Chapter 1
.....Overview of International & Federal Activities

HABITAT FRAGMENTATION DUE TO INFRASTRUCTURE

A European Review on Habitat Fragmentation
Wildlife and Traffic - A Handbook for Identifying Conflicts and Designing Solutions

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Abstract: Habitat fragmentation, the splitting of natural habitats and ecosystems into smaller and more isolated patches, is recognised as one of the most important global threats to the conservation of biological diversity. Habitat fragmentation is mainly a result of changes in land use, but a major impact also results from the barrier effect caused by the construction and use of linear infrastructure of transportation systems. This problem has been recognised all over Europe, but the impact differs from country to country.

The project COST[1] 341 *Habitat fragmentation Due to Transportation Infrastructure* started in 1998, and 16 European countries and one NGO (European Centre for Nature Conservation) have been officially involved in the initiative.

The main objectives of the action are:
- To promote a safe and sustainable pan-European transport infrastructure through recommending measures and planning procedures in order to conserve biodiversity and reduce vehicular accidents and fauna casualties
- To increase the awareness of the problem
- To offer practical solutions and to exchange knowledge and expertise through workshops and presentations
- To bring together the different groups involved

The first main product of the project is a *European Review* on habitat fragmentation on a European level, based on state-of-the-art-reports from the participating countries. The project found a strong awareness of the problem throughout Europe and that a diversity of approaches to counteract and solutions have been tested. However, there is still a need for a systematic approach, retrofitting existing infrastructure where necessary, and integrating concerns on fragmentation in the planning of new ones. And frequently asked questions are: 'How do we do it?' 'How many passages are necessary?' 'When is the problem solved?' and 'Can it be cheaper?' The conclusions and recommendations of the review will be presented.

The second important outcome of the project is the handbook *Wildlife and traffic - A European handbook for identifying conflicts and designing solutions*. This is a solution-oriented handbook, based upon the accumulated knowledge of a broad range of experts from the participating countries and from numerous international contacts. It gives practical guidance to the various actors involved in the planning, construction and maintenance of transportation infrastructures. The barrier and fragmentation effects of infrastructure can be minimised during several phases of development and use, and often avoided if considered in the early phases of planning. It shows as well different solutions for the same problem in different countries. The handbook takes the reader through all the different phases, from the first steps of *strategic planning*, through the *integration of roads in the landscape*, the use of *mitigation measure*s such as over- and underpasses for different animals, the developing field of *compensatory measure*s, and to the use of different methods for *monitoring* and *evaluating* the chosen solutions.

This paper presents the major findings of the *European Review* and an overview of the solutions recommended in the handbook. The handbook will be published late 2003. The authors have been involved in coordinating the project and in writing the contents of the handbook.

IENE (Infra Eco Network Europe), a network of experts and authorities within the field of habitat fragmentation caused by construction and use of linear transportation infrastructure, was the applicant of COST 341. IENE is the framework in which the dissemination takes place.

The results of COST Action 341 will be presented in Brussels, Belgium, 13 – 15 November 2003. See: www.iene.info

Cost 341: http://www.cordis.lu/cost-transport/src/cost-341.htm

[1]COST = European Cooperation in the field of Scientific and Technical Research

Introduction

The Problem

As elsewhere, one of the most radical changes to the landscape of Europe over the past centuries has been the creation and extension of infrastructure. Local roads, tracks and trails have extended into the landscape and even in the last areas of wilderness of Europe. All these lead to the severe fragmentation of natural areas, while urbanisation has rapidly increased the built-up area. Habitat fragmentation involves the splitting of natural habitats and ecosystems into smaller and more isolated patches. For example, habitat fragmentation reduces the availability and the suitability of adjacent areas for wildlife.

Nature organisations, researchers and authorities have expressed their concern over the impact of fragmentation. The general public reacted at the steadily growing number of animal casualties on roads and railways. Impact studies in several countries have underlined the risks related to reducing the size of remnant patches of habitat and, as a consequence, increasing the edge and barrier effects. The consequences for wildlife of constructing transport infrastructure include traffic mortality, habitat loss and degradation, pollution, altered microclimate and hydrological conditions, and disturbance caused by increased human activity in adjacent areas. In addition, roads, railways and waterways impose movement barriers to many animals, barriers that can isolate populations and lead to long-term population declines.

COST 341 Habitat Fragmentation Due to Transportation Tnfrastructure

Only during the past decade has there been sustained, international collaboration to review knowledge and expertise about the wider impacts of fragmentation due to transportation infrastructure and about the possibilities to avoid and mitigate it.

Fig. 1. Transportation infrastructure can fragment habitats, but building fauna passages can mitigate habitat fragmentation. (Photo by Peeters and Slagboom BV)

Mitigation of these adverse effects on wildlife to obtain an ecologically sustainable transport infrastructure needs a holistic approach that integrates both the social and ecological factors operating across the landscape. Hence, one of the challenges for ecologists, road-planners and engineers is to develop adequate tools for the assessment, prevention and mitigation of the impacts of infrastructure.

In 1997, the representatives of several European countries belonging to the Infra Eco Network Europe (IENE) identified the need for co-operation and exchange of information in the field of fragmentation (Teodorascu, 1997). The IENE members recognised the need for support from the European Commission, leading to the start of COST 341, in 1998. It has been the task of the COST 341 Action to address the issues associated with *Habitat fragmentation due to transportation infrastructure*. (COST is an intergovernmental framework for European Co-operation in the field of Scientific and Technical Research, allowing the co-ordination of nationally funded research on a European level. COST Actions cover basic and pre-competitive research as well as activities of public utility. COST has 33 member countries.) (COST 341 Management Committee, 1998, MoU). 16 countries (Austria, Belgium, Cyprus, The Czech Republic, Denmark, France, Hungary, Norway, Portugal, Romania, Spain, Sweden, Switzerland, The Netherlands, The Republic of Ireland, United Kingdom), and one NGO (The European Centre for Nature Conservation, ECNC) signed the Memorandum of Understanding and have participated in the action.

The COST 341 Action had two major goals. First, to produce a *European Review*, describing the European situation and the main future challenges. Second, to develop a handbook presenting all known measures for how to avoid, minimise or mitigate the barrier effects caused by transportation infrastructure.

As a tool for distributing existing knowledge about habitat fragmentation, an on-line database was established. The *COST 341 Database* offers information about data on existing literature. It is continuously up-dated, and is accessible through the IENE web-site (www.iene.info).

European Review

The European Review (Trocmé et al 2003) describes the state-of-the-art for Europe, and underlines the importance of taking habitat fragmentation into consideration in all the different stages of the development of transportation networks (planning, designing, constructing and maintaining the network). The review is built upon national reports from the participating countries, and most of these national reports are published separately in the countries themselves. The review presents a common overview of the major ecological concepts that aid to understand the large-scale effects of infrastructure on wildlife and of the major ecological impacts of infrastructure.

We distinguish between five major categories of primary ecological effects that negatively affect biodiversity and a group of secondary effects. The five primary effects:

1. Loss of wildlife habitat: this is the physical loss in land cover as natural habitat by transportation infrastructure as asphalt. Roads and roadsides cover an area of about 0.3% of the land surface of Norway to more than 5% in the Netherlands.
2. Barrier effects: this is probably the greatest negative ecological impact because the dispersal ability of individual organism is one of the key factors in species survival. For some species transportation infrastructure is a complete barrier due to fences (large mammals) or because the substrate is inhospitable (some invertebrates). Other species avoid areas near roads. This is often related to the traffic density or the secondary development along the road. Wild reindeer in Norway under-utilise their grazing resources within 5 km of roads.
3. Fauna casualties: this is mostly the best-known and most visible impact of traffic on wildlife. Traffic mortality of common species is a small proportion (1-4%) of the total mortality. However for more sensitive species traffic can be a major cause of mortality. In Flanders, for instance, more than 40% of the badger population is killed on the roads each year. Such losses are a serious threat to the long-term survival at the regional level.
4. Disturbance and pollution: road and railways alter the ecological characteristics of adjacent habitats. Beside hydrological changes there is chemical pollution, noise and vibrations and lighting and visual disturbances. Artificial light can affect growth regulation in plants; disturb breeding and foraging behaviour in birds. Lights attract insects and can result in increased bat mortality.
5. Ecological functions of verges: the value of verges is a much debated topic. Verges can be important for wildlife; for instance, through careful management verges may complement and enrich landscapes where much of the natural vegetation has been depleted. But it can also lead animals to places where mortality is increased or aid the spread of alien species. Verges can provide links in an ecological network, especially in agricultural landscapes. Positive values are more common in northern Europe and problems mostly associated with southern Europe.

Changes in land use, human settlement or industrial development induced by the construction of transportation are secondary effects. These secondary effects are usually outside the responsibility of the transport sector, but should be considered in Strategic Environmental Assessments. Another important secondary effect is the increased degree of human access to otherwise undisturbed wildlife habitats.

Throughout Europe the process of addressing the impact of habitat fragmentation due to transportation infrastructure is still in its infancy. Nevertheless, it is also clear that positive progress has been made in tackling the negative effects. Valuable experiences can be learned from densely populated and intensively developed countries like The Netherlands, where the problems of habitat fragmentation have long been recognised. Many other European countries have also developed national programmes of research into the effects of infrastructure on biodiversity, the findings from which must be used to inform the planning and design procedures for new infrastructure. But there is still a long way to go before ecological tools are fully developed and implemented in transportation planning.

Major findings

Habitat fragmentation has been recognised as one of the most significant factors that contributes to the decline of biodiversity in Europe, and should thus be a major concern for society. Transportation infrastructure is often considered to be a principal cause of fragmentation.

In general, species with large area requirements or strong dependence on a specific type of habitat will be most vulnerable to habitat fragmentation. Unfortunately, these are quite often the species that are of greatest conservation concern, *e.g.,* wild reindeer in Norway, badgers in the Netherlands, or the Iberian lynx in Spain.

In summarising the experiences of the COST 341 countries, the following principles and recommendations should act as guidelines for dealing with the issue of fragmentation of natural habitats by transportation infrastructure in the future:

- Habitat connectivity is a vital property of landscapes, especially important for sustaining animal movement across the landscape. It should be a strategic goal in the environmental policy of the transport sector, and infrastructure planning should be focused on the landscape scale.
- Sustaining animal movements across the landscape by means of ecological networks should be a strategic goal in the environmental policy of the transport sector.
- European and national nature protection legislation needs to be integrated in the planning process at the earliest possible stage. Only an interdisciplinary approach involving planners, economists, engineers, ecologists, landscape architects, etc., can provide all the necessary tools for addressing fragmentation successfully. The approaches need to be integrated at all levels of the transportation network.
- The fragmentation of natural habitats by transportation infrastructure is a problem, which cannot be solved without an acceptance of the issue at a policy level, or without interdisciplinary co-ordination and co-operation at scientific and technical levels. Public involvement is also essential to ensure the success of the chosen solutions.
- Because of the complexity and widespread nature of the problem, an ongoing exchange of knowledge between countries is vital. A systematic and uniform approach to collecting information on mitigation techniques and measures is necessary if statistics are to be compared between countries.
- When planning and upgrading new infrastructure, the primary objective should be to avoid fragmentation. If this is impossible to achieve, a package of mitigation measures should be designed, and where residual impacts remain, compensatory measures should be employed as a last resort.
- Mitigation measures such as fauna underpasses and overpasses have a proven record of success. However, mitigation should not only focus on the more prestigious passages for large animals. Much can also be done, at relatively low cost, to increase the permeability of the existing and future transportation infrastructure by adapting the design of engineering structures to wildlife.

Fig. 2. Adapted bridge under highway in The Netherlands. (Photo by H. Bekker)

- Monitoring programmes to establish the effectiveness of mitigation measures are essential and need to be standardised. The cost of monitoring programmes should be included in the overall budget for new infrastructure schemes.

- Maintenance of measures needs to be integrated in infrastructure planning and design from the start, and an appropriate budget needs to be assigned.

The Handbook

The main topic of the handbook *Wildlife and traffic- a European handbook for identifying conflicts and designing solutions* (Iuell et al. 2003) is to minimize ecological barriers and fragmentation effects of transportation infrastructure. The primary target groups for the handbook are those involved in the planning, design, construction and maintenance of infrastructure, as well as decision makers at the national, regional and local levels. The handbook is solution-oriented, based upon the accumulated knowledge of a broad range of experts.

The barrier- and fragmentation effects of infrastructure can be minimised during several phases of development and use, and even avoided if considered in the early phases of planning. The handbook takes the reader chapter-by-chapter through all the different phases, from the first steps of *strategic planning,* through the *integration of roads in the landscape*, the use of *mitigation measures* such as over- and underpasses for different animals, the more unknown field of *compensatory measures*, and to the use of different methods for the *monitoring* and *evaluation* of the chosen solutions.

As the title of the handbook indicates, the solutions and measures described in the handbook are designed to deal with different kinds of transportations systems, not only roads. Railways can also have a huge impact on nature and create barriers even though rail networks and traffic are far less dense than roads. In several European countries there is a massive network of waterways used for transportation. Especially the man-made canals with steep sheet piling are barriers for wildlife.

The European Approach

The handbook is produced to cover the many different circumstances found across Europe. There are important differences between the countries regarding cultural, political and scientific contexts of transport infrastructure development at local, regional and national levels. A good solution in one country may be less effective or less suitable in another. How to deal with all these differences? With broad general solutions on the one hand and more detailed local solutions on the other.

Therefore, the design of fauna passages and other mitigation measures used differs between countries, partly due to different traditions, and partly due to different physical and ecological contexts. As a result, there are few general formal standards for the design, construction and maintenance of mitigation measures in Europe. Based on experience and the evaluation of alternative structures, designs can be improved and eventually standards can be formulated. The ongoing exchange of knowledge and experience across Europe and beyond is necessary to develop these new standards.

With this as a background, it is important to empahsize that there are no solutions that fit completely. It remains necessary to adapt and adjust measures to the geographical context, as well as to the specific needs and possibilities of the location. The handbook is, therefore, no substitute for the advice of local experts such as ecologists, planners and engineers, and should be used in conjunction with their advice.

Integrated Solutions

This approach forces infrastructure planning:

- To look outside the normal bounds of the transport corridor
- To examine the development of the whole infrastructure network and wider land use issues including national and international spatial planning strategies
- To link the several phases of development and use from planning through maintenance.

While habitat fragmentation is increasingly taken into account when new infrastructure is planned, there remain many existing stretches of roads and railway lines where mitigation measures are badly needed. This need often increases when new infrastructure is built, which may result in changing the ecological impact of existing infrastructure. When designing measures to counteract habitat fragmentation, the focus should, therefore, be on three key questions:

- What is the impact of the infrastructure network as a whole?
- When and where are measures needed?
- What are the criteria for success?

The barrier- and fragmentation effects of infrastructure can be eliminated or minimised in different ways and during several phases of its development and use. If the “right decisions” are made in the early phases of planning, fragmentation problems can be completely avoided. The barrier effect can be reduced by integrating the infrastructure into the surrounding landscape, or by building secure and sufficient crossing points for wildlife. Also during use and maintenance of existing infrastructure, consideration should focus on how to reduce the barrier effect of infrastructure and to de-fragment landscapes.

The best practice approach promoted by this handbook for planning new or upgrading existing transport infrastructure adopts the following principles for coping with the threat of habitat fragmentation.

- Avoidance > Mitigation > Compensation
  The basic philosophy is that prevention is better than a cure in avoiding the negative effects of habitat fragmentation. Where avoidance is impossible or impractical, mitigation measures should be designed as an integral part of the scheme. Where mitigation is insufficient or significant residual impacts remain, the compensatory measures should be considered as a last resort.

- Finding integrated solutions to road planning requires information on how to plan the routes of transportation infrastructure to minimise impacts within the constraints of cost and engineering. Assessment of new infrastructure will increasingly focus on integrated solutions attempting to find the route and design producing the least impact and greatest benefit to the greatest number of interests. The integration process is especially difficult in geographic areas where the competition for space is very high, such as narrow valleys, coastal strips, etc. Such areas, already under pressure from housing, industrial activities, farming and natural drainage, are fragmented into linear strips by road and railway development with negative impacts on most interests.

- Integrated solutions to infrastructure planning can be viewed from several scale levels, namely, the site, landscape and regional levels.

- Integrated solutions can be achieved by providing a package of measures: fauna passages at highways, provincial roads and local roads, cooperation and appointments with owners and maintainers of adjacent areas, coherent maintenance.

Planning Tools
Minimising habitat fragmentation should be done when planning new infrastructure or when planning the upgrading of existing infrastructure. By carrying out Strategic Environmental Assessments (SEA) on programmes and Environmental Impact Assessments (EIA) on projects it is ensured that environmental considerations are included already at an early stage. The overall aim of the SEA and the EIA is to identify possible environmental impacts of plans and projects before a decision about implementation is made.

The definition of the study area is crucial for a meaningful study of fragmentation issues, and in many cases it is necessary to evaluate the potential impact in a regional context. Different data and methods can be used in the planning process, and for defining conflict points between ecological infrastructure and man-made infrastructure for transportation.

Adapting to Surrounding Landscape
When the decision is made to build new highways, railways or waterways, it is still possible to minimise the barrier effect and thus fragmentation by adaptation of the infrastructure to the adjacent landscape and ecology. Good alignment and sensitive design can be employed to minimise the magnitude of these effects.

Mitigating Measures
The most comprehensive chapter of the handbook describes individual technical measures designed to mitigate the negative effects of transportation infrastructure. It includes landscape bridges, wildlife over- and underpasses, culverts and pipes for aquatic species, and several measures for reducing wildlife mortality. For each measure a general description is given followed by important information on design and points for special attention. Technical specifications for materials and technical design details are presented if they are of particular importance to ensure the functionality of the measure.

Fig. 3. Overpass in Norway over train. (Photo by B. Iuell)

Some measures have been well tested and considerable experience has accumulated. Others are new and still being developed and tested. This means that some recommendations may be different from those in existing handbooks, especially the earlier ones. In some cases, recommendations in a particular country may differ from the ones presented here because they take into account regional issues such as a specific climate or habitat.

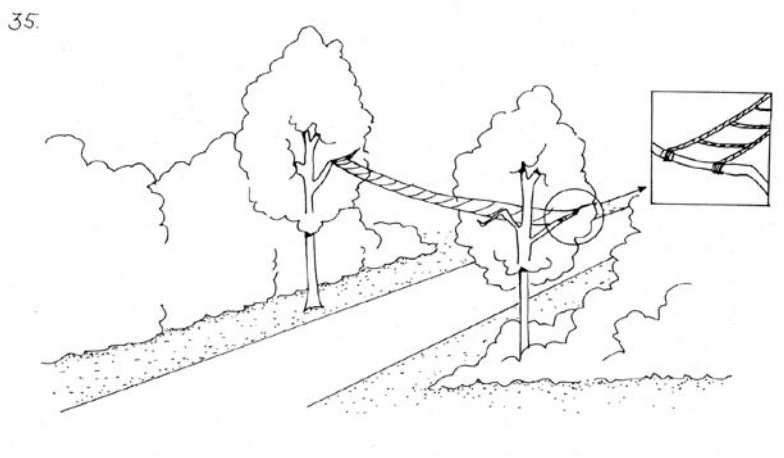


Fig. 4. Tree bridges are relatively new for tree living mammals.

Some measures that are still widely used have been shown not to be effective. Such measures are mentioned in the handbook, but no design details are given, since their use is not recommended in future schemes.

1. Fauna passages as part of a general landscape permeability concept
Fauna passages and other structures adapted to increase the crossing of transportation infrastructure by animals should never be considered in isolation. They are part of a general *permeability concept* to maintain the necessary contact within and between populations of animals. This concept emphasises the connectivity between habitats on at least a regional scale and considers not only the transportation infrastructure, but also the distribution of habitats and other potential barriers such as built-up areas. Fauna passages can then be regarded as small but important elements used to connect habitats by enhancing the movements of animals across a transportation infrastructure.

At a more specific level, a permeability concept can be produced for a particular road or railway project. All connecting elements, such as tunnels, viaducts or elevated roads, river crossings, culverts and passages designed specially for animals should be integrated in such a concept. Again, the primary objective must be to maintain the permeability of the infrastructure for wildlife, to ensure the connectivity of the habitats at a larger scale.

Mitigation measures, and in particular fauna passages, are necessary if a transportation infrastructure bisects important patches of habitat or creates barriers to migration routes. Fauna passages are necessary for animals where:

- A road, a waterway or railway line results in significant damage or loss of special habitats, communities or species.
- Infrastructure affects species particularly sensitive to barriers and traffic mortality.
- The general permeability of the landscape, i.e., the connectivity between habitats in the wider countryside, is significantly impaired by the infrastructure development.
- Other, less costly measures are unlikely to be effective.
- The road or railway line is fenced along its length.

The type of measure to be used, the location, the numbers, and how to make it effective, are all matters that will have to be dealt with in each specific project.

2. Choice of appropriate measures

Fauna passages and modifications to infrastructure that enhance safe animal movements are the most important measures for mitigating habitat fragmentation at the level of a particular infrastructure. The selection of the most appropriate type of measure requires consideration of the landscape, habitats affected and target species. The importance of the habitats and species should be evaluated in a local, regional, national and even international perspective as part of an environmental impact assessment. In general, the more important habitat connectivity is to the species of concern, the more elaborate the mitigation measures have to be. Thus, where an internationally important corridor for movements of large mammals is cut by an infrastructure development, a large landscape bridge may be the only measure, which may help to maintain functional connectivity. In contrast, a small culvert may be sufficient to maintain a migration corridor for a locally important population of amphibians. In practice, however, there is rarely just one measure required to effectively mitigate habitat fragmentation. Instead, a package of integrated measures is required that addresses the detected problems as a whole. A combination of diverse measures suitable for different groups of animals will often be the best solution.

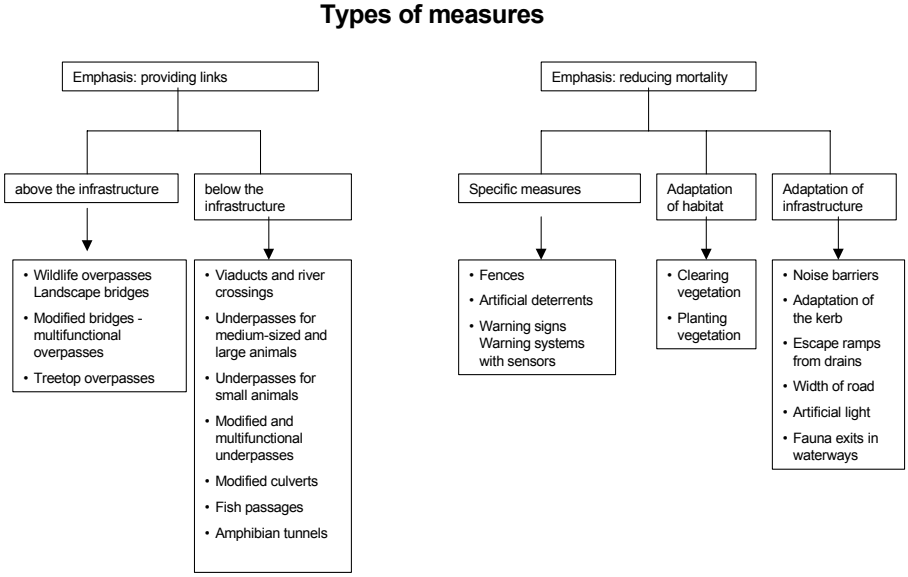


Fig. 5. Different types of measures to mitigate habitat fragmentation.

3. Density of passages

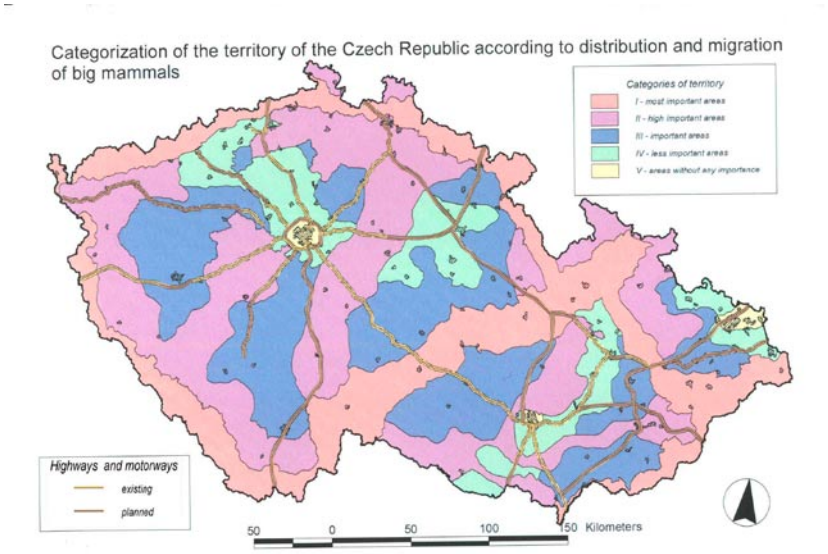
The density of fauna passages required to effectively maintain habitat connectivity is a major decision in planning mitigation measures. Deciding on the required number and the type of measures will depend on the target species and the distribution of the habitat types in the area. Sometimes one wide passage will be appropriate, whereas other problems will be better tackled by a larger number of smaller-scale measures. An additional argument for constructing several passages is to 'spread the risk" in case a passage is not used as predicted.

In order to determine the number of passages all opportunities for animals to cross an infrastructure have to be considered, including the ones that may already be available, e.g., due to a watercourse passing the road by a culvert or a road being led through a tunnel.

The landscape in many parts of the Czech Republic is relatively unfragmented by infrastructure, and a patchwork of forests and agricultural areas offers good habitat for many mammal species. The motorway network will be enlarged in the coming years. In order to preserve landscape connectivity for mammals, the following steps have been taken:

1. Actual and potential distribution and movement corridors of large and medium-sized mammals were mapped.
2. Based on these data the overall importance of the different regions for mammals was classified.
3. The use of different types of passages and the behaviour of mammals in the neighbourhood of the existing motorways was investigated.

Based on these results, recommendations were formulated on the density of passages.



Example 1. Recommendations for the density of fauna passages for mammals in the Czech Republic.

Categories of area		Mammal category		
Cat	Area	Red Deer	Roe Deer	Red Fox
I	Exceptional importance	3 – 5 km	1,5 – 2,5 km	1 km
II	Increased importance	5 – 8 km	2 – 4 km	1 km
III	Medium importance	8 – 15 km	3 – 5 km	1 km
IV	Low importance	not necessary	5 km	1 km
V	Unimportant	not necessary	not necessary	1 – 3 km

Maximum recommended distance between passages for different mammal categories in areas of varying importance (source: Hlavac and Andel, 2002)

In general, the density of passages should be higher in natural areas, e.g., forests, wetlands, and in areas with traditional agriculture, than in densely built-up or intensively-used agricultural areas. However, in areas where many artificial barriers due to transportation infrastructure or built-up areas exist, fauna passages can be essential for maintaining the general permeability of the landscape. In such cases solutions can be integrated with all remaining open corridors.

4. Location of passages
The location of the passages has to be decided on the basis of sound knowledge regarding animal movements and the distribution of important habitats. Where clearly defined animal trails exist, passages should be placed as close to them as possible. Often topography and landscape structure can help to identify likely migration routes such as valley bottoms, streams, hedgerows, and continuous woodland. Where the principal aim of a passage is to link particular types of habitats, the passage has to ensure the connectivity to suitable habitat on either side of the infrastructure. Other barriers existing in the surrounding landscape have to be considered when locating passages. Access to the passage must be guaranteed in the future.

5. Integration with surroundings
Fauna passages should be well connected to the surroundings, either by way of habitat corridors leading towards passages for small animals or by way of guiding lines for larger ones. As a result of the channelling effect of guiding structures, the probability of an animal encountering a fauna passage can be improved considerably. Barriers that prevent or hinder animals from reaching passages need to be removed or mitigated. Where other infrastructure elements occur in the vicinity, an integrated approach to defragmentation, including all infrastructures is required.

Fig. 6. Tree stumps as guidance for amphibians, insects and small mammals under a viaduct. (Photo by H. Cormont)

6. Adapting engineering works for use by animals
Engineering works are designed and constructed for crossings between two different flows. These can be two flows of traffic (e.g., one road crossing the other with an overpass), traffic and water (e.g., a culvert leading water under a road or an aqueduct leading water over it), and more recently traffic and fauna. Road bridges or culverts are mostly not used by animals to cross a road or railway line, because they don't fulfill the requirements for more demanding species. However, if the demands of animals are taken into account, such traditional structures can often be adapted to serve as fauna passages. Such passages, combining the flows of fauna and traffic or fauna and water, are called joint-use passages.

7. Solving problems on existing roads and railway lines
In Europe, thousands of kilometres of motorways and other roads as well as railway lines had been built before people became aware of the potential problems they caused for wildlife. An obvious need for adapting existing structures arises:

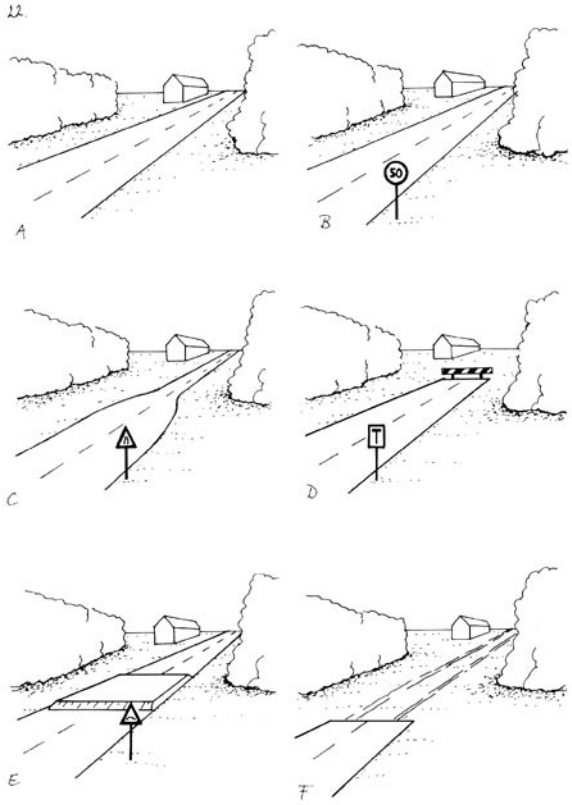
- When a high number of collisions between animals and vehicles are registered
- When model studies pointed out that connectivity of two areas provide a more stabile population of the target species
- When for viaducts or other large civil works a little adaptation works out in a genuine alternative to specific passages

When planning adaptive measures for existing infrastructure the general principles discussed in the handbook should be considered, not just the particular local situation. This is particularly the case when fences are installed to reduce the number of collisions between vehicles and animals. Fences will increase the barrier effect and should never be installed without accompanying measures. Most measures described in the handbook are also suitable for existing infrastructure or may be adapted accordingly.

The principles for dealing with existing infrastructure can be summarised as follows:

- Construction of new engineering works (passages, etc.) above or below existing roads may give the best results but is often more expensive.
- Adaptation of existing engineering works that have been designed for other purposes (e.g., water, forestry) are often not an optimal solution, but in general less expensive. A large number of adapted passages, etc., may, in some cases, give better results for the same price as constructing one new specific passage.
- Modification of maintenance procedures (e.g., treatment of vegetation) may improve the use of existing engineering works by animals. Different types of measures can be beneficial for wildlife to minimize the barrier effect and the mortality of smaller roads, such as:

    - Reducing the width of the infrastructure: no tarmac, two paved strips as agricultural track
    - Reducing the amount of traffic: temporal closure, one way and dead-end roads
    - Reducing the speed of the vehicles: (temporally) speed limits (including fines), speed ramps



8. Maintenance and monitoring of mitigation measures

All mitigation measures have to be routinely inspected and maintained to ensure their functioning in the long term. Maintenance aspects, including the costs of maintenance, have to be considered at the earliest possible stage, i.e., when a measure is designed. Planning should define the type and frequency of maintenance procedures and the organisation of maintenance in terms of responsibility. Specific maintenance aspects are dealt with in the sections on the different measures.

Maintenance of measures is closely linked to monitoring aspects. Monitoring procedures are mainly designed to check whether a measure fulfills its purpose, but at the same time they can identify maintenance deficits and needs.

Compensatory Measures

Despite good planning and use of mitigation measures aimed to avoid or reduce adverse impacts on natural values, it is impossible to completely avoid the negative effects of infrastructure development. This realisation has led to the principle of ecological compensation in many European countries. *Ecological compensation* implies that specified natural habitats and their qualities, such as wetlands or old-growth forests, should be developed elsewhere when they are impacted by an approved project. When compensation is implemented, the measures should balance the ecological damage, aiming for a 'no-net-loss' situation that benefits both habitats and their associated species. Ecological compensation may be defined as creating, restoring or enhancing natural qualities in order to counterbalance ecological damage caused by infrastructure developments.

Compensatory measures are fundamentally different from the protection or enhancement of natural values (nature conservation policy). However, compensatory measures must be in line with local and national nature conservation targets. In contrast with landscaping and mitigation measures, ecological compensation is generally undertaken outside the construction area. As initiators of projects are held responsible for the implementation of the compensatory measures, developers should put serious effort toward acquiring land in the neighbourhood of the infrastructure for compensation objectives. By locating the compensation sites properly, for example, spatially linked to nature reserves or networks, ecological functions and relations may be protected or enhanced.

Compensation may include conversion of land for the development of new nature qualities (woods, river beds, etc.). Habitat enhancement may encompass the adaptation of farming activities towards the development of nature qualities (e.g., meadow-birds or plants). Artificial wetlands may be created in order to attract species such as amphibians and reptiles.

Monitoring and Evaluation

To identify examples of good practice and to provide the basis for codes of good practice, we need to monitor the success of the various methods for mitigating the effects of habitat fragmentation. The handbook provides detailed guidelines on how to monitor the success of mitigation measures and gives advice on maintenance issues.

Monitoring requires clear definition of the objectives of the measures, and programmes should be planned in parallel with the design of the measures themselves.

After the construction of roads, railways and waterways, the application of monitoring is of crucial importance as it is this mechanism that allows us to check the effectiveness of measures, which have been applied in order to reduce the impact on habitat fragmentation.

A well-designed monitoring scheme will help to achieve several goals:

- To detect failures in the installation, construction or maintenance of measures
- To establish if the mitigation measures fulfil their purpose
- To evaluate if the measures provide long-term mitigation for the species and the habitats

In short, monitoring will contribute to establishing whether or not suitable and sufficient mitigation measures have been provided for during the planning and construction phases of a transport infrastructure, guaranteeing minimal impact on the fragmentation of animal populations and habitats.

The dissemination of monitoring scheme results is also very important for gaining knowledge of the development of more effective and less expensive measures. Therefore, an important objective of monitoring is also to help planners and road- and railway designers to:

- Avoid repeating the mistakes
- Provide new information for improving the design of mitigation measures
- Identify the measures with an optimum relation between cost and benefit
- Save money for future projects

Monitoring schemes should be an integral part of the routine technical management that leads to the adaptation and improvement of the design of measures that avoid or reduce the effects of transport infrastructure on the fragmentation of habitats.

A wide number of methods can be applied for the monitoring of mitigation measures. In this handbook the description of the most commonly used methods to record fauna casualties and to check the use of fauna

passages is provided, giving information about the procedures, variables to be recorded and standards to be achieved. Standards of reference cannot be generalised because they depend on many factors, such as the population level of target species, the landscape conditions or the objective of the measure. For this reason, only some orientations about which standards can be used for the evaluation are provided.

Fig. 7. Ledge for small animals in culvert with ink-method. (Photo by H. Bekker)

Modified Bridges Over Infrastructure – Multifunctional Overpasses

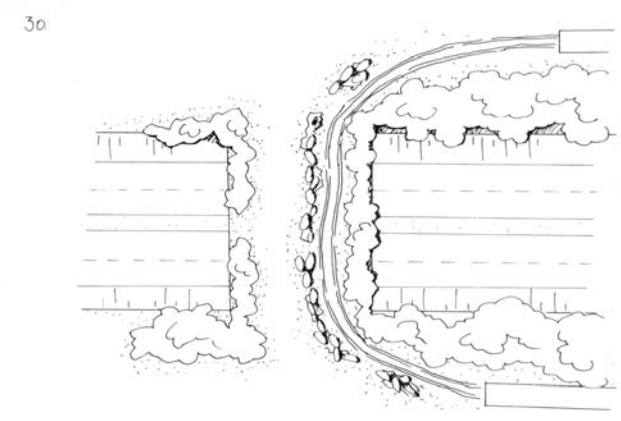
General Description and Targets

There are large numbers of bridges for local roads, forestry or agricultural tracks. They are usually covered with concrete, asphalt or tarmac and are hardly used by animals. With the simple addition of an earth-covered strip an improvement can be achieved. Such earth-covered or vegetated strips are used by invertebrates, small vertebrates, carnivores and occasionally by ungulates. They favour the dispersal of animals. They are no alternative for specific wildlife overpasses, but an additional measure to improve the general permeability of infrastructure barriers. If all local bridges outside built-up areas were equipped with an earth-covered strip, this would contribute to a mitigation of the barrier effect at little cost. Wider overpasses can be combined with local roads or forestry tracks as long as traffic intensity is low.

Design Requirements

Road bridges with vegetated strip

- For the vegetated strip, a minimum width of 1 m recommended.
- Soil cover does not have to be deep (0.3 m).
- In most cases spontaneous vegetation is sufficient and no seeding is required.
- The road surface on lightly used bridges should not be tarmacked.
- The modification of bridges with strips is recommended only when traffic intensity on the bridge is low.



Example 2. Adapting engineering works

Joint-Use Overpasses

- Roads, cycle paths and forestry tracks, etc., should only be combined with a wildlife overpass if traffic intensity is low.
- The width of any road on an overpass has to be added to the width required for the fauna passage, i.e., joint-use passages in general have to be wider than specific overpasses.
- Any paths or forestry tracks should be placed towards one of the outer edges of the overpass to ensure a maximum width of vegetated and undisturbed area.
- Access for the animals onto the overpass must not be hindered by roads at the entrance to the overpass.

On landscape bridges, a lateral road that is likely to be the source of disturbance may be separated from the vegetated part of the overpass by an earth wall. Where a lateral road is used very lightly, separation is not necessary.

Conclusions

A significant challenge to ecologists, road-planners and civil engineers alike is the establishment of an ecologically adapted, safe and sustainable transportation infrastructure system. The key to success is the adoption of a holistic approach that allows the whole range of ecological factors operating across the landscape to be integrated within the planning process. The problem of fragmentation and its solutions are universal; therefore, joint research and combined international efforts are required. To develop adequate tools for assessing, preventing and mitigating against the ecological impacts of infrastructure requires interdisciplinary work.

It is the hope of all the participants of the COST 341 Action that the *European Review* and the handbook *Traffic and Wildlife* will be useful tools for both engineers, ecologists, decision makers and others in the future development and use of the European transportation infrastructure.

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