.e., the post-mitigation situation for the targeted species is identical to the pre-road construction situation.

Limited-net-loss implies that a limited road impact will be accepted. If not already done during the assessment of mitigation goals, the target level should be specified in procurement. The decision on a target level will depend on the local situation, including the local conservation status of a species, but may also be suggested by legislation.

Guideline 3: Use the SMART-approach to develop clear and objective specifications
In outcome-based contracts it is fundamental that the required 'outcome' can be measured. This implies that, for successful outcome-based procurement arrangements, performance indicators need to be set out in the early stages. To do so, the specifications are preferably SMART, i.e. Specific, Measurable, Achievable, Realistic and Time-framed. Road mitigation goals, and consequently the specifications for mitigation works, should ideally: specify what road impact(s) is/are addressed; quantify the reduction in road impact(s) aimed for; be agreed upon by all stakeholders; match available resources; and specify the timespan over which the reductions in road impact(s) have to be achieved.

Guideline 4: Make use of baseline conditions or reference standards
Road mitigation measures can only be properly evaluated if a clear definition of success has been formulated in the design phase of the project. It will not be sufficient to only list the road impacts that should be reduced, but this reduction should also be quantified. For this purpose the specifications should preferably make use of either baseline conditions or reference standards.

Guideline 5: Link the specifications directly to the indicators used in regulations and policies
Unlike the more conventional contract types, outcome-based contracts articulate requirements in the form of end goals without specifying exactly how these are to be achieved. The overall end goal of road mitigation is in line with the end goals of EU regulations and policies i.e., preserving or restoring biodiversity, ecosystems and ecosystem services. In this respect it makes sense to link road mitigation specifications to the indicators derived from these regulations and policy plans. After all, this will ensure that road mitigation projects correspond to the overall environmental objectives and allow better evaluations of whether road mitigation enforces the implementation of such objectives.

Guideline 6: Link the specifications to multiple indicators whenever possible and relevant
Outcome-based specifications will gain in strength if multiple indicators are addressed. For example, if the road mitigation aims to reduce roadkill and increase the road permeability of a vulnerable wildlife population, the specifications should preferably include requirements that relate to wildlife-vehicle collisions, road barrier effect and population viability. If, in this case, the specifications focus only on roadkill and all requirements are being met, population survival may still be in jeopardy as a result of insufficient wildlife movements.

Guideline 7: Link the specifications to the road section to be mitigated and not to a single structure
The exact number and placement of crossing structures are preferably not decided upon in advance, but are part of the procurement arrangement. Both number and placement strongly affect the performance of mitigation works; hence, if these factors are determined in advance, potential contractors will have less room for innovations and designs may be less differential. In fact, linking specifications to indicators that relate to populations or species distribution may become impossible as the number and spatial distribution of structures are key factors for achieving the pre-set goals for such indicators.

Guideline 8: Keep the use of technical specifications to a minimum
Although technical - or design - specifications can be included, their use should be kept to a minimum as they inhibit the functioning of a risk and rewards payment model. For example, if a functional requirement (e.g. '90% reduction in road-kill') is combined with a technical

Box 3.1 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 a 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 1-km 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 that should bring the toads safely across the road and keep the population healthy. The following set of outcome-based specifications may be proposed:

1 The mitigation measures will allow at least 90% of the migrating toads to get across safely.
2 The mitigation measures will ensure that no more than 5% of the migrating toads will be killed in traffic.
3 The mitigation measures will ensure that the survival probability of the toad population is >99% calculated over a 100-year period.
4 The mitigation measures will be in effect year-round.
5 The mitigation measures will meet the requirements of specification 1 to 4 in the first year after installation.
6 The mitigation measures and population will be monitored for a period of 5 years to determine whether specifications 1 to 4 are being met.

Amphibian tunnels (top) are frequently installed to help toads safely across roads during spring migration (bottom).

specification (e.g. ‘construct fences 1.5 m high’), the contractor can no longer be held responsible when the functional requirement is not met in the end. Further, technical specifications do not stimulate innovations and evaluations in which mitigation performance is assessed. Technical specifications may be used for structures or structural features that are considered ‘non-negotiable’. For example, specific dimensions for a structure can be included if there is a comprehensive body of proof that a structure of such dimensions is functional. Nevertheless, a regular check is needed to determine whether the technical specifications used are still state-of-the-art.

Implementing the guidelines

The use of these guidelines is illustrated by two hypothetical examples of road mitigation projects. The first example addresses the mitigation of a road where large numbers of toads are being killed during spring migrations, and consequently the

Box 3.2 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 4-km 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; 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 but they 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. The following set of outcome-based specifications may be proposed:

1. The mitigation measures will reduce the number of moose-vehicle collisions at the collision hotspot by at least 80%, compared to the mean number of collisions at the hotspot over the past five years.
2. The mitigation measures at the hotspot will not cause an increase in the number of moose-vehicle collisions on adjacent highway stretches without mitigation, compared to the mean number of collisions at these stretches over the past five years.
3. The mitigation measures will be in effect year-round.
4. The mitigation measures will meet the requirements of specification 1 to 3 in the first year after installation.
5. The mitigation measures will be monitored for a period of 5 years to determine whether specifications 1 to 3 are being met.

Mitigating road stretches where moose cross frequently are vital to guarantee road safety.

survival of the local toad population is at stake (Box 3.1). The second example addresses the mitigation of a road on which moose is frequently killed, and consequently road safety is in jeopardy (Box 3.2).

To implement the use of outcome-based specifications in the procurement of mitigation works it is recommended to: (i) make sure that environmental authorities are closely involved in the procurement process in order to ensure that environmental objectives are adequately reflected in the contract; (ii) develop a generic set of functional specifications that can be easily adapted to the situation and ambitions of the project at hand; (iii) write outcome-based specification in a

language style similar to that of technical specifications; (iv) develop a clear set of performance indicators that accompany the outcome-based specifications; (v) contract an independent contractor to evaluate the road mitigation works on the basis of the performance indicators provided; (vi) develop a strategy to systematically assess baseline conditions and reference standards; (vii) develop an open access database on road mitigation evaluations so that future projects will be able to learn from previous ones; (viii) evaluate the use of outcome-based specifications in road mitigation procurement as compared to the use of design specifications and gather empirical evidence on the possible benefits and/or disadvantages of the approach.

Further, we recommend carefully testing the guidelines presented here in practice as well as a generic set of functional specifications that can be derived from them. If deemed appropriate after testing, the guidelines should be modified to optimise their application in road mitigation projects throughout the EU.

Source: This chapter is a summary of SAFEROAD deliverable 2.

Road mitigation effectiveness

There is growing evidence that roads and traffic reduce the populations of many wildlife species. Over the last few decades concern for the impacts of roads on wildlife has resulted in the installation of numerous mitigation measures. Do they work? Are they effectively preventing road-kill and enhancing movement of wildlife across roads? What lessons can be derived from existing works to optimise future mitigation?

What is the problem?

The detrimental effects of roads on wildlife have been extensively studied. Roads and traffic may cause mortality of wildlife due to wildlife-vehicle collisions, act as barriers to animal movement and migration and affect both the amount and quality of wildlife habitat. Consequently, roads potentially jeopardise the long-term persistence of wildlife populations or even the survival of a species.

Over forty types of road mitigation measures intended to reduce road effects on wildlife have been implemented or described. These include measures that:

- influence motorist behaviour, such as wildlife warning signs, animal detection systems, measures to reduce traffic volume and/or speed and temporary road closures;
- scare animals away from the road and/or alert them to approaching traffic, such as wildlife reflectors, mirrors and repellents;
- increase the attractiveness of areas away from the road, such as the restoration of salt licks or water holes;
- decrease the attractiveness of the road, such as cleaning up grain spills;
- introduce a physical barrier along the road, such as fencing;
- create safe road-crossing opportunities, such as crosswalks and wildlife crossing structures (under- or overpasses).

Road agencies face the challenge of making informed decisions on which method to use. Although practical issues have to be considered in such decisions - e.g., available budget, hinder to traffic during construction, necessary maintenance after installation, public support - knowledge of the effectiveness of each type of road mitigation should be the key criterion. After all, if all practical issues are accounted for but the mitigation goals are not reached, the mitigation may not only waste financial resources but may also create the unjust impression among stakeholders that the problem has been solved and further measures are not needed (Box 4.1). Consequently, we may endanger the viability of wildlife populations or even the survival of species.

Box 4.1 Economy versus effectiveness

Economic considerations strongly influence the chosen mitigation measure. Comparatively inexpensive measures - e.g., warning signs, wildlife reflectors, whistles or repellents - are commonly employed by road agencies despite there being little evidence concerning their effectiveness. For example, warning signs are perhaps the most common mitigation measure implemented across the world to reduce large animal collisions with vehicles, yet many transportation and natural resource agencies report they did not know whether this measure was 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 costs rather than effectiveness drives decision-making, mitigation effectiveness may be compromised.

Warning signs are one of the mostly used type of road mitigation although there is little evidence that they effectively reduce road impacts.

Questions

- What road mitigation measures were found to be effective in reducing road-kill or enhancing road permeability?
- What guidelines can be provided to help road planners in preparing a mitigation plan?

Our approach

We assessed the effectiveness of road mitigation measures through a literature review and meta-analysis. In addition we carried out two empirical studies, one in the Netherlands and one in Norway, to illustrate the importance and benefits of proper information on mitigation performance.

The literature review focussed on both road-kill and barrier effect mitigation and aimed to assess (1) what mitigation measures have been evaluated for their performance; and (2) the extent to which the mitigation reduces road-kill or improves road permeability for wildlife. The focus was on peer-reviewed publications in which either a Before-After-Control-Impact (BACI), Before-After (BA) or Control-Impact (CI) study design was used.

The meta-analysis focussed on road-kill mitigation and aimed to estimate (1) the extent to which road-kill mitigation effectiveness differs among measures; (2) the extent to which the effectiveness of particular road mitigation measures differ among taxa; and (3) the extent to which study design influences the estimated effectiveness of road mitigation measures.

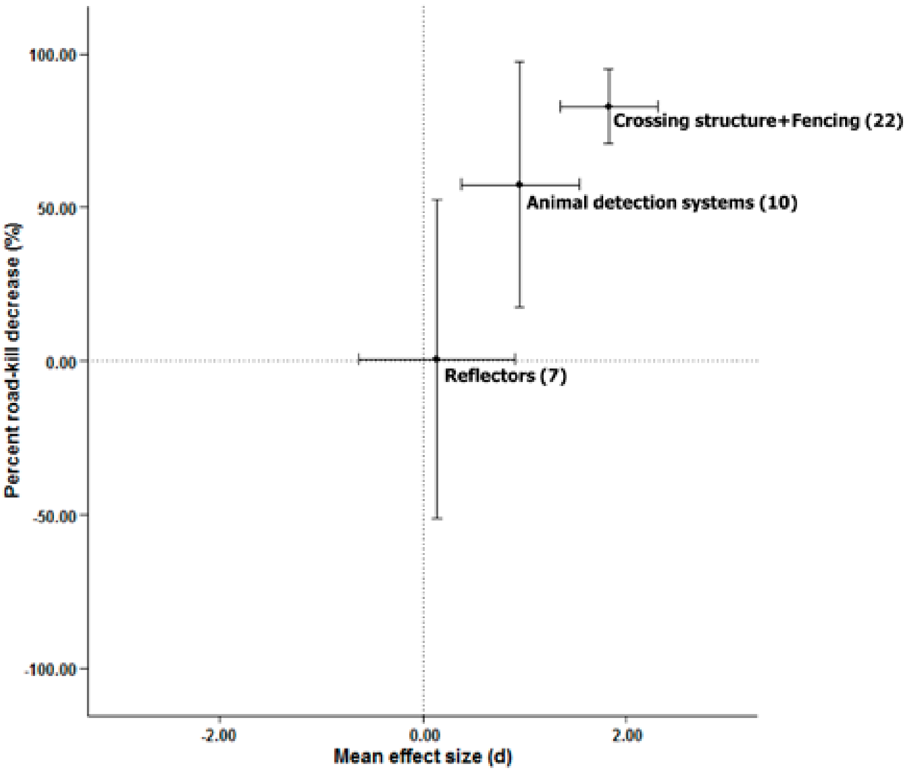
We used the outcome of both reviews and the empirical studies to develop a set of practical guidelines to select appropriate mitigation. These guidelines should be seen as a checklist that helps to address all relevant issues in preparing an effective road mitigation plan based on the current knowledge of what works and what not.

Findings

Results literature review

The number of studies addressing the effectiveness of road mitigation on wildlife in Europe is rather limited, considering the fact that in many European countries road mitigation measures have been implemented for over twenty years, and in some case for over forty years. Fifteen scientific studies from eight countries were identified that addressed the issue of road mitigation effectiveness. These studies contain 50 data sets, with most studying a single species and mitigation type (37 data sets); some (13 data sets) reported the effects of multiple types of mitigation measures, the effects for multiple species or species groups, or effects assessed by using different trial types or response variables. The studies address ten categories of road mitigation: wildlife warning sign, in-vehicle warning, wildlife reflector, chemical repellent, acoustic repellent, wildlife fence, crossing structure, wildlife fence and crossing structure, speed limit enforcement and reduced traffic volume.

In 16 data sets (32%) no response, or only a temporary response, to the mitigation measures was detected. In 20 datasets (40%), mitigation measures had a positive effect, i.e. reducing road-kill or increasing road permeability. In 8 datasets (16%), mitigation measures had a negative effect, i.e. increasing road-kill or reducing road permeability. Six data sets (12%) concerned response variables that may potentially affect road-kill and road permeability but were far removed from the assessment endpoint, i.e. the effect on road-kill or road permeability; for example, measuring changes in vehicle speed or behavioural responses of the animals. In these data sets responses were measured that may



Relationship between weighted-mean effect sizes and the weighted-mean percent of road-kill reduction among large mammals for three different types of mitigation measures. The effect size is a statistical measure based on the difference in standard deviation units between the means of the control sites (or before-monitoring period) and impact sites (or after-monitoring period). A positive effect size indicates a reduction in road-kill with the road mitigation and a negative effect size indicates an increase in road-kill with the road mitigation. Values in brackets are the number of effect size estimates. Error bars indicate 95% confidence intervals.

result in: a road-kill reduction (3 data sets), only a temporary road-kill reduction (2 data sets), or road-kill increase (1 data set).

For each study an ‘evidence score’ was assessed on the basis of six criteria that relate to the scientific quality of the study. Studies received a 100% score if they were randomised, replicated, controlled, included before-after trials with paired-sites and there was no need to exptrapolate from measured response variable to the assessment endpoint. The mean evidence score of the fifteen identified studies was relatively low (28%). Currently, therefore, evidence for the effectiveness of road mitigation is not only limited because of a relatively small number of studies but also because of limitations in the inferences that can be made.

Fences are the best option for reducing the road-kill of terrestrial fauna
In general, the meta-analysis showed that 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 of crossing structures without fencing. Within taxa, large differences may occur between mitigation measures. For example, the combination of fencing and crossing structures led to an 83% reduction in the road-kill of large mammals, compared to a 57% reduction for animal detection systems and only a 1% reduction for wildlife reflectors.

Comparatively expensive mitigation measures (e.g., fences with crossing structures) reduce large mammal road-kill much more than inexpensive measures (e.g., reflectors)
While manufacturers often claim that reflectors are a scientifically proven method for reducing deer-vehicle collisions, for example, their long-term effectiveness is rarely considered, and road planners should not take these claims at face value. Simultaneously, many of the more expensive measures (e.g. animal detection systems, crossing structures with associated fencing), have shown high returns on investment, with the ongoing benefits exceeding their costs over time. Overall, when choosing a mitigation measure to reduce road mortality, road agencies should consider the cost-benefit of the measures that go beyond unfounded assumptions on the functionality of these measures.

There are insufficient data to answer many of the most pressing questions that road planners ask about the effectiveness of road mitigation measures
Based on the current literature many questions cannot be answered, such as whether other less common mitigation measures (e.g., measures to reduce traffic volume and/or speed) reduce road mortality, what mitigation measures are most effective for small to medium-sized mammals, amphibians and reptiles, and birds, or to what extent the attributes of crossing structures and fences, for example, influence their effectiveness. The study also revealed that many road mitigation evaluations could not be included in the analyses due to the lack of baseline data on pre-mitigation conditions and/or low sample size. Therefore, we recommend that studies incorporate data collection before the mitigation is applied and that they use a minimum study duration of four years for BA and either a minimum of four years or four sites for BACI study designs.

Guidelines

Here we present a set of ten guidelines to help road planners decide on mitigation measures.

Guideline 1: Elaborate clear goals of mitigation
The point of departure for any mitigation plan should be the goals of mitigation, including a description of the target species. Moreover, the goals should answer to the SMART approach, i.e. they should be specific, measurable, achievable, realistic, and with a clear time frame. Road mitigation goals should ideally: specify what road impact(s) is/are addressed; quantify the reduction in road impact(s) aimed for; be agreed upon by all stakeholders; match available resources; and specify the timespan over which the reductions in road impact(s) have to be achieved. In practice

the descriptions of the mitigation goals are often less specific; they should first be elaborated as without clear goals no decisions can be made upon the most favourable approach in mitigating road effects.

Guideline 2: Derive the need for provisions that restore road permeability from measured or predicted population level barrier effects
Mitigation that restores connectivity, such as crossing structures, crosswalks or temporary road closures, is needed when wildlife populations are proven or expected to be affected by barrier effects. In the mitigation of an existing road, measured barrier effects should direct decisions on crossing measures. In mitigation in association with the construction of a new road, predicted barrier effects should be the key criterion in decisions on crossing measures. Such population-level barrier effects are diverse and may include (1) a reduction in population size and, consequently, a decrease in population viability; (2) a reduction in movements and gene flow between populations and, consequently, an increased risk of genetic deficiencies; (3) a barrier to accessing key habitat and consequently affecting, for example, fitness and reproductive success; and (4) a barrier to accessing new habitat and consequently slowing down colonisations and population growth. Population-level barrier effects can also be indirect, for example when the road is a barrier for a species that highly affects the life cycle of other species.

Guideline 3: Select road mitigation types whose effectiveness has been proven
For wide use within road projects, only those measures should be selected that have convincingly been shown capable of reducing the barrier effect of roads and/or road-related wildlife mortalities. This requires well performed evaluations of the effectiveness of road mitigation

Estimates of wildlife crossing rates at crossing structures may help to infer population survival probabilities, although such estimates do not directly answer the question of the extent to which the impacts of the road and traffic on wildlife have been mitigated.

measures, including (1) comparisons between impact sites (i.e., sites where mitigation measures are installed or modified) and control sites (i.e., sites where a road is present but there is no mitigation or modification); (2) data collection before the mitigation is applied; (3) replication in space and time; and (4) randomisation of impact and control sites across the pool of potential study sites. If scientific support for effectiveness is lacking, the measures should not be applied. If innovative measures have been developed, we recommend thoroughly testing them using a high-quality experimental approach before applying them widely in road projects.

Guideline 4: Include wildlife fencing if road-kill reduction is the aim, but combine fencing with wildlife crossing structures to prevent fence-induced barrier effects

Fencing has been proven to be essential in reducing road-kill, in particular for large mammals. While a 100% road-kill reduction in large mammals is rarely reached through fencing, the measure is significantly more effective than, for example, animal detection systems. There is little or no evidence in the literature that mitigation measures aiming at affecting driver or animal behaviour, such as warning signs and wildlife reflectors, reduce road-kill. These measures should no longer be applied until their effectiveness has been proven. It is best practice to always combine wildlife fencing with safe crossing opportunities for wildlife to ensure connectivity between habitats/ecosystems. Cosntructing crossing structures without associated fencing should not been seen as an effective measure to reduce road-kill.

Guideline 5: Select a fence type that addresses the requirements of all target species

There is no one fits-all approach in fencing. Each target species should be considered in decisions on fence length, height and material. The climbing or burrowing ability of animals should also taken into account. For example, fences should be modified with top extensions, or built with a smooth vertical surface, to prevent animals from climbing over them, or the base of the fence should be buried or include a skirt to prevent animals from digging under and breaching the fence.

Guideline 6: Base the road length over which fencing is needed on road-kill or species distribution data and account for potential fence end effects

Decision on fence length should be carefully made on the basis of the local situation. In the case of mitigation of an existing road, road-kill data of the target species should direct decisions on fence length. In the case of mitigation in association with the construction of a new road, no road-kill data exists, and detailed distribution data of the target species should be the key criterion in decisions on fence length. If such distribution data is lacking, the presence of potentially suitable habitat for the target species can be used. Fencing should not just take place at road stretches where road-kill occurs or is expected, but should be continued beyond these stretches to prevent fence end effects, i.e. elevated road-kill immediately adjacent to fence ends. The distance over which fencing should be continued depends on the target species and the local situation. As a rule-of-thumb mean daily movement distances of the species can be used to decide on fence length beyond the road stretch where road-kill occurs or is expected.

Guideline 7: Select measures that create crossing opportunities in which the requirements of all target species are taken into account

Each target species should be considered in decisions on type, design and positioning of crossing measures. In this respect it is essential to have information on the acceptance and use of different types and designs of crossing measures by the target species as well as the conditions these species prefer in the direct surroundings of the crossing measures. This does not imply that all crossing measures should facilitate all target species. For example, if a mitigation project targets two species and one of them needs one crossing structure and the other needs three, one crossing structure can be selected that facilitates both species, while the two other structures can be selected solely on the basis of the needs of the second species.

Guideline 8: Base the density of crossing measures on the mitigation goals
The mitigation goals should refer to both target species and the road effects to be mitigated. With these goals as a starting point, the density of crossing measures can be assessed on the basis of empirical data on the mean distance over which crossing measures can be reached by each target species (Box 4.2 and 4.3).

Guideline 9: Select types of mitigation measures that have proven to be sustainable
Some mitigation measures tend to show failures only few years after installation. Clear examples are small crossing structures and fences for amphibians, reptiles or mammals. Such fences easily get broken, and small crossing structures easily get flooded or blocked-up. This implies that

Box 4.2 Tunnels for toads

One of the largest common toad (*Bufo bufo*) population 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 put up 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 and permanent drift fences along a 1-km road stretch. During spring migrations in 2013, 2014 and 2015 toads that tried to cross the road were captured, individually marked and released at the spot where they had been captured (Ottburg & Van der Grift, in prep). Use of the amphibian tunnels was monitored with the help of a pitfall at the northern tunnel exit. As the permanent drift fences did not prevent all toads from entering the road, the roads were surveyed for toads, dead or alive. The researchers found that on average only 31% of the marked 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 minimum estimate of the average distance covered by the toads along the drift fences was 67 m. Therefore, it was recommended to increase the number of tunnels as the current tunnel density did not create sufficient road permeability for toads.

Marked toads along the drift fence (top) and captured in the pitfall at one of the tunnel exits (bottom).

Box 4.3 Spacing of crossing structures for moose

In Norway, fences are built along highways with high traffic volume and high speed limits to avoid animal-vehicle collisions. 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. (in prep) studied how many and what kind of structures are needed for moose (*Alces alces*) to reach pre-set mitigation goals. For this purpose they analysed the movements of 55 moose that had been fitted out with a GPS-collar. 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 and traffic 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 increased, the likelihood of moose choosing to use the structure declined. For wildlife crossing structures, the results suggest that building a structure every 1.4 kilometres 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.

Female moose marked with GPS collar and ear tags.

such measures need frequent inspection and maintenance. It is thus better to emphasise constructing more robust fences and wildlife crossing structures. For example, amphibian fences made of concrete are more sustainable than those made of plastic. And large wildlife over- or underpasses will not be easily blocked-up or flooded. Higher construction costs are balanced by lower costs of maintenance and a reduced risk of failure.

Source: This chapter is a summary of SAFEROAD deliverable 8, 9, 10, 11, 13 en 14.

Synthetic amphibian fences tend to show failures a few years after installation (top). Concrete barriers are a sustainable alternative (bottom).

Chapter 5

Cost-efficient road mitigation strategies for wildlife

In many wildlife species, the transport sector has a special responsibility for avoiding or reducing traffic mortality and for maintaining or restoring connectivity across infrastructure barriers. Approaches to achieve these goals are many, but only a few are effective and economically defendable. How can mortality and barrier effects be mitigated in a cost-effective way? Which of both impacts should be given priority? When and where should mitigation be mandatory, and how much impact can be tolerated from an economic or ecological point of view?

What is the problem?

Millions of mammals and birds perish every year on European roads, and the loss of other animal groups is innumerable. Statistics are rather poor and incomplete and refer mostly to larger species, especially game species, in which cultural, ethical and economic interests, legal obligations or, above all, traffic safety concerns provide reasons to report accidents. Large mammals in particular are the targets of many road mitigation projects for wildlife in Europe. Exclusion fences and wildlife crossing structures are typically designed to meet the requirements of these species or to increase traffic safety, while benefits to other species are welcomed but often not necessarily mandatory.

Each year, collisions with large wildlife, especially ungulates, cost billions of euros in socio-economic losses, thousands of injured people and several dozens of human fatalities. Despite decades of prevention attempts, collision statistics indicate a steady increase in numbers. The question thus arises of whether mitigation investments have so far been insufficient or ineffective. More roads may need to be fenced against wildlife in the future, but fences are expensive and alternative measures to keep wildlife off roads have not yet proven effective. Fencing also entails secondary problems that may trigger the need for additional mitigation. For example, a long fence increases barrier effects on wildlife and may require installing special crossing facilities that allow animals to move between populations and habitats. Short fences may only displace accident risks towards fence ends and thus even comprise a traffic hazard if these ends are not secured. Gaps and openings in fences will inevitably allow animals to enter the fenced road corridor, with the consecutive risk of causing accidents or increasing wildlife mortality.

But even without fences, busy roads can impose functional barriers to wildlife. Small species may be unable to cross the road as they avoid spaces without cover, and larger species may avoid attempting to cross roads because of the dense traffic. Where many busy roads crisscross the landscape, meshes in the road network may eventually become too small to support local populations or even individuals to survive or to be managed sustainably.

Fences and crossing facilities, i.e. barriers to prevent mortality and passages to prevent isolation, are thus two sides of the same coin with which road mitigation for wildlife can be achieved. The challenge is to decide on how much of either or both is needed in a given situation, for a certain species or with a limited budget.

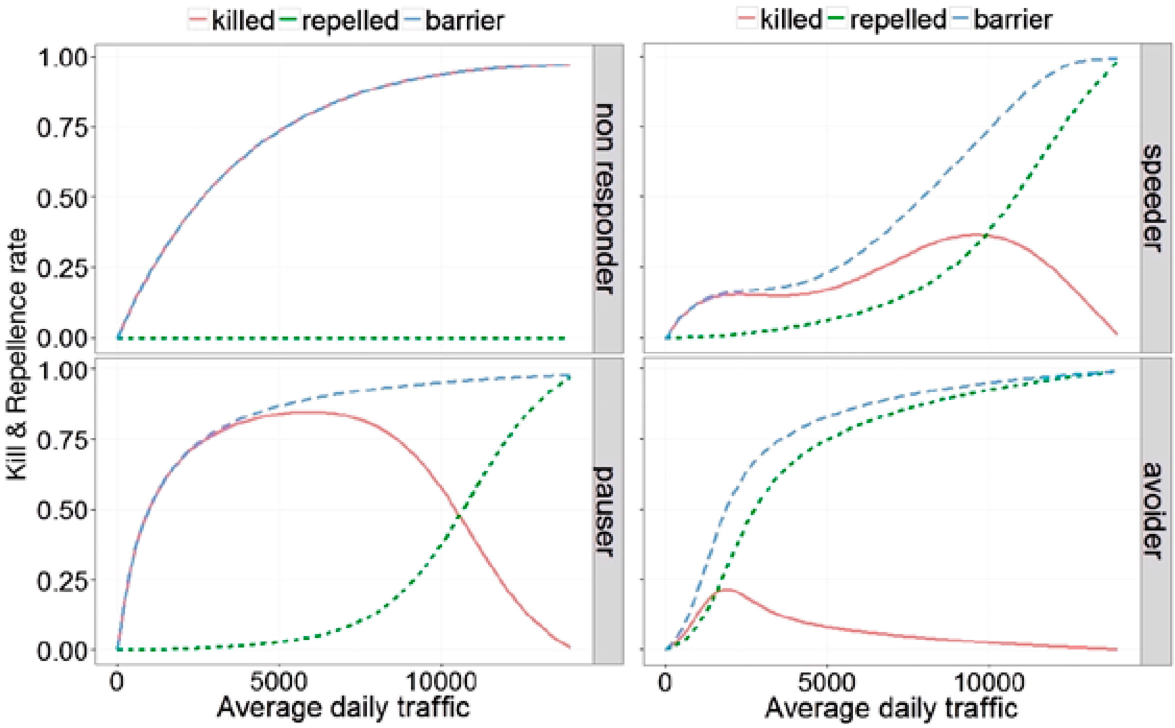
Questions

- How can mortality and barrier effects to wildlife be mitigated in a cost-effective way? Which measures are reliable and robust and which have a potential for being this, if further developed?
- Which of both impacts should be given priority? Are there differences between species and between situations?
- How much mitigation is needed or desired to meet national and international objectives on species conservation, environment, and road safety? Are there other objectives that can motivate mitigation?
- What knowledge is still missing to develop or implement optimal mitigation solutions? Where and what type of research is needed to produce this knowledge?

Our approach

We combined literature reviews, analyses of empirical accident data and simulation models to study general relationships for four types of 'species' - non-responder, pauser, speeder and avoider (see graph) - and create scenarios that can help in deciding on mitigation. We studied the influence of environmental factors related to landscape and road design on the spatial distribution of wildlife-vehicle collisions. This was

Warning to drivers and consequent speed reduction near the end of wildlife fences in Sweden.



Graph illustrating the relevance of road traffic on mortality and barrier effects on species with different responses to traffic. Animals that do not respond to traffic at all will be killed more often as traffic volume increases, while species that avoid cars may suffer less from mortality but be increasingly repelled from busier roads. Both species, however, may experience a similar overall barrier effect. Based on Jacobsen et al. (2016).

done in three case studies, in Spain, Sweden and Norway, all relying on the geographical analyses of police-reported ungulate-vehicle collisions (UVC).

Combining these findings with information from scientific and technical literature and practical experiences of road administrative personnel with both wildlife-vehicle collisions and the costs and efficacies of mitigation measures, we developed a simple tool for cost-benefit evaluation and proposed a simple strategy to address mitigation planning.

We then developed a road permeability model to simulate the effect of road networks and mitigation efforts on the viability of wildlife populations. The model allowed for the study of specific general traits in animal behaviour or the degree of landscape fragmentation. The simulation model was parameterised using results from previous studies combined with expert opinions.

Findings

Road mitigation for wildlife should primarily focus on reducing mortality and secondly on providing permeability

Our simulation models strongly suggest that, in most conditions, population viability is more dependent on the survival of individuals than on migration abilities. Migration, i.e. the permeability of road networks, is of significance when populations are small and the movements of individuals are large relative to the mesh size of the road network. However, animal species differ in their area requirements and response to road traffic. Mitigation approaches must therefore consider these differences and target barrier or mortality issues appropriately.

A significant part of traffic-induced mortality in wildlife occurs on rather few locations in the road network

Clusters in UVC may contain between 20-40% of all reported UVC, but cover only 1-2% of the road network. This implies that rather limited but well-targeted mitigation efforts can substantially reduce accident numbers.

UVC clusters can be explained by and predicted from a combination of landscape and road factors operating primarily on a local scale

These local factors typically relate to either road accessibility or road attractiveness. Accessibility refers to the presence of physical barriers, i.e. mainly exclusion fences and safety rails, and partly also to the landscape elements that may funnel and direct animal movements towards roads. Attractiveness is a more complex property, involving the presence of forage and cover, e.g., road verge vegetation and garbage containers in Spain or shrubs and trees in Sweden and Norway, as well as the animals' need to access resources on the other side of the road.

Inclusive fencing systems appear as the most effective albeit relatively expensive mitigation approach

Such fencing systems combine wildlife fences with escape ramps, electrified mats, grids or gates to secure fence openings, warning systems to alert drivers approaching fence ends and safe crossing facilities for wildlife. Well-designed and properly installed systems can reduce UVC by over 90-95%, ensure sufficient permeability and still be cost-effective in many if not most UVC clusters.

Wildlife detection and automated driver warning at a crosswalk in Sweden.

Vehicle speed and traffic volume are further important factors for the spatial aggregation of UVC
On average UVC clusters occur on busier roads with higher speeds than accidents that are not clustered. Local and temporary reductions of speed may hence provide powerful mitigation. This can be achieved through installing on-site warning systems triggered by animal-detection systems, through in-car GPS-based navigation tools that alert drivers when entering a road section when risks are predictably high or through a combination of both, i.e. a GPS alert activated by animal presence near the UVC.

A significant part of UVC is, however, rather randomly distributed across the road network
If UVC are widely dispersed along roads and not clustered, they cannot be appropriately addressed by local mitigation such as fencing systems. Instead, mitigation efforts must aim at factors operating on "global" scales, such as the ability of the driver or vehicle to respond to animals in time. Relevant mitigation options may be found in intelligent in-car animal detection and driver assistance systems that may automatically adjust vehicle speed or shorten reaction time, but also in driver education, probably based on risk-prediction models that can teach drivers to identify risky situations and adopt preventative driving behaviour. How much these mitigation approaches may be able to reduce UVC is not yet known.

Cost-benefit analysis for mitigation against UVC will always underestimate the potential benefits
Cost-benefit analysis (CBA) is a useful tool and should be employed more often in mitigation planning; however, the main challenge is assessing the potential benefits of reducing UVC over many years in the future. The socio-economic costs of UVC are substantial but strongly underestimated due to the present focus on traffic-safety policy. As few UVC entail human injury or death, most costs for UVC relate to material damages and lost values for wildlife. Benefits must therefore include not only costs of human injuries or material damages in accidents, but also the overall costs of managing this conflict, as well as consumptive and non-consumptive and non-monetary values of wildlife that cannot be appropriately monetised and must therefore be integrated into CBA via policy objectives or legal requirements.

Mitigating wildlife-vehicle collisions can produce significant socio-economic benefits
Even if only the monetised benefits are considered, our studies suggest that high socio-economic benefits can be gained from a targeted approach at UVC clusters. Accidents occurring outside clusters require other mitigation approaches that still need further development and research. Although some obstacles to effective implementation may result from inadequate technical solutions, many more probably result from the lack of data, limited knowledge and inappropriate policy.

Guidelines

Guideline 1: Develop a multi-stakeholder policy on mitigation for wildlife
Road mitigation of wildlife conflicts cannot be done solely by the road agency; several stakeholders and actors must be involved in developing and implementing mitigation approaches. Together, they must develop quantifiable mitigation objectives that can be used to motivate implementation, direct further development of mitigation and monitor the overall progress. Such goals can be expressed as X% reduction in collision numbers during Y number of years and be specific for the target species, regions, types of accidents or respective stakeholder responsibilities. Multi-stakeholder strategies may involve the installation of inclusive fencing systems with green bridges, tunnels or crosswalks, depending on traffic conditions, combined with adjusted land use plans on vegetation, plantation and wildlife management, as well as driver education methods and enhanced in-car driver assistance systems.

Guideline 2: Acknowledge the full costs of wildlife-vehicle collisions or traffic related mortality in wildlife
Existing cost standards for road accidents (that typically only consider human injury and death)

need to be updated and complemented by estimates of material damages, administrative and management costs and the lost values of wildlife (consumptive and non-consumptive values). Benefits that can be gained or saved through effective mitigation are generally underestimated and incomplete. Clarify which costs are included in a cost-benefit analysis and which are not monetised and thus must be considered in policy targets.

Guideline 3: Improve empirical data on mortality/collisions and establish reliable and long-term geo-referenced statistics

Reliable and extensive empirical data is essential to planning and evaluating mitigation. If not already existing, develop a reliable reporting system for road-killed animals that at least focuses on the most relevant species from an ecological, economic or other stakeholder point of view. A reporting system can be based on citizen-

Fences are only effective when installed properly and regularly maintained. When animals are trapped inside a fenced road corridor, the risk of accidents significantly increases.

science approaches or derive from standardised inventories, police reports or road maintenance records. Estimates of the spatial and numerical accuracy of these statistics must be made and correction factors should be developed for extrapolation to the assumed real number of accidents. Accident statistics should be publicly available, with accident positions and clusters visualised on maps. Calculate descriptive statistics that may be used for regional benchmarking and monitoring of the overall mitigation success.

Guideline 4: Develop a targeted mitigation approach to reduce wildlife-vehicle collisions along identified accident clusters
Combine the above geo-referenced accident data and results from cluster analyses with estimates of accident costs to map the most costly roads where local road mitigation may be cost-effective. Employ cost-benefit analyses, compare different mitigation alternatives and rank potential mitigation sites with respect to their cost-benefit ratio and their effect on policy targets. Where static and long-term installations are planned, such as green bridges or wildlife tunnels, involve other stakeholders and develop a joint strategy to ensure the future effectiveness of the proposed measures. These statistics and traffic and landscape data can produce risk prediction models that can be updated automatically and used in driver information systems.

Guideline 5: Ensure the proper monitoring and evaluation of mitigation activities and initiate experimental studies
Develop scientifically sound monitoring schemes and employ follow-up studies as a standard in mitigation. Initiate and allow for experimental studies on mitigation alternatives that may be evaluated using the above monitoring schemes. Produce annual status reports based on mitigation efforts, monitoring results and accident statistics described above. This will increase evidence-based knowledge and foster the development of innovative and probably more cost-effective approaches.

Guideline 6: Initiate cooperation with stakeholders and support research on innovative approaches
Cooperation is highly advisable between road administrations and many other stakeholders that can engage in the research, development and evaluation of mitigation measures, especially those that address global and landscape scales. Support research on both fundamental questions in wildlife-vehicle collisions, their spatio-temporal pattern and socio-economic costs, and on developing applications such as model-based driver-warning systems or in-car animal detection systems.

Source: This chapter is a summary of SAFEROAD deliverable 3, 4, 7 and 12.

Objective	Responsibility	Scale	Target	Mitigation approach	Function
to separate animals and traffic	Transport Administration and Road Agency	road, local	animal	fence	to keep animals off the road and lead them to safe passages
				repellents	to repel animals from approaching the road
				reflectors, acoustic signals	to warn or scare animals when cars approach
			animal & driver	verge management	to reduce attractiveness of road verge, increase detectability
			driver	speed reduction to 50 km/h	to increase driver response time
				traffic calming / rerouting	to reduce occasions for collisions
	Landowner, Hunters, Municipality	landscape	animal	population control	to reduce the abundance of animals near the road
				habitat management	to reduce the abundance of animals near the road
	Driver, Companies, Public	global + local	driver	education	to increase risk awareness and influence driving behaviour
				active in-car warning	to inform drivers when they enter a high-risk road section during high-risk times
				driver assistance systems	to assist drivers in detecting animals and braking in time
to maintain animal mobility	Transport Administration and Road Agency	road, local	driver	local speed reduction to 50 km/h	to increase driver response time and reduce accident risks
			animal	gap in fence with static speed reduction	to funnel movements to safer crossing places and separate animals from traffic in time
				crossing structures	to separate animals from traffic permanently
			animal & driver	crosswalk with animal detection and driver warning	to funnel movements to safer crossing places and separate animals from traffic in time
	Landowner, Hunters, Municipality	landscape	animal	habitat management, Green Infrastructure	to divert animal movements parallel to or away from the road to safe crossing locations
				supplemental feeding, salt, water, etc	to reduce the animals' need or motivation to move across the road

Table summarising an evaluation of road mitigation measures for wildlife. Measures are grouped according to objective, target, responsible stakeholder and spatial scale.

Pro's	Con's	Overall judgement
highly efficient if done and designed appropriately	expensive, risk of malfunction, barrier effects, requires add-ons	most advisable if combined with crossing facilities
presumably cheap	no proven effect	not advisable
presumably cheap, teaching effect on animals	inconclusive evidence	not advisable yet, further research required
possible positive side effects on overall traffic safety	requires frequent maintenance, inconclu-sive data	partially applicable, further research needed
overall benefit to traffic safety, reduced barrier effects	increased travel time produces high costs	highly advisable if temporary
reduced overall impact on wildlife, fewer barrier effects	limited applicability, only dislocates problem	applicable with restrictions
on a large scale presumably effective	ineffective on a small scale, loss of wildlife and ecological values	only advisable on a large scale
presumably long-lasting effects	possible effect on land use productivity, sensitive to changes in land use, untested	further research needed
general spin-off on traffic safety	individuality in responses, low overall effectiveness	further research and technical develop-ment needed
evidence-based, concrete and relevant information	individuality in responses, yet untested	further research and development needed
in-car solutions, reliable, likely a future standard anyway	yet untested for WVC, presumably not sufficient in high-speed travel	further research and development needed
overall benefit to traffic safety, reduced barrier effects	increased travel time produces high costs	conflicts with transport policy, further research needed
cheap, simple	requires speed cameras, risk of accidents if speed limit not obeyed	advisable, further research needed
high efficacy if done well, multi-purpose use, long-term effect	expensive if built only for wildlife	most advisable, existing standards may be optimised
proven efficacy, very limited effect on traffic	technically sensitive, applicable to smaller roads only	highly advisable, further research needed
presumably long-lasting effects	possible effect on land use productivity, sensitive to changes in land use, untested	further research needed
presumably long-lasting effects	possible effect on land use, inconclusive empirical data	further research needed

Chapter 6

Maintenance practices to improve wildlife conservation and traffic safety

Several conflicts between roads and wildlife can potentially be avoided through the application of proper maintenance practices. Wildlife-vehicle collisions have proven to be strongly related to the management of verges and other road features. What maintenance practices that address road-wildlife conflicts are currently being used? Which of these practices seem promising? What guidelines can be provided for improving road maintenance practices to enhance wildlife conservation as well as traffic safety?

What is the problem?

Road operators are increasingly aware about wildlife issues, probably due to the rise in wildlife hazards, particularly ungulate-vehicle collisions, but also because of the need to maintain the numerous wildlife mitigation measures that have been implemented and the environmental regulations that require greater protection of habitats and species inhabiting roadsides.

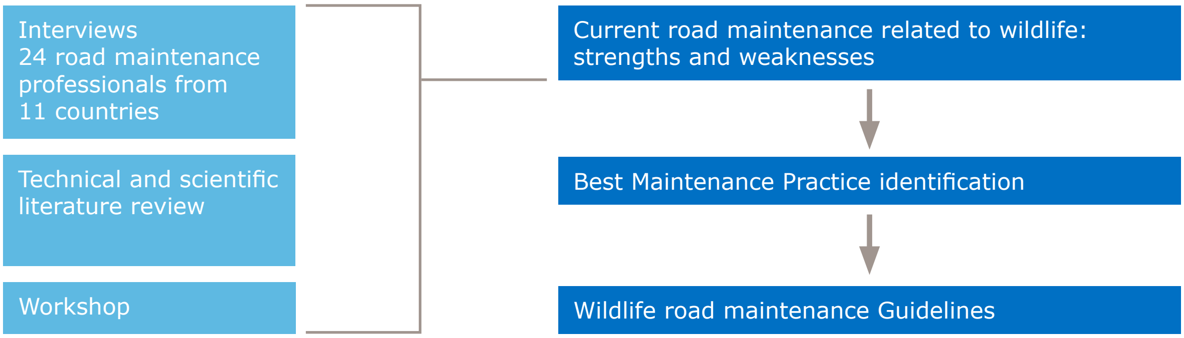
During the last twenty years the attention paid to the effects of roads on wildlife has increased notably. A vast number of wildlife crossing structures and other mitigation measures have been constructed on roads all around Europe since the first European handbook 'Wildlife and Traffic' in 2003 was published by the COST341 Action. Wildlife crossing structures, together with properly managed road verges, retention ponds and other roadside habitats, have been recognised by the European Commission as potential elements of the 'Green Infrastructure' in Europe that can play an important role in wildlife conservation, particularly in intensively-managed landscapes. However, as a consequence of the global economic crisis, budgets for road infrastructure maintenance have declined. Consequently, identification of strategies to optimise the costs-benefits ratio of road maintenance investments has become a priority as well as the effectiveness of the measures that aim to reduce road-wildlife conflicts.

Questions

- What maintenance practices are currently being used and which of these practices show high potential in preventing or mitigating road-wildlife conflicts?
- What guidelines can be provided for improving road maintenance practices to enhance wildlife conservation as well as traffic safety?

Our approach

To investigate current maintenance practices and to identify opportunities to improve them, we interviewed 24 professionals involved in road maintenance from 11 European countries and reviewed technical documents about road maintenance. A workshop that brought together engineers and wildlife experts to discuss how road maintenance could be improved for the benefit of wildlife and traffic safety was organised along the IENE Conference 2014 and, finally, the analysis was complemented by a literature review to gather evidence-based knowledge that could be used to determine best practices and provide new guidelines.



Flowchart of our approach to develop guidelines for road maintenance

Findings

Existing guidelines and handbooks provide only brief and mostly general recommendations for the maintenance of wildlife-related issues

Fencing and roadside vegetation management are included in all road maintenance guidelines, but often with no particular focus on wildlife topics. On the other hand, handbooks about designing wildlife mitigation measures usually pay little attention to maintenance issues. However, drafting guidelines that address wildlife-related maintenance (such as road verges and landscaped areas management) is increasing and can be seen as a positive trend. In some cases 'Road verges management plans' or 'Wildlife management guidelines' are provided for a single road, thus allowing maintenance to be properly adapted to local road features and environmental conditions.

Most wildlife mitigation measures are regularly inspected and repaired, but the lack of inventories and specifications of standards to be accomplished make it difficult to undertake appropriate maintenance

Fencing, wildlife warning signs (including temporary signs), road verges, drainage systems and wildlife crossing structures are the road elements that are commonly inspected and maintained by road maintenance staff. Maintenance schemes vary widely among countries and regions and differ according to road features, traffic capacity and regulations as well as in relation to environmental conditions in the surrounding landscape. Regular inspections mainly focus on structural rather than on functional conditions, and budget restrictions reduce the maintenance activities undertaken. Inadequate management of wildlife mitigation measures has been pointed out as the cause of failures and lack of effectiveness. However, maintenance and environmental follow-up conducted on new motorways for 3 to 5 years is common practice in many countries and allow an appropriate maintenance at least during this period.

Applying maintenance practices to enhance biodiversity in roadside habitats is increasing throughout Europe. However, in many countries verge maintenance strategies focus only on reducing large-mammal hazards to traffic safety

Most actions aim to control alien invasive species and to benefit endangered flora and small or aquatic fauna. Usually these practices are carried out in sensitive, protected areas, such as roads crossing Natura 2000 sites or endangered species' habitats. Providing refuges or resting places for bats, birds and other small animals (e.g. dormouse or pollinator insects) is carried out in many countries, particularly on new motorways. In Mediterranean countries, fire risk is a big constraint on vegetation management. A high density of prey such as rabbits in verges or voles in medians is seen as a wildlife hazard in many sites because predators are attracted to areas with a high mortality risk.

Animal-vehicle collisions involving large animals and traffic victims are registered all over Europe by traffic police. Nevertheless, the results are rarely reported to road operators and, when available, data accuracy is often poor and not applied to define mitigation measures

Best practices for animal-vehicle collisions (AVC) registration are found in Scandinavian countries, where moose-vehicle accidents cause a major conflict; AVC data are compiled in integrated databases with the participation of several stakeholders. The lack of GPS-based tools for geographical precision, of standardised data collection criteria (including species identification) and of wildlife training of field staff collecting those data are the main reason for poor data accuracy. Accurate data could provide a good basis to identify road stretches where clusters of wildlife-vehicle collisions are registered and to design and evaluate mitigation measures.

Evaluating the effectiveness of maintenance practices is key to identifying and expanding the most cost-effective practices, but such evaluations are only reported occasionally

The collection and analyses of environmental and wildlife data allows the effectiveness of wildlife mitigation measures and habitat management practices to be evaluated. The definition of thresholds above which mitigation measures must be applied is not a common practice. However, road operators apply mitigation measures such as installing wildlife warning signs or fencing in road sections where clusters of accidents involving animals are registered.

The stakeholders conducting road maintenance vary according to the road management system, which can be public or operated in public-private partnership

The vast majority of the road network is a public asset, but public-private partnership (PPP) management is a rising practice across Europe. Providing standard prescriptions about wildlife-related issues to be included in contracts to

Placing wildlife warning signs is one of the most common activities undertaken. Temporary signs require higher maintenance than standard ones, but allow adaptation to the risk period and reduce the risk of a driver's habituation.

operator and maintenance companies is reported to be a crucial tool to quickly improve wildlife-related issues management. In some countries contracts already ask for ecology experts to be part of the inspection staff and/or training on wildlife issues is provided to maintenance staff.

Guidelines

Guideline 1: Standards on wildlife-related topics must be included in general Road Maintenance Guidelines to allow a proper maintenance of wildlife provisions

Guidelines should include information about how to inspect and maintain roadside habitats and wildlife mitigation measures and must allow or even encourage an adaptation to local conditions. Such standards must provide detailed information to road operation staff to guarantee that tasks are properly undertaken and focus not only on structural features but on all conditions to guarantee their long-term functionality.

Guideline 2: Wildlife maintenance actions should be adequately planned and prioritised to enhance their cost-benefit ratio

Maintenance should be undertaken on the basis of clear prescriptions and checklists of points to be inspected. Inventories of all installed wildlife provisions and detailed specifications of standards to be accomplished are needed to develop a proper maintenance plan. Multiuse of crossing structures is an increasing practice, but where human and fauna uses are combined, different and more costly maintenance tasks may be necessary. However, costs can be limited through providing clear regulations and information. Wildlife fences must be managed to provide traffic safety but also to funnel animals to safe crossing points. Vegetation beside fences must be maintained in such a way that the structures are not damaged and opportunities for animals to get onto the road are avoided. Adapting fences to each target species may largely improve their

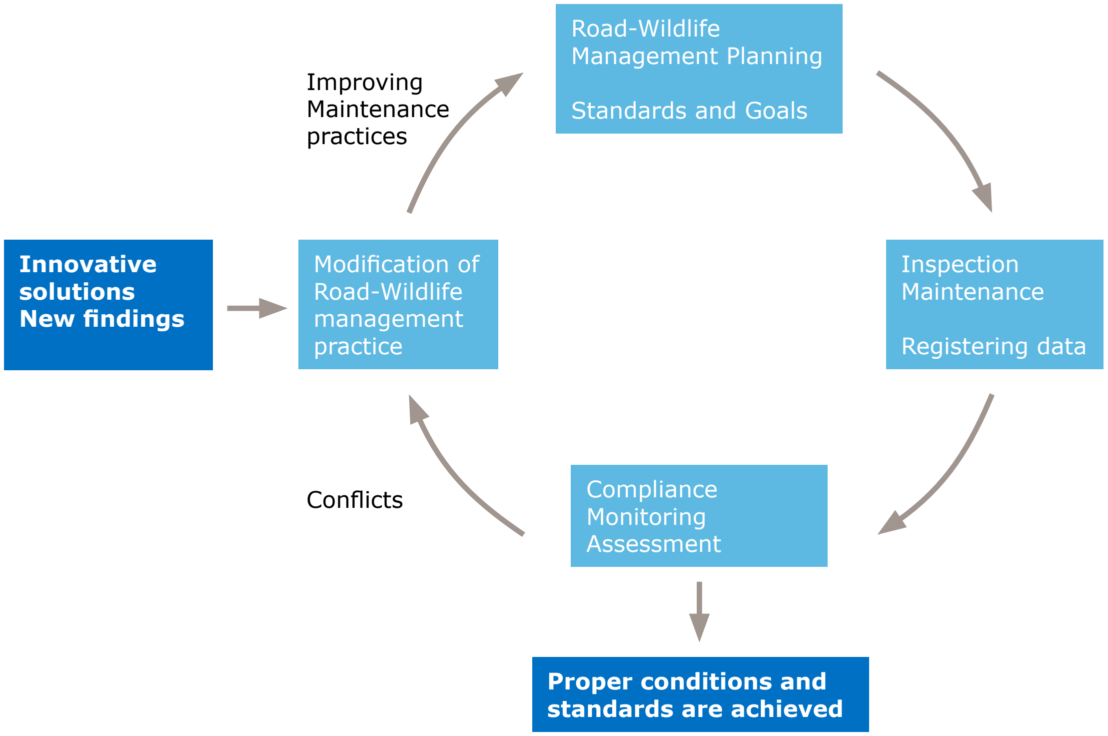
Properly managed retention ponds may be valuable habitats for aquatic species but require appropriate maintenance to reduce aquatic fauna mortality.

effectiveness. Monitoring is needed to ensure than an adaptive maintenance strategy is applied.

Guideline 3: Road managers can favour biodiversity conservation and Green Infrastructure development by conducting wildlife-friendly roadside habitat management
Some examples of maintenance activities to be conducted to promote biodiversity are: (i) removing alien invasive species that could damage local habitats or species, (ii) creating suitable habitats for pollinators on verges and other green areas in highly anthropogenic landscapes, (iii) managing road verge vegetation to avoid high densities of prey in sites where they could attract predators to high risk roadsides or (iv) creating refuges for small and aquatic fauna in drainage systems or retention ponds. Some practices will also benefit humans by providing ecosystem services such as pollination. However, attracting animals to roadsides could also create ecological traps, increase the road mortality of endangered species and, when large animals are attracted, could increase the hazards to traffic safety. Proper maintenance practices play a relevant role in preventing these negative effects.

Guideline 4: Animal-vehicle collisions should be accurately monitored to assess where conflict points are located and to evaluate which mitigation measures are most effective
Web-based databases and other smart technologies will help to achieve the goal of compiling and evaluating all the information about wildlife mortality and other wildlife observations. Accurate registration of road casualties by road maintenance patrols is a first step to be achieved, but the cooperation of other stakeholders (traffic police, road users hunters, etc.) is strongly recommended. Regular standardised analyses of road-kill and the use of thresholds for applying mitigation measures are needed to take decisions about which measures need to be applied to reduce conflicts. These data may also allow the evaluation of the effectiveness of the overall mitigation strategy in a road project or a road network.

Adaptive road-wildlife maintenance strategy.



Cooperation agreements with landowners, conservation organisations and other stakeholders could provide valuable help for roadside habitats maintenance. As an example, suitable grazing may help to control vegetation growth on road verges.

Guideline 5: Develop and monitor an adaptive road-wildlife maintenance strategy

An adaptive road-wildlife maintenance strategy should include: drafting standards for wildlife mitigation measures, to be met according to the instructions provided by designers and constructors on road safety and operation requirements; scheduling inspection and maintenance tasks adapted to the local conditions of wildlife and habitats; establishing procedures for identifying conflicts or their deviation and how to proceed to solve them; defining proper training programmes for maintenance crews; and defining procedures for monitoring and reporting compliance with standards, and disseminating this information to road planners and other stakeholders involved.

Guideline 6: Cooperation between stakeholders is needed to ensure an information flow during the entire road lifecycle

A lifecycle approach will provide excellent opportunities to improve wildlife mitigation measures and to identify the best strategies for wildlife-road maintenance. Road authorities should be the link between all stakeholders throughout the road's lifecycle. Providing standards, goals and outcome-based specifications for wildlife mitigation measures could help road authorities to supervise maintenance or operator contractors and ensure compliance. Measurable indicators and thresholds will be helpful to determine when a practice must be improved.

Guideline 7: Cooperation with external stakeholders will benefit wildlife-road maintenance

Collaborating with other stakeholders, such as owners of surrounding lands, NGOs, environmental agencies and research centres, is a challenging issue. Cooperation will contribute to ensure long-term mitigation and to improve the effectiveness of mitigation measures, like wildlife crossing structures, and reduce wildlife conflicts. Collaboration with other stakeholders can also contribute to data collection for cost/benefit analyses of on-going management programmes.

Source: This chapter is a summary of SAFEROAD deliverable 5.

Evaluating road mitigation performance

In many countries road mitigation for wildlife has become common practice. Nowadays, in procuring mitigation measures a shift can be seen from design specifications to outcome-based specifications in which desired functions are described. Such a transition demands careful evaluations of the performance of road mitigation. 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?

What is the problem?

Road mitigation performance evaluations have been an important means to increase our knowledge of what mitigation works and what does not. They have been crucial to assess whether measures taken result in aimed-for reductions in road impacts. More recently, such evaluations also became essential in procuring mitigation works. National road administrations increasingly make use of Design & Construct contracts in road building. In these contracts, the constructor not only builds but also designs the desired road or road modification. Although such contracts are not yet widely used to construct mitigation measures for wildlife, some road agencies are experimenting with these procurement approaches, and there seems to be increasing interest in shifting to such approaches.

This shift implies that procurement documents no longer present detailed prescriptions on the technical design and dimensions of road mitigation measures, e.g. wildlife crossing structures or wildlife fences, but provide descriptions of what the measures should achieve, i.e., what the outcome should be of the desired measures. It is the task of the contractor to translate these outcome-based specifications into technical solutions and to prove that the solutions are functional. With such a transition from design specifications to outcome-based specifications for road mitigation measures, new approaches are needed to assess whether the outcome aimed for has indeed been achieved.

Questions

- What guidelines can be provided to evaluate road mitigation conformance with outcome-based specifications?
- What recommendations can be provided to implement these guidelines?

Our approach

To develop guidelines to evaluate road mitigation performance, we used the state-of-the-art knowledge on conducting scientifically sound evaluations, including recent publications on how to evaluate road mitigation functioning and effectiveness. Our point of departure was the recommended set of guidelines for defining outcome-based specifications (see Chapter 3).

The guidelines should not be seen as a ‘cookbook’ for all mitigation evaluations, as decisions on, for example, study design, sampling scheme or survey methods highly depend on the mitigation goals, target species, local situations, etc. The guidelines can be better seen as a checklist that helps to address all relevant issues when preparing a scientifically-sound plan to evaluate whether or not the desired outcome for road mitigation has been achieved.

Guidelines

Here we present a set of ten guidelines to help road planners in their assessments of whether mitigation measures are functioning in conformance with the outcome-based specifications provided.

Guideline 1: Select performance indicators that are most closely related to the desired outcome

In most cases performance indicators can be directly derived from the outcome-based specifications (Box 7.1). In some cases multiple performance indicators may suit, and a choice has to be made. Note that if no suitable performance indicators can be found, the use of an outcome-based approach in road mitigation should be reconsidered.

Box 7.1 Outcome-based specifications

The point of departure for any evaluation plan in procuring road mitigation should be the outcome-based specifications provided. Such specifications should link directly to the goals of mitigation, including a description of the target species, and answer to the SMART approach, i.e., they should be specific, measurable, achievable, realistic and with a clear time frame. Hence, if worked out well, the outcome-based specifications indicate what road impacts need to be addressed and what needs to be achieved, include clear thresholds for each road impact that needs to be addressed based on baseline conditions or reference standards and provide a clear time frame for both the availability of the mitigation works and the time period over which the performance should be assessed to decide whether the specifications are being met.

Box 7.2 Road Mitigation Calculator

Population-level effects of road mitigation may be explored with the help of models in which population dynamics are simulated. Such models, however, are not widely available and often complex to use. For this reason the Road Mitigation Calculator was developed (see www.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. The tool addresses two potential questions of road managers: (1) How many animal movements should be facilitated by the crossing structures to guarantee the survival of the population? (2) What is the survival probability of the population, given the number of animal movements that were registered at the crossing structures? The questions relate to respectively the planning of future crossing structures or the evaluation of existing ones. Currently, the Road Mitigation Calculator can be used for five animal groups: small, medium-sized and large mammals, toads and salamanders.

Wildlife overpass 'Treeker Wissel' and exclusion fencing at highway N227 in the Netherlands.

Guideline 2: Select a study design that incorporates the assessment of reference values
The study design should include the collection of data on reference values, such as baseline conditions or reference standards. Baseline conditions refer to the local conditions before mitigation. Reference standards may refer to, for example, the conditions at reference sites, standards generated by model simulations (see Box 7.2), or standards that have been derived from regulations or policies.

Guideline 3: Select a study design that incorporates data collection at control sites
The optimal study design for evaluating road mitigation performance includes the collection of data before and after road construction, at the road sites where mitigation is installed (mitigation sites) and at road sites without mitigation (control sites). We refer to such a study design as Before-After-Control-Impact (i.e. BACI) design. Collecting data at control sites ensures that measured changes can be attributed to the mitigation (Box 7.3).

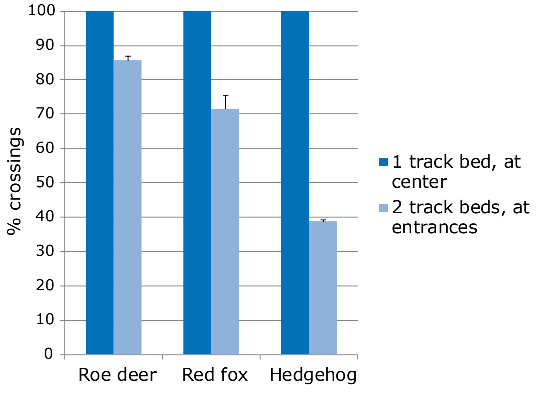
Guideline 4: Select survey methods that are the most accurate, informative and efficient
The survey method depends on the selected performance indicator and target species. If more than one survey method is available, the one that is the most accurate, informative and efficient should be selected (Box 7.4). If multiple target species are surveyed, survey methods that monitor multiple species simultaneously are recommended because they provide more information for similar effort and cost. Consistent use of the same methods and personnel over time is important to decrease bias and provide comparable results.

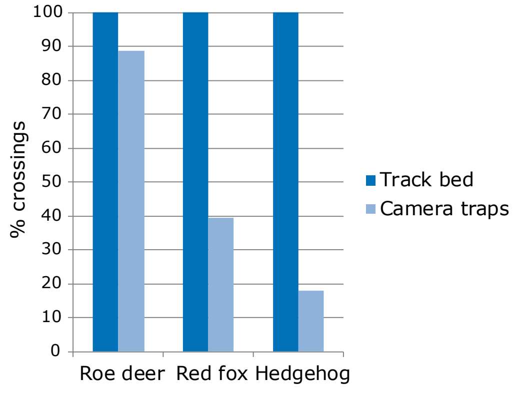
Box 7.3 BACI study design

In 2009 a wildlife overpass and wildlife fences were constructed to reduce road-kill numbers of roe deer at a two-lane highway (N227) in the Netherlands. A BACI study design was used to evaluate the effectiveness of the mitigation works; hence, road-kill data was collected both before and after the mitigation at the site where the mitigation measures had been installed and at two control sites elsewhere on the same highway. The study showed that mitigation significantly reduced the road-kill of roe deer at the road stretch with fencing on both sides. With the help of the control sites, a road-kill reduction of 88% could be attributed to the mitigation works.

Box 7.4 Survey techniques

In the Netherlands a comparison was made between surveys of wildlife crossings with (1) the use of one track bed at the centre of an overpass versus the use of two track beds, one at each entrance of the overpass; and (2) the use of one track bed versus the use of camera traps. The estimated number of wildlife crossings based on two track beds (one at each entrance), was significantly lower if compared to estimates based on one track bed in the centre of an overpass. The estimated number of crossings based on camera traps was significantly lower if compared to estimates based on the track bed. In both cases the differences in estimates increased with the decreasing body size of the target species. The reliability of the methods depends on a number of factors, some of which can be manipulated by the researcher, such as the frequency in which track beds are inspected and the type and number of cameras installed. Hence, the study does not conclude that one method should always be preferred over the other, but illustrates that different survey techniques may result in significantly different results, partly due to decisions on how the method is applied. Rigorous comparing and testing of techniques is needed previous to the start of any evaluation.





Percentage of crossings per target species detected by either one track bed in the centre of an overpass or two track beds at the overpass entrances (left) and one track bed or two camera traps at the entrance of an overpass (right).

Guideline 5: Select an appropriate spatial scale for data collection
The spatial scale for data collection should match the spatial scale of the road effect being mitigated and the performance indicator selected. The desired spatial scale depends on the road effect, the species of concern and the local situation.
A proper spatial scale can only be selected if baseline information is available on the distance over which road effects reach and the biology of the target species. Special attention should be paid to data collection at fence-ends (Box 7.5).

Guideline 6: Time data collection on the basis of the mitigation goals, lifecycle of the target species and moment an effect is expected
The timing of data collection should be based primarily on the mitigation goals. For example, if the aim is to restore access to seasonal habitats, the sampling can be limited to the period in which those migrations occur. The lifecycle of the target species may affect the timing of sampling if predictable periods of presence/absence or inactivity can be identified, e.g., in the case of migratory species or species that hibernate. Data collection should preferably take place for the full period in which the performance indicator is relevant (Box 7.6) and should not begin before an effect of the mitigation is expected to have occurred.

Guideline 7: Base study duration on the expected sampling time needed for adequate statistical power
The duration of data collection should allow for sufficient statistical power to determine whether or not the mitigation results in a significant change in the performance indicator of concern.
Consequently, study duration is closely related to the chosen performance indicator and the characteristics of the studied species. It also relates to the number of data points that are expected to be collected in each year or sample. However, even if yearly data sets are relatively large, it may be advisable to collect data for multiple years as some performance indicators may vary considerably across years.

Guideline 8: Use a sampling frequency that allows for rigorous estimates of the performance indicator
The frequency of sampling should allow for rigorous estimates of the performance indicator. For example, in most cases surveying road-kill just once a month will not be sufficient to calculate rigorous estimates of mean road-kill per year. And estimates on between-population movements will likely be more accurate if, for example, track beds are sampled daily instead of once a week. Pilot studies may be needed to assess the optimal sampling frequency in which sampling effort is

Box 7.5 Fence ends

Positive effects at a mitigation site may be nullified by negative effects in adjacent areas, for example as a result of fence end effects. At highway N227 in the Netherlands road-kill was not only monitored where fences were installed but also at the road stretches beyond the fences. At these fence end sites, an opposite trend in road-kill numbers was found; after mitigation, at one site road-kill numbers went down, while at the other site road-kill numbers went up. Although the changes in road-kill numbers were not statistically significant, possibly due to the limited sample size, the data clearly illustrate that road-kill numbers beyond the fence ends may change after road mitigation measures have been taken. It also shows that the direction of change may differ per fence end site. Hence, fence end sites should be included in all road mitigation evaluations where fencing is included to avoid that the effects of mitigation are over- or underestimated. At highway N227, a significant 88% road-kill reduction changes into a statistically not significant 50% if fence end effects are taken into account.

minimised without jeopardising accuracy.

Guideline 9: Measure explanatory variables that may affect mitigation performance

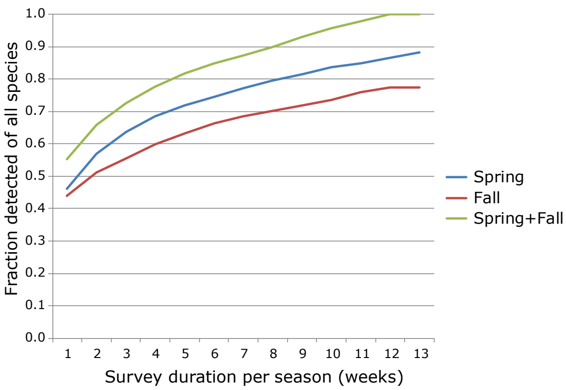
Variables other than the performance indicators of interest should also be measured to improve the interpretation of the results. Especially if data collection at control sites is lacking, measuring explanatory variables will allow for stronger inferences concerning the causes of observed differences. We recommend documenting spatial and/or temporal variability in: (i) features of the road and traffic; (ii) features of the road mitigation works; (iii) features of the surrounding landscape; and (iv) weather conditions.

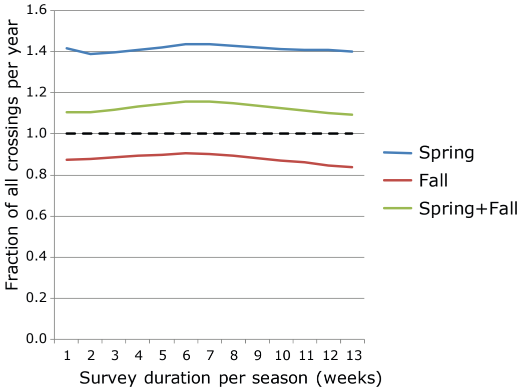
Guideline 10: Make the evaluation report and raw data widely available

In order to learn from each other and make sure that all findings can be easily accessed and used, new methods to report and share the data should be developed. We recommend developing a standard protocol for archiving the collected data across projects, including all relevant meta-data. Furthermore, it is essential to arrange peer reviews of reports and aim for publication in scientific journals to improve the quality and rigor of the scientific methods as well as improve access to the findings. This will help to ensure that future road mitigation projects can build on existing knowledge.

Box 7.6 Timing of data collection

A study on five wildlife overpasses in the Netherlands showed that there is low probability of detecting all species in scenarios where surveys are conducted only in spring or autumn, even if the surveys cover the whole season. Detection probabilities are higher if the surveys take place in both spring and autumn; however, for a complete species list, surveys must take place for at least twelve weeks in both seasons. On average, it takes 240 survey days to detect all species. This number of survey days can be lowered if the starting date is in spring, especially in March. Yearly crossing rates are either overestimated or underestimated if survey periods are limited; however, the variation between species is high. Consequently, we conclude that great care is required if one is planning on limiting surveys to certain weeks or months of the year.





Relative difference in number of species detected (left) and yearly crossing rate estimates of all species (right), depending on the season in which the survey takes place and number of survey weeks per season.

Implementing the guidelines

- Successful evaluations of road mitigation performance will require close collaboration - from the earliest stages of a road mitigation project - between research ecologists and those who plan, design, construct and manage the road. We recommend research ecologists in road agencies to become more involved in the procurement process of road mitigation works, e.g., to write SMART outcome-based specifications, organise the collection of baseline information and judge evaluation plans proposed by contractors. The researchers need to inform the road agency of the essential components of good study design for road mitigation evaluations.
- We recommend contracting an independent contractor to evaluate road mitigation performance. It is not advisable to put both the designing/constructing and evaluating the mitigation measures – whether or not the objectives are being met - in one contract. Besides possible conflicts of interests, this approach allows for selecting a contractor for the evaluations solely based on their ecological knowledge and experience.
- We recommend forming an independent advisory board, consisting of experienced road ecologists, to assist the road agency in preparing outcome-based specifications as well as in planning and conducting evaluations that meet good science. Such an advisory board may also play a key role in ensuring that acquired knowledge and best-practices will be available to all stakeholders.
- We recommend that the preparation of an evaluation plan for planned road mitigation measures is made an inseparable part of the legal processes that must be followed during the road planning and procurement stages. Evalua-

Roe deer buck crossing a track bed at a wildlife overpass.

tions of mitigation performance should not be optional but rather a statutory duty that forms an integrated whole with the procurement of the works.
- We recommend developing a strategy for systematic assessments of baseline conditions and reference standards. Baseline conditions should be known at the start of procurement, and this also applies to certain reference standards that the road agency may want to prescribe. This implies that a new way of working should be adopted as currently such systematic assessments are often lacking at the start of procurement.
- We recommend that all necessary resources to evaluate road mitigation performance are secured beforehand. Road mitigation evaluations based on outcome-based specifications require significantly more resources than evaluations based on design specifications. Therefore, early insight into the costs of evaluation studies is required, and these costs have to be treated as an integral part of the road or road mitigation construction project.
- We recommend that the outcome of all evaluations, including research reports and raw data, is made available to all stakeholders through an open access database. Research methods, results and conclusions should be documented systematically, thus allowing for quick reference and proper comparisons between projects. Furthermore, all data should be analysed and reported in a timely manner to ensure existing structures can be modified within an adaptive framework and the design of future mitigation measures can be improved.

An evaluation of mitigation works based on the guidelines presented here will clearly require more efforts and resources than most current approaches. On the other hand, it will provide much more feedback on what we do right and wrong and is strongly linked to the reasons of why the mitigation was implemented, i.e., the mitigation goals. If, in turn, these goals are strongly linked to (inter)national legal and policy plans, the outcome of the evaluations will result in a better view on how the mitigation works contribute to overall strategies for biodiversity conservation. This will even be more so if evaluation reports are standardised and the results as well as raw data - from both studies that showed successes and studies that exposed failures - are stored in an open-access database. This will enable all stakeholders to review the information, better facilitate learning from previous projects and allow for more comprehensive meta-analyses of the collected data.

Source: This chapter is a summary of SAFEROAD deliverable 6, 13 and 15.

What is next?

The SAFEROAD project has addressed new developments in legislation, policy and procurement; the cost-efficiency of different mitigation strategies; maintenance practices that aim at reducing road-wildlife conflicts; the effectiveness of mitigation measures to maintain viable wildlife populations and improve traffic safety; and monitoring approaches to assess whether road mitigation goals have been achieved. The project provides guidelines to practitioners involved in road planning, construction and maintenance for the implementation of research findings in daily practice. However, what is needed to encourage the use of project outcomes and the improvement of mitigation practices? What should our next steps be to make sure the SAFEROAD project has an impact?

No applied research matters if it does not reach the people and institutions it was meant for. That is why we consider our deliverables in the SAFEROAD project not as an 'endpoint' but as a 'starting point'. Our next steps will all focus on communicating the project findings to policymakers, road planners, road managers, researchers, consultants and, to some extent, the general public. This ambition has already been put into action as some research findings have recently been presented at (inter)national conferences and seminars where both scientists and practitioners convene, such as IENE 2014, ICCB 2015, ICOET 2015 and IENE 2016. We will again use these forums in the near future to disseminate, discuss and build upon the project outcomes.

Within the project, seven technical reports but also six scientific papers have been drafted. These papers will be submitted to peer-reviewed journals. Not only will this ensure that the research is presented to the scientific society, but it will also function as a scientific quality control and thus provide scientific support to the proposed guidelines.

The SAFEROAD project was one of three in the CEDR Transnational Road Research Programme Call 2013: Roads and Wildlife. Together with the other two projects - HARMONY and SafeBatPaths - SAFEROAD will be used to compile a new handbook for practitioners. This *CEDR European Handbook for Wildlife* will present all key findings and provide guidance for their implementation in the daily practice of road planning, construction and maintenance. The handbook will not replace the COST341-handbook on *Wildlife and Traffic*, published in 2003, but will complement it as the new handbook will address issues that were not included or only briefly touched on before. Hence, the new handbook will enlarge our 'toolbox' to deal with the challenge of avoiding road-wildlife conflicts.

Successfully implementing the research findings is mainly in the hands of the road authorities. Modifications in road planning, designing and operating procedures, a possible shift towards outcome-based specifications in procurement, more emphasis on defining mitigation goals and an adapted approach to evaluate mitigation performance demand a new mindset, different skills and expertise and a more transdisciplinary way of working. They also possibly require organisational changes that allow engineers and environmental experts to work in closer collaboration as well as new regulations on changes in procedures and the division of responsibilities. A different time planning in road projects may even be required as proper evaluations of road mitigation performance need to start long before the measures have been installed. And staff may have to be trained to better prepare them for new tasks and increase their understanding of the ecological context in which these tasks have been developed.

Finally, further efforts are needed in strengthening the cooperation between all stakeholders involved in solving road-wildlife conflicts across Europe and beyond. It is vital to exchange new knowledge and best-practices in order to avoid repeating mistakes and increase the effectiveness of our mitigation actions. Cooperation is also essential to address new challenges, such as climate change. Only then can we have a chance of creating a road network that is safe for both wildlife and people.

On the road again..... Close collaboration is needed between all involved stakeholders to make roads safe for both wildlife and people.

SAFEROAD Deliverables

Technical reports:

1 Technical report 1 - *Roads and wildlife: Legal requirements and policy targets* (Helldin et al. 2016)
2 Technical report 2 - *Guidelines for outcome-based specifications in road mitigation* (Van der Grift & Seiler 2016)
3 Technical report 3 - *Modelling the performance of road mitigation strategies: Population effects of permeability for wildlife* (Seiler et al. 2016)
4 Technical report 4 - *Cost-efficacy analysis: wildlife and traffic safety* (Seiler et al. 2016)
5 Technical report 5 - *Road maintenance guidelines to improve wildlife conservation and traffic safety* (Rosell et al. 2016)
6 Technical report 6 - *Guidelines for evaluating the performance of road mitigation measures* (Van der Grift et al. 2016)
7 Technical report 7 - *Case studies on the effect of local road and verge features on ungulate-vehicle collisions* (Seiler et al. 2016)

Scientific papers:

8 *Van der Grift et al.* - Effectiveness of road mitigation for wildlife: A review
9 *Rytwinsky et al.* - How effective is road mitigation at reducing road-kill? A meta-analysis
10 *Ottburg & Van der Grift* - Effectiveness of road mitigation measures for a common toad (*Bufo bufo*) population in the Netherlands
11 *Rolandsen et al.* - You shall pass! A mechanistic evaluation of mitigation efforts in road ecology
12 *Seiler et al.* - Effects of roads on wildlife population viability
13 *Van der Grift et al.* - Estimating crossing rates at wildlife crossing structures: methods matter!

Other:

14 Movie: Tunnels for toads
15 Road Mitigation Calculator (www.roadmitigationcalculator.eu)

All deliverables are available through www.saferoad-cedr.org

Colophon

Authors

Edgar van der Grift
Andreas Seiler
Carme Rosell
Vanya Simeonova

SAFEROAD Project Team

www.wur.nl	Edgar A. van der Grift Vanya Simeonova Peter Schippers Arjan de Jong	Mirjam Broekmeyer Fred Kistenkas Fabrice Ottburg
www.slu.se	Andreas Seiler Guillaume Chapron Julian Klein Mattias Olsson	
www.minuartia.com	Carme Rosell Roser Campeny Valls Ferran Navàs Albert Cama	Marc Fernández
www.calluna.se	Jan-Olof Helldin Kristina Kvamme	
www.conservation.uni-kiel.de	Heinrich Reck	
www.rodis.ie	Eugene OBrien	
www.nina.no	Christer Moe Rolandsen Erling J. Solberg	

CEDR Programme Executive Board

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Elke Hahn
Ola-mattis Drageset
Adam Hofland
Marianne Lund Ujvári
Vincent O'Malley
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Udo Tegethof

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Saferoad office

Wageningen University & Research
Environmental Research
Droevendaalsesteeg 3
Building 101
6708 PB Wageningen
T +31 317 48 16 00

Project coordinator
Edgar van der Grift
E edgar.vandergrift@wur.nl

Contact person
Vanya Simeonova
E vanya.simeonova@wur.nl

www.saferoad-cedr.org

Partners