# New approaches for ecological consideration in Swedish road planning

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**Abstract**

*Habitat loss and fragmentation due to transport infrastructure is recognised as a growing problem in northern European countries. Until recently, environmental impact assessment (EIA) in Sweden focused mainly on rather small-scaled, local effects. To achieve a sustainable development in land use, however, ecological impacts of road and railway construction must also be considered on a landscape scale. There is urgent need to develop appropriate methodology to consider landscape ecological effects of roads and traffic at all decision levels of the infrastructure planning process. For this purpose, we need*

- *a better understanding of how road networks influence natural processes and dynamics in the landscape;*
- *methodologies for the prediction and evaluation of effects; and*
- *concepts for measures to prevent, mitigate, or compensate for impacts on nature.*

## Introduction

During this century, roads and railroads have become an important landscape feature in most industrialised countries. In Sweden, the entire roads network, including private and forestry roads, totals a length of about 415,000 km (in 1995). The total area set aside for road communication (roads and right-of-ways) covers about 5,000 km$^2$ or 1.2% of the Swedish land surface (Swedish National Road Administration, SNRA, database). This approximates the total area designated for national parks in Sweden (4,877 km$^2$).
Road construction causes a considerable loss of natural habitats. However, the impact of roads on the environment is not solely restricted to the paved surface of the road or its verges. Effects of

pollution, and altered microclimatic and hydrological conditions, easily spread throughout the landscape and cause a broad-scale degradation of environmental quality (see Scanlon 1991, Reck & Kaule 1993). In addition, roads impose dispersal barriers to many, if not most non-flying terrestrial animals. Roads divide habitats and cut through existing topographical and vegetation structures, which leads to a fragmentation of the landscape in a literal sense (compare Reichelt 1979, Mader 1984, Cuperus et al. 1993). Thus, roads cannot be considered simply as transportation lines where the influential zone is a narrow corridor; roads relate to the landscape as a whole.

In Sweden, environmental concern for landscapes arose in the beginning of this century due to the construction of the first highways and hydroelectric power plants. In the 1930's, a special consultant bureau was established to advise landscape architects and road planners (Nihlén 1966). Since 1987, approved environmental impact assessments (EIA) are required for road construction (Pettersson & Eriksson 1995). During the 1990's, increased environmental responsibility of the transport authorities, together with the implementation of Agenda 21 into national policies and plans, stimulated a greater engagement of road planners in ecological-environmental concern. In 1994, the SNRA initiated a project with the goal to develop appropriate methodology for assessment of ecological impacts for integration into the road planning process. The project aimed to improve adaptation of roads with the ecological patterns and processes occurring in the landscape. The Swedish National Rail Administration, as well as the Swedish Environmental Protection Agency, support the project. A first concept for ecological effect evaluation in the EIA was developed and is presently beeing tested in case studies. Principal recommendations for ecological consideration in the planning process have been published as a complement to the existing EIA guidelines of the sector (SNRA 1995, 1996a, b). In this paper, we summarize these concepts to stimulate further discussion and development at an international level.

## Identifying goals and concepts

### *EIA in Sweden*

In Sweden, EIA for roads has been formally required since 1987, and from 1992 - 93 was also applied to strategic planning of roads. Preparations are now ongoing for the integration of environmental adaptation in an upcoming communication plan that will be carried out by a parliamentary committee. As stressed by the Road Transport Research Bureau of OECD (1994), environmental effects should already be considered at the strategic level of decision making, in the strategic environmental impact assessment (SEIA) concerning policies, plans and programs at a regional and national scale.

According to the new EIA guidelines of the SNRA (1995), evaluation of ecological effects on wildlife populations and landscape ecosystems should be one part in the EIA document. In many cases, however, ecological evaluations have to be based upon expert judgements, because no relevant experiences exist and the empirical data cannot be gathered within the given time limits of the EIA. Due to the lack of methods for ecological effect evaluation, it is common practise to focus at the descriptive level, i.e. to present lists of the occurring species, habitats or specific landscape features. Predictions of possible consequences of road construction for future development of the landscape (including changes in human settlement, traffic flow, or land use), and their consequent effects on ecological qualities and processes, can rarely be found. Where predictions are made, assessments of uncertainties are generally missing. Overall, ecological effect evaluations within the EIA document at present provide only little advice to road planners in Sweden (RRV 1996) as well as elsewhere (Treweek et al. 1993).

*Shortcomings in nature conservation practices*

Nature conservation in Sweden focuses on the protection of selected objects such as species or biotopes, but pays rather little attention to the sustainable management of landscapes. This object-orientated approach may be adequate for site related conservation works, but for use in infrastructure planning, it has proven to be insufficient (RRV 1996).

First, the general approach focuses on spatial explicit patterns, but it pays no attention to the ecological processes that link these patterns throughout the landscape. The natural environment is usually described in terms of geological and vegetational characteristics and thus appears rather stable from a human point of view. Ecological processes are more dynamic and complex.

Second, because not all nature is considered as valuables in the common approach, measures to mitigate adverse effects are only required for high ranking, protected areas. No mitigation concepts are developed for the landscape itself.

Third, categorisation of nature is dependent upon the investigator's perspective and may therefore fail to identify important patterns that are dominant on another scale. This problem is especially apparent in GIS-based analysis of remotely sensed landscapes, since grid size of the image may not necessarily be identical with the ecological grain of the landscape.

Fourth, the common approach is static with only little consideration of the temporal and spatial dynamics in the landscape ecosystem. Descriptions of a status quo in the landscape offer no tool for prediction and evaluation of composite effects of landscape changes.

Thus, a more holistic and process-oriented approach is needed to achieve a sustainable utilisation of landscape resources.

## Alternative approaches

*Ecological infrastructure*

First attempts to integrate process-orientation in the analysis of landscape pattern are, for instance, the concepts of landscape connectivity (Baudry & Merriam 1988), and ecological infrastructure (Van Selm 1988). Ecological infrastructure refers to the combined features in a landscape that enable and direct the exchange of species between ecosystems. Linear landscape elements as well as the spatial arrangement of biotopes in mosaic landscapes are known to affect dispersal in animals and plants (Saunders & Hobbs 1991, Wiens et al. 1993, Hansson et al. 1995). For quantification of these patterns, biotopes have to be classified according to their functional relationship in the landscape system rather than to their rank in a protection category, as is practised now. Important parameters are size, shape, proportion, and distribution of biotopes, their continuity in time and space, variation in internal structure, and the ecological contrast to adjacent biotopes.
Similar to the human-made, technical infrastructure, the ecological infrastructure is not spatially limited, as it composes a network that trespasses the entire landscape at different scales. It focuses on processes (exchange, transport, and communication) rather than on pattern, because the connecting features between landscape units may vary greatly. Therefore, the concept of ecological infrastructure is especially applicable to infrastructure planning.

*Ecological processes*

The concept of ecological infrastructure appears very useful, but is still to be validated by empirical studies, which focus directly on the relation between the spatial pattern and the ecological processes of interest. This can preferably be done using keystone species or signal species as bio-indicators for certain landscape situations (see Noss 1990, Spellerberg 1991). Processes that can be studied in bio-indicators at a landscape scale are e.g. movements, predation, reproduction, immigration rates, or population growth. Related ecological patterns are mortality rate, population density and genetic variation, home range sizes, or foraging behaviour. Since these processes and patterns are highly species-specific, the selection of indicator(s) must be done considering landscape composition, landscape scale, and type and amplitude of expected effects. In general, process-indicators at the landscape scale should be abundant, range throughout the landscape and show little or no specialisation to specific biotope types, but should be sensitive to habitat disturbances and fragmentation.
The selection of an adequate set of indicators for infrastructure planning should also refer to the hierarchical organisation of nature in ecological (e.g. individuals, populations, communities) and spatial levels (e.g. biotopes, landscapes, regions). Some indicator species may be studied more efficiently at the individual level, whereas others may be easier to study at the population or community level. Within the hierarchy, levels are strongly interdependent, but each

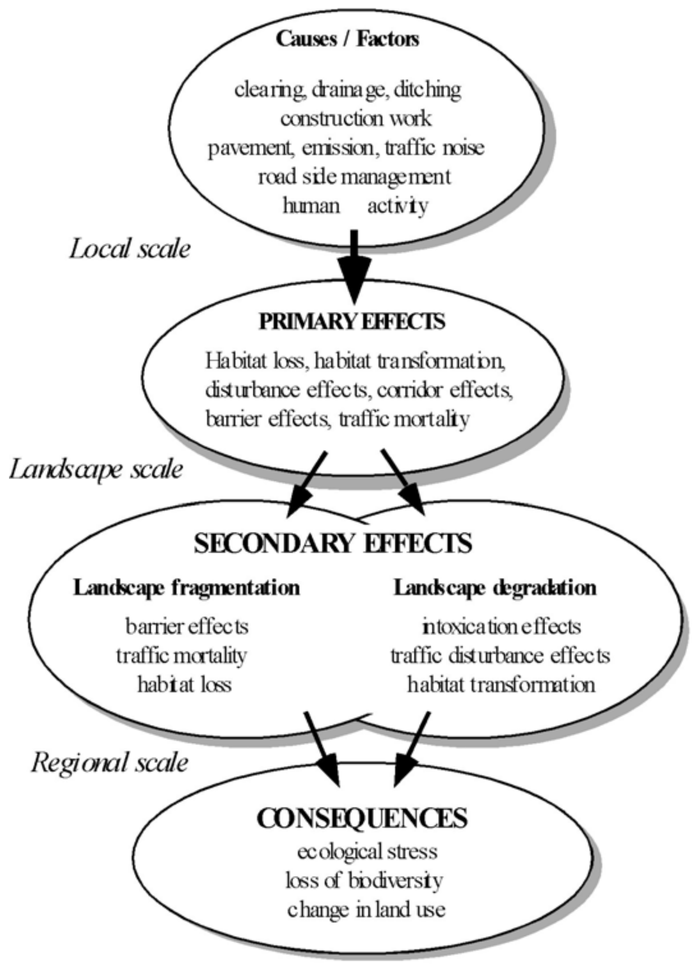
has its specific set of processes and rules that can only be studied at the appropriate scale (Allen & Starr 1982, Picket et al. 1989, Wiens 1990). To achieve comprehensive understanding of how infrastructure affects the ecological properties of a landscape, various levels of the ecological hierarchy must be considered.

## Identifying effects and consequences

### *Ecological effects*

Roads and traffic exert a number of different effects on the environment (Fig. 1). They lead to a loss of natural areas and a reduction in quality of the remaining ones. Traffic leads to pollution by toxins and noise, and causes mortality in wildlife species. Roads impose dispersal barriers to many animals, divide habitats, and lead to a fragmentation of the landscape in a literal sense (Reichelt 1979, Mader 1984, Cuperus et al. 1993). On the other hand, roadsides may provide a new and valuable habitat for some plant and animal species, and also function as transition or dispersal corridors. Comprehensive data and reviews on the effects of roads and traffic on wildlife populations can be found in e.g. Oxley et al. (1974), Knutsson et al. (1974), Göransson et al. (1978), Van der Zande et al. (1980), Mader et al. (1990), Bennett (1991), Reck & Kaule (1993), and Forman (1995).

**Figure 1.**
Cause, effects, and consequences of road construction.
Primary and secondary ecological effects relate to different ecological scales, i.e. individuals and populations, as well as to different spatial scales. Immediate effects of a single road refer to the biotope level, and the combined effects of the road network, i.e. fragmentation and stress, relate to the landscape as a whole. How effects spread from the individual level to the population level, and how this relates to conservation of biodiversity has to be discussed in the EIA document.




According to Van der Zande et al. (1980), we distinguish between six classes of primary ecological effects of roads and traffic: biotope transformation, habitat loss, barrier effects, corridor effects, disturbances, and road mortality. Primary effects are the immediate effects of road construction, and therefore often confined to a single road and its nearest surrounding. They are measurable in the behaviour, condition, or fitness of individuals. Primary effects from different roads interact and cause secondary effects such as landscape fragmentation and landscape degradation. Secondary effects thus refer to higher organisational levels and broader scales, i.e. to populations and landscapes.

For EIA work, it is necessary to distinguish between causes, effects, and consequences (Fig. 1). Until now, environmental concern in infrastructure planning focuses on measurable and quantifiable causes, such as traffic-induced pollution or the loss of designated biotopes due to road construction. However, without knowledge of the dose-effect relationship, these measurements do not provide a useful basis for ecological evaluation. Further, the choice of mitigation and compensation measures must refer to whether causes, effects, or consequences are considered.

*Landscape fragmentation*

Landscape fragmentation due to road construction refers to physical changes in the connectivity of the landscape and is mainly a consequence of the barrier effect of roads. The barrier effect usually contains both a physical and a behavioural component, and is increased by traffic mortality. Sensitive indicator species for evaluation of fragmentation effects of roads can be found among larger mammals primarily and are characterised by low reproduction, low dispersal, and small population sizes. Individuals are relatively long-lived, range over large home ranges, and select various biotopes for different purposes. Examples are e.g. large mammals (Harris & Gallagher 1989, Mader et al. 1990, Harris & Scheck 1991, Verkaar & Bekker 1991).

*Landscape degradation*

Landscape degradation refers to changes in functional relationships among biotopes caused by altered disturbance regimes or land use patterns. Disturbances (noise, pollutants, human activity), habitat changes, and road mortality may all alter the viability of local populations by affecting survival and fitness of individuals. Sensitive indicator species for degradation effects of roads share special requirements on the environment (biotope specialists), their dependence on late successional stages in vegetation, and their high rank position in trophic webs. Indicators for disturbance effects will likely show shorter generation times and higher reproductive output than indicators for fragmentation. Relevant species can be found among birds, insects and certain smaller mammals (see Mader 1987, Reck & Kaule 1993, Reijnen & Foppen 1994).

## Ecological effect evaluation

*Existing planning process*

In accordance with the new EIA guidelines of the SNRA (1995), ecological effect evaluations should be implemented at all levels of infrastructure planning to achieve a multimodal consideration of the combined effects of infrastructure, agriculture, forestry and urbanisation. A hierarchical organised planning process considers four planning levels (Eriksson 1991):

- At the *strategic level*, planning concerns changes in the transport system, which includes railroads and motorways. The EIA deals with the evaluation of system related impacts and the risk of impacts on other types of land use. The aim is the fulfilment of communication needs in an environmentally sound way. Improvement of environmental quality and traffic safety along existing roads form important parts at this level.
- If the road is the preferred alternative for the improvement of the infrastructure network, an initial *project study* is ordered (scooping stage, see UNECE 1987). It aims to reveal issues to be discussed among all interested parties, and to give directives for

further planning of the actual project. Planning continues with the preliminarily outline of a transportation corridor. Recommendations for the EIA document are given.
- The *location study* shall identify and select possible alternative routes for comparison in the EIA. The "do-nothing" alternative and its effects (also concerning future development of the area) shall be used as a reference for effect evaluations of the action alternatives. Possibilities for mitigation and compensation measures shall be discussed here.
- The *detailed design study* focuses on the design of the final route decided upon. Mitigation and compensation measures against adverse environmental effects or for traffic safety are to be designed at this level. Estimations concerning cost and effectiveness shall be given, as well as propositions for follow-up studies if needed.

**Hierarchical concept for evaluation**

Evaluation of ecological effects can be implemented in the road planning process at three levels. At each level, specific groups of ecological effects shall be considered, various methods for effect evaluation applied, and strategies or measures for mitigation proposed. The levels are:
1. the system level (referring to the strategic planning and initial project study);
2. the project planning level (referring to the location study); and
3. the design level (referring to the detailed design study).

If significant effects are expected and if mitigation measures are applied, evaluation studies are to be succeeded by follow-up studies. Follow-up studies shall allow for making post-constructional improvements on the road design and give recommendations for future EIA.

*1. System level: if?*

The starting point for ecological assessment is the feasibility of improving the infrastructure network. Thus, the main question dealt with here is whether improvement of transport facilities is necessary at all, and if a road measure is the optimal solution to that. For that decision, assessments have to be made upon possible effects on the development of land use pattern in the region, i.e. human settlement, land use types, traffic situation, and the consequent effects on biodiversity in the landscape. Historical as well as future development of the landscape shall be presented in different scenarios and possible changes in the relationship between ecological infrastructure and land use shall be predicted.

A hierarchical approach is helpful to structure the spatial relationships. The following steps are proposed (Fig. 2.):
- Identification of the bio-geographical region to which the considered landscape belongs (e.g. Nordic Advisory Board, NMR 1994).

- Identification of major landscapes types within the area, and a description of the degree of heterogeneity and fragmentation in relation to infrastructure.
- Functional classification of landscape pattern and structures referring to the ecological infrastructure of the landscape.
- The degree of fragmentation due to infrastructure shall be assessed and be used as a reference for the evaluation of expected changes caused by the new road project.

At the system level, most attention shall be given to fragmentation and degradation effects, since choosing an alternative route cannot mitigate these effects. Assessments of the change in the overall burden from traffic noise, edge effects, and pollution will have to be made and compared to regional or general policies concerning thresholds in tolerable environmental damage. Delimitation and evaluation of ecologically important aspects in the region highlights those effects that need to be analysed in more detail at the project level.

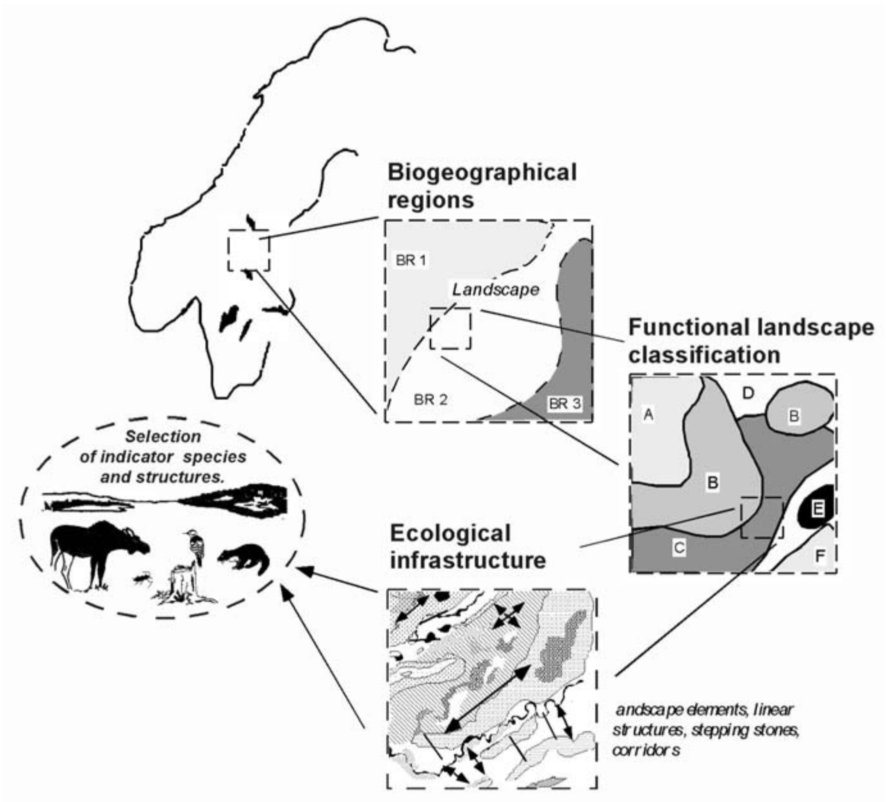



**Figure 2.**
Hierarchical structured analysis of landscape pattern. A functional classification into bio-geographical regions summarises a number of characteristic landscape units, which consist of various biotopes of different significance to the ecological infrastructure. To analyse ecological processes at the landscape scale, a set of indicator species could be used, and selected according to their relation to the prevalent landscape pattern.

*2. Project planning level: where?*

Work at the project level presumes the decision that road measures are needed to improve infrastructure in the region. The main task at this level is to decide upon road localisation. Effects to be considered here are those that can be avoided or reduced by choosing alternative routes. These effects are thus primarily related to landscape degradation (habitat loss and disturbance effect). Barrier and mortality effects can be of significance to local populations, however, choosing an alternative route will only translocate the problem but not solve it.

The first action at this level is the identification of possible routes within the defined transportation corridor. For that work, the spatial classification started at the system level shall be continued with a more detailed description of the ecological infrastructure in the landscape. Evaluation of possible route alignment shall then seek to reduce conflicts between road project and ecological infrastructure. In those cases where a conflict cannot be avoided, specified mitigation measures shall be proposed.
The work continues with a comparison of disturbance effects expected for the route alternatives. Consequences shall be assessed and evaluated by forecasting the development of environmental and ecological conditions within the next 10-15 years for each alternative. The predictions must be comprehensive but may focus on selected indicator species to enable post-project evaluations.

*3. Project design level: how?*

At this level, the exact localisation and the design of the final road has to be adapted to the surrounding environment. Where adverse effects are expected to be significant, monitoring studies shall be initiated to monitor the actual impact and test the efficiency of the chosen measures. Follow-up studies are not yet considered as a specific stage in the planning/construction hierarchy. However, even today, decisions can be taken that force adjustment of the final road design if new information appears during construction. Follow-up studies shall give implications for post-constructional improvements on the road design and make recommendations for future EIA.

### Mitigation and compensation

Mitigation and compensation measures that have been considered at the strategic and project planning level are to be designed and integrated into the construction plan of the road. It is generally distinguished between mitigation measures to avoid or reduce adverse effects, and compensation measures to re-create and enhance ecological values if the damage can not be mitigated.

- Mitigation measures are usually restricted to the road corridor and seek to avoid or reduce immediate disturbance and barrier effects by means of technical and ecological improvements of road and surrounding. So far, there is very little experience with mitigation measures for animals in Sweden, and ecoducts or special fauna passages have not been built or evaluated yet (Folkeson 1996). The SNRA gives general recommendations for ecological adjustment of conventional pathway passages or wildlife fences, and the first monitoring studies for evaluation of the existing passages have been initiated. Mitigation measures and ecological adjustment shall become a natural part in the planning at the design level and be integrated in the conventional planning of e.g. bridges, pathway passages, fences, and roadside management.

- Compensation measures seek to compensate for loss and degradation of natural biotopes by re-creation of the lost areas elsewhere in the landscape, and by enhancement of the ecological infrastructure and quality of the surrounding landscape (see Cuperus et al. 1993). Re-creation of new wildlife habitats must seek to resemble the destroyed ones in a qualitative and functional way. A fully re-creation is principally not possible, however, the overall effect can be lowered if structures and features in the landscape can be adjusted to enhance the ecological continuity of the landscape. Enhancement measures can also be directed towards the existing infrastructural network, for instance by exchanging existing culverts and tunnels with larger bridges. Ecological management of road verge vegetation shall create new but valuable habitats for many plants and animals (Hammarqvist 1994).

  Implementation of the compensation concept does not justify an impact on the environment, particularly not if protected areas are affected which normally should be avoided in the route alignment at the project level. Instead, compensation shall draw attention to the ongoing degradation of natural landscapes.

### Conclusions for implementation and application

It is the responsibility of the transport sector to develop adequate methodology for the evaluation and mitigation of ecological effects of roads. The fast growth of transport infrastructure requires continuous adaptation of concepts and methodologies that consider landscape-wide relationships. Increasing the scale of environmental consideration is crucial for the achievement of sustainable development in land use. This demands, however, the adaptation of EIA and effect evaluations. Therefore, we suggest:

- Considering the landscape as a hierarchical level of its own, with specific processes and patterns that can only be studied at the appropriate scale.
- Aiming at an understanding of landscape processes and functions, instead of focusing on single landscape elements for protection.
- Applying adequate ecological effect evaluations to all cases of infrastructural development.

- Conducting follow-up studies, establishing ecological monitoring and making results available for future EIA.
- Interdisciplinary co-operation when evaluating past and planning future development of land use and environment.

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