European Co-operation in the Field of Scientific and Technical Research

Chapter 6

COST Action 341

Habitat Fragmentation due to Transportation Infrastructure

The European review

European Commission
Directorate-General for Research

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A great deal of additional information on the European Union is available on the Internet. It can be accessed through the Europa server (http://europa.eu.int)

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Chapter 6. Minimising Fragmentation through Appropriate Planning

This chapter gives an overview of the existing planning policies and instruments that can contribute to the avoidance or minimisation of habitat fragmentation. The legal framework both for impact avoidance and the protection of natural areas is also dealt with here given its direct implications for the planning process. Avoidance tools will be discussed on a more technical level in Chapter 7. Strategic Environmental Assessment (SEA) and the identification and development of ecological networks are discussed as key steps in minimising habitat fragmentation. The integration of ecological values within the development planning process of different economic sectors *e.g.* transportation is also discussed.

Models and indicators are important instruments for the large-scale planning of transportation infrastructure. Their value in the monitoring of current trends and in the evaluation of different future scenarios is explained and their potential future role in SEA is identified. The most widely used models and indicators are presented to illustrate the types of possible approach to assessing the scale and nature of the fragmentation problem.

6.1. LANDUSE PLANNING POLICY AND GUIDELINES

Good landuse planning is a tool which has enormous potential for minimising future habitat fragmentation caused by the different human demands on the landscape, in particular that caused by transportation infrastructure. Currently, three international institutions are taking forward the subject of the prevention of habitat fragmentation in the planning phase: the Organisation for Economic Co-operation and Development (OECD), the European Commission (EC) and the Council of Europe (CoE).

Since the 1960s, initiatives have been undertaken to formulate a common vision on landuse planning for specific regions in Europe *e.g.* The Netherlands (Rijksplanologische Dienst, 1999). In 1991, the Committee on Spatial Development was formed which marked the start of the co-operation in landuse planning within the European Union (EU) and in 1993 the European Consultative Forum on the Environment was formed under the 5th Action Programme on the Environment, along with the Environmental Policy Review Group, with the purpose of advising the EC on policy development. This Forum set up a Working Group on Urban and Spatial Issues with the objective of developing the 'European Spatial Development Perspective: Towards Balanced and Sustainable Development of the Territory of the European Union' (European Commission, 1999). This document establishes the guidelines for initiatives regarding spatial development in Europe within a framework for sustainability, with special attention to the precautionary principle. Aspects such as the need for balancing environmentally sustainable development and market competitiveness are included in the guidelines.

Piepers, A.; Alvarez, G.; Bouwma, I.M.; De Vries, H. (J.G.) and Seiler, A. (2002) Minimising Fragmentation Through Appropriate Planning. In: Trocmé, M.; Cahill, S.; De Vries, J.G.; Farrall, H.; Folkeson, L.; Fry, G.; Hicks, C. and Peymen, J. (Eds.) *COST 341 - Habitat Fragmentation due to transportation infrastructure: The European Review*, pp. 115-128. Office for Official Publications of the European Communities, Luxembourg.

The Sixth Programme of Community Action on the Environment encourages the use of planning tools as a system for improving environmental protection and achieving regional sustainable development. In this Programme, the EC goes beyond a simple declaration of good will to promote the integration of strategic planning principles and procedures in order to reduce current negative environmental trends.

On the 6th October 1999 the CoE, supported by the European Councils of Cardiff and Vienna, adopted a strategy for the 'Integration of the Environment and Sustainable Development into Transport Policy' (document 11717/99 TRANS 197 ENV 335). The strategy encourages Member States to 'establish and apply a sustainable transport system which allows for the movement and development of individuals and commerce in a safe manner compatible with human health and that of ecosystems'. The CoE has invited the candidate countries to follow this path when elaborating their national and local strategies during the period prior to adhesion.

The European Landscape Convention, promoted by the European Council, gathers together all existing knowledge, procedures and techniques with the aim of integrating the multifunctional facet of landscapes within the planning process. The Convention aims to underline the importance of landscapes that must be protected by means of political, scientific and technical means and gives high priority to public participation, which is recognised as a crucial tool in the planning process.

Landuse planning in Europe is the responsibility of the national administrations and in all countries it is undertaken at the local level. Local planning authorities define new infrastructure requirements and assign land in local development plans. These plans, which are revised periodically, have to adhere to all the legal elements of landuse planning at a higher rank (*i.e.* regional, national and international levels) and constitute an accessory instrument for preventing, at a local scale, the alteration of natural areas and key corridors of connectivity between them. In many countries landuse planning is also undertaken at a regional level. For example, in Spain (E-SoA, 4.5.1) there is an initiative in which the Catalan government has prepared a proposal for guidelines (pending approval by the Catalan parliament) that define the obligation to consider, in local and regional plans (*e.g.* urban landscape plans, Local Agenda 21 Plans and other elements of territorial planning), the prevention of alterations to areas considered as having a strategic interest for the connectivity between protected areas. In some countries *e.g.* The Netherlands, landuse planning documents are also developed at the national level (Rijksplanologische Dienst, 1999).

6.2. PLANNING FRAMEWORK AND INSTRUMENTS

The objective of spatial planning is to organise functions and space in such a way that it shows the best mutual relationship, or to develop human and natural potentials in a spatial framework in such a way, that all can develop as well as possible (Buchwald and Engelhardt, 1980). In general, infrastructure has a major impact on the quality of the land and on its ecology. For this reason it is increasingly recognized that more sustainable approaches are needed for planning and managing landscapes worldwide. Appropriate tools are needed to effectively apply sustainable principles to planning and management. The spatial dimension of sustainability engages processes and relations between different types of landuse, ecosystems and biotopes at different scales, and over time. Therefore, ecological knowledge is essential when planning for sustainability. Sustainable landuse planning requires a thorough analysis of the current patterns of landuse, the likely changes that will ensue and the potential impacts associated with these changes. Landscape ecological concepts offer important possibilities for developing sustainable landuse planning (Botequilha Leitão & Ahern, 2002; Jongman, 2002).

6.2.1. Regional planning

At regional level in Europe there exist a number of financial instruments which have been established to promote development and transboundary co-operation in the field of spatial planning, *e.g.* the INTERREG funds. In providing economic aid for such initiatives it is possible to impose, as a condition for financing, the obligation to integrate environmentally sustainable criteria within plans and projects.

The firm will of the EC with regard to environmentally sustainable development has materialised in the form of Structural Funds and Cohesion Funds, from which many transportation infrastructure projects benefit. Regulation (EU) 1260/1999, by which the general dispositions are established with regard to Structural Funds, establishes the obligation to carry out environmental monitoring of the Regional Development Programmes. It also provides other associated planning instruments of use during project implementation. An evaluation of the repercussions of certain public and private projects on the environment is further regulated by Directive 97/11/CE (the EIA Directive). This promotes the application of the precautionary principle at the earliest possible phase, *i.e.* prior to the financing of projects. The implications include the possibility of financial penalisations and withdrawal of finance if it is shown that the projects have a significant effect on the environment. The fragmentation of habitats by transportation infrastructure, and especially any effects on the Natura 2000 Network, must be avoided if one wishes to use European funding, in order to comply with European legislation. The European Commissioners for Regional Policy and for the Environment have made clear statements regarding this. Regularly, the European Environmental Commission intervenes in planning and project development by prosecuting the Member States for their lack of sufficient consideration of the effects on these specially protected wildlife habitats. In some cases, the transportation infrastructure scheme has been subsequently abandoned.

6.2.2. Environmental Impact Assessment (EIA)

More than acting as an instrument in itself, the EIA procedure provides an important legal framework in which planning is carried out. EIA is, at present, the central tool for advocating the avoidance of habitat fragmentation in Europe. However, most countries point out that measures for the prevention of habitat fragmentation need to be applied earlier in the planning stages, *i.e.* during preliminary studies before the formal EIA. This is often when the least-impact corridor is chosen. For this purpose, Norway has published guidelines for the routing of transportation infrastructure in the landscape (Norwegian Public Roads Administration, 1994). The EIA process provides an adequate framework within which effective planning may be carried out. More and more frequently, projects in which route options and mitigation measures have been poorly considered during the design phase are running into problems during the EIA process because of ecological incompatibility. At best, time and money is lost and in some cases the project may even be abandoned if ecologically sustainable criteria have not been given due regard during the planning phase.

Route choice and design is part of project level EIA and can avoid serious impact on habitat fragmentation, especially because several different alternatives must be analysed and the least impact option must be chosen. Nevertheless, more often EIA procedure tries to mitigate the effects of a chosen alternative, by means of small changes in routing, construction of tunnels and viaducts, or the application of mitigation measures (see Chapter 7). Nevertheless, the shortcomings of EIA in adequately safeguarding against ecological degradation have been recognised by the European Spatial Development Perspective, particularly the fact that this instrument is often wrongly interpreted and implemented (European Commission, 1999). The European Commission highlights the need for Strategic Environmental Assessment (SEA) to identify the longer-term ecological effects and it also stresses the need for monitoring ecological changes with appropriate indicators.

6.2.3. Strategic Environmental Assessment (SEA)

In the EU Directive 2001/42/CE regarding the 'Evaluation of the Effects of certain Plans and Programs on the Environment', provides new opportunities for evaluating habitat fragmentation at a higher spatial scale. This new legislation (see also Chapter 9) establishes mechanisms that will allow for the analysis and prevention of habitat fragmentation due to territorial, spatial and urban planning (which includes transportation infrastructure), new road plans, etc. At present most countries analyse the effect of each project at an advanced stage in its development, without considering the synergic effects caused by the landuse changes that are brought about by each individual project, or the sum of the combined effects that are produced by different infrastructures in the same territory. This is a new way to introduce strategic territorial analyses in politics (Oñate *et al*., 2002).

SEA legislation is still in a transposition phase in most European countries and clearly defined procedures, such as those for EIA, are not yet in place. However, in some countries, *e.g.* The Netherlands, procedures similar to SEA are already being applied. Also, indicators and GIS techniques have been used in an assessment of methodologies used in the Spatial and Ecological Assessment of the Trans European Transport Network (TEN-T) undertaken by the European Environment Agency (EEA, 1998). In this analysis, both proximity to, and fragmenting of, nature conservation areas was considered.

6.3. ECOLOGICAL NETWORKS

By identifying the ecological network of a region or country the spatial requirements of nature are expressed and can be taken into account during the spatial planning process. The legal protection of sites included in such networks allows for them to be given due consideration in landuse planning for other types of development *e.g.* those associated with infrastructure. In order to include biodiversity conservation in landuse planning and to avoid further fragmentation of valuable nature areas, several European countries have developed national or regional ecological networks (see Figure 6.1). Ecological networks try to tackle the underlying causes of the decline in nature, *i.e.*:

- the absolute loss of habitats;
- the negative impact on vital conditions (e.g. due to the quality of soil and water, change in land or water management) and;
- wildlife areas diminishing in size and/or by becoming isolated.

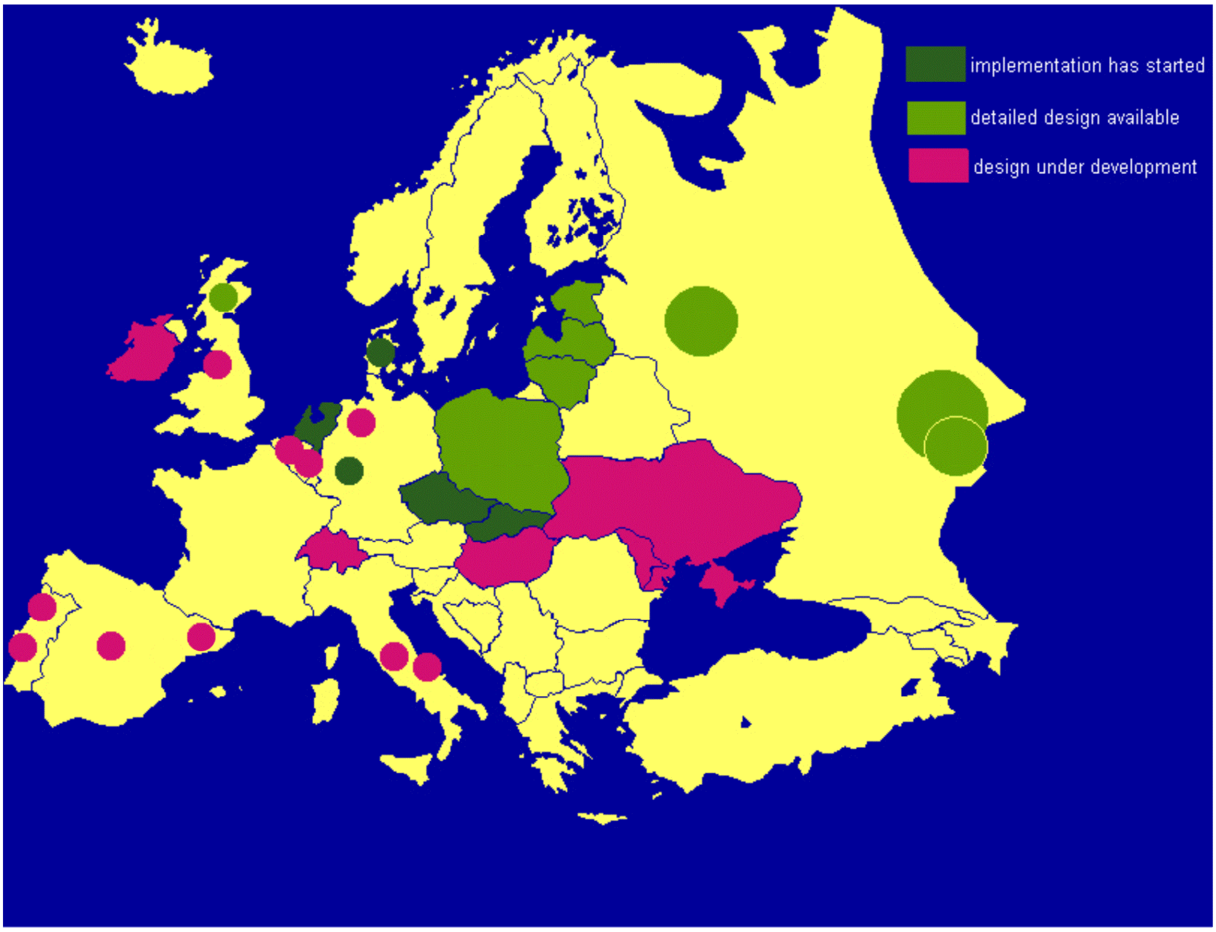

Figure 6.1 - Overview of regions and countries that are in the process of developing networks. (Revised from Jongman, 2000)

Within EU, the most significant instrument for landuse planning with regard to nature conservation is the ecological network currently being established under Natura 2000 within the framework of the Birds and Habitats Directives (adopted in 1979 and 1992 respectively). This network includes both Special Protection Areas (SPA) for birds and Special Areas of Conservation (SAC) which must be identified and designated by the Member States. As part of the process of establishing Natura 2000, each country must first draw up a list of Sites of Community Importance which must then be designated as Special Areas of Conservation. This process must be completed by 2004 at the latest.

The European Commission proposes the establishment of an ecological network in Europe, as is being developed under Natura 2000, but also recognises the fact that ecological continuity is required between protected areas in order to assure the biological diversity of Europe (European Commission, 1999). In this regard, initiatives are being undertaken in different countries to define ecological networks which integrate with and link the sites included in Natura 2000. Once established, the ecological corridors must also be preserved in order to guarantee connectivity between the sites that form the network, and as a result guarantee its functioning. The mapping of these ecological networks will improve the possibilities for analysing the effects that the development of new infrastructure can cause on ecological function.

Under Article 6 of the Habitats Directive, the development of new plans or projects which may have significant effects on Natura 2000 sites must take into account the ecological values and criteria of the site. In cases where significant negative effects cannot be avoided, and no other viable alternative exists, then Article 6 of the Directive establishes the obligation to apply compensatory measures in order to guarantee protection of the overall coherence of Natura 2000 (see section 7.4). Also, the Member States are obliged to inform the EC of the compensatory measures that have been adopted. In planning road and railway infrastructure, Natura 2000 must be a fundamental consideration, not only because it reduces its impact on protected sites but also time, effort and money may be saved if expensive, last-resort, compensatory measures can be avoided.

In Belgium, Estonia, Hungary, Switzerland and The Netherlands, the existing ecological networks are used as tools to identify bottlenecks between nature and infrastructure (B-SoA, 4; EE-SoA, 5; H-SoA; CH-SoA, 4; NL-SoA, 4).

Specific planning instruments also exist for protected areas, *e.g.* management plans, which regulate activities within and uses of the sites. In drawing up these plans, it is possible to include restrictions to prevent transportation infrastructure from affecting the site or compromising the connectivity with other areas of natural interest.

6.4. MODELS TO PREDICT FRAGMENTATION

The development of a series of validated indicators and models to measure and predict the degree of habitat fragmentation is an urgent requirement. Tools are needed which allow different development options to be compared to identify the least damaging option (in terms of the habitat fragmentation it causes). To address this challenge, some countries in Europe have already made progress and some of their experiences are reviewed in this section. Although the need for a quantifiable evaluation of large-scale ecological effects is apparent, especially in terms of strategic assessment, the methodology is still in its infancy. None of the countries contributing to COST 341 has reported a regular use of computerised models to evaluate the fragmentation impacts of infrastructure.

Over recent years, however, technology such as computer hardware, Geographic Information Systems (GIS) and simulation software, as well as the necessary databases on nature, land cover and wildlife have improved considerably. Much of the ongoing landscape ecological research now involves GIS-based spatial assessment using remotely sensed data such as satellite images. Through combination of GIS data and simulation programmes, the door to spatially explicit modelling has been opened. When used in a GIS environment, simulation models can create various landscape scenarios and visualise them in 2D or 3D-format. They enable habitat fragmentation, corridors, barriers and bottlenecks (at the present time or in the future) to be visualised from a human or animal perspective. The identification of barriers to animal movement is a first step in the defragmentation of landscapes. Once the location of barriers are known, fully functional corridors and wildlife crossing structures can be established at optimum locations to promote ecological connectivity on the ground. More importantly, by simplifying reality, models can facilitate the identification of the critical factors which are driving the fragmentation process and which should become the focus for mitigation effort. Models can also help to identify gaps in our knowledge regarding species ecology and to address questions that are otherwise difficult to study empirically *e.g.*:

- At what point does the degree of habitat fragmentation become critical?
- What is the optimum spatial configuration of linked habitat patches?
- Where are the optimum locations for wildlife corridors?
- Where are potential barriers or bottlenecks located?
- What effect will the restoration of habitats (e.g. the creation of a corridor or the development of transportation infrastructure) have on specific species?

Broadly, simulation models used in the analysis and evaluation of fragmentation impacts can be divided into three categories:

- Dispersion models
  Individual-based simulation models focused on animal movements and spread across a mosaic of habitats (such as those derived from field or satellite mapping). Usually species-oriented, they require detailed knowledge of the species in question and can cover both local as regional scales. Examples of commercially available models are e.g. GRIDWALK, POLYWALK, and SmallSteps. The modelling results can be presented visually as maps showing the relative abundance of the species after a given time. Dispersion models are mostly a scientific tool that can help to locate barrier conflicts and evaluate landscape connectivity from the point of view of individuals.

- Metapopulation models
  Numerical models that simulate the survival of local populations using birth, death and migration dynamics in relation to habitat quality, size, and connectivity. These models are species-specific, relating more to regional than local scales, but not all are spatially explicit (i.e. the spatial arrangement of habitats is not always considered). Examples include METAPHOR, RAMAS, and META-X. These models usually result in tables on the survival probabilities of metapopulations or single local populations. They help to evaluate landscape suitability for populations of species.

- Expert systems
  Models that make statements about the expected or possible existence of ecosystems and viable network populations based on information from thematic landscape databases. Examples are GREINS, LEDESS, and LARCH. These models facilitate the comparison of different landscape scenarios and thus support decision-making.

A wide variety of computer models that could be used for the analysis of fragmentation effects exist, but most have been designed purely for scientific purposes, or to study a particular species or problem. Many models may be applied to investigate barrier, isolation, disturbance or mortality effects, but none has yet considered the direct effect of infrastructure per se (*e.g.* traffic density, noise, road width). Many of the (traditional) GIS-based assessments and expert systems are not spatially explicit, meaning that they do not consider the spatial arrangement of habitats (*e.g.* distance, clumping, size variation etc.). Few models are flexible enough to be used across a wide range of environments or are applicable to a range of different species. Examples of models currently available (mostly commercially) are listed in Table 6.1.

Table 6-1 - Examples of available simulation programs (both scientific and commercial) currently available for the analysis of fragmentation impacts on species and populations.

Model Type	Name	Country	Description	Reference
Dispersion	GRIDWALK POLYWALK SMALL-STEPS	NL	These models aim to determine the accessibility of neighbouring habitats and to identify dispersion streams and ”bottlenecks”. GRIDWALK is based on raster data and is most suitable for large-scale analyses. POLYWALK was developed for vector-based GIS. SmallSteps considers important species-specific responses to landscape, habitat and infrastructure components.	NL-SoA, 9.4
	DISPERS	BE	Simulates habitat accessibility for a specific species or group of species.	B-SoA, 8.4
	-	SE	A set of dispersion models has been developed at the SLU to predict invertebrate movements.	S-SoA, 8.4
	-	NO	NINA is working on various GIS-based models of habitat fragmentation related to animal movement, *i.e.* dispersion models. The work involves varied species from moose to small butterflies.	N-SoA, 8.4
Meta-population	METAPHOR	NL	Computes the chance of survival in a metapopulation in relation to the quality and the spatial arrangement of habitats, age and sex structure of local populations and other intrinsic factors.	NL-SoA, 9.4
	RAMAS®-GIS	USA	Metapopulation, GIS-based simulation software. Includes a set of different software packages, mainly for scientific use.	
	META-X®	Germany	Metapopulation, GIS-based simulation software assists the development of species' protection plans, habitat network design, and technology assessment.	
	Flashing models	NL	Compute extinction and colonisation probabilities for specific species in a given area.	NL-SoA, 9.4
	-	DK	Frogs and roads	Hels, 1998
Expert systems	LARCH	NL	Evaluates effects of landscape composition on a given species. It is based on spatial rules developed in METAPHOR. Assists with landscape ecological analysis.	NL-SoA, 9.4
	LEDESS	NL	Decision-supporting system testing development proposals for ecological and environmental feasibility. Based on GIS, it contains, amongst others, a vegetation and a fauna module.	NL-SoA, 9.4
	GREINS	NL	Developed for the evaluation of development scenarios for nature (*e.g.* vegetation structure) based on abiotic habitat factors (*e.g.* soil, hydrology).	NL-SoA, 9.4
GIS-assessment (examples)	-	DK	Danish Forest and Landscape research institute has developed a GIS-based model to illustrate the barrier effect of infrastructure on recreation (measured as loss of accessibility to the landscape).	Kaae *et al.*, 1998

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	-	CH	GIS model that illustrates landscape	Hel-Lange, 2000

Model Type	Name	Country	Description	Reference
			connectivity for amphibians in one area of Switzerland.	
	-	FR	GIS-based analysis of landscape pattern and habitat sensitivity.	
	EVV	NL	The Traffic and Transport Evaluation instrument (EVV), developed by the Environmental Science Center in Leiden, aims to address regional infrastructure problems. The model has not been applied in practice, but its basic concept is still valid.	Cuperus and Canters, 1997

The models described in Table 6-1 are all available, either from universities or commercially, but none has so far been regularly used in strategic assessment. Before simulation models can be fully implemented in the spatial planning sector, some major obstacles must yet be overcome. Among these, the lack of knowledge on the actual response of wildlife to infrastructure is the most prevailing. Until now, the majority of studies on the ecological effects of infrastructure have been descriptive and the empirical data is usually insufficient to construct predictive models (compare Chapter 3). Few studies have focused on general pattern and process or tried to identify thresholds in impact-effect relationships. The contribution of road traffic to the barrier effect for fauna, for instance, is fundamental to the overall fragmentation effect, yet is seldom quantified. Critical thresholds in traffic volume for animal movements have also not yet been established clearly (see Chapter 3.5). The relationship between traffic-related mortality, traffic volume, animal density and mobility, are crucial factors that could be easily quantified, but so far lack sufficient empirical data.

Other obstacles in the development of predictive models are related to shortcomings in GIS techniques, insufficient resolution of spatial data and classification of satellite images. Depending on the differences in scale (extent and resolution) and quality (accuracy) of base maps and thematic map layers, the results of GIS models can be misleading and may fail to detect important aspects. It is a common problem that data obtained from different sources *e.g.* agencies, authorities, and governments can vary greatly in accuracy and it is not always possible to combine different data sets. Remotely sensed data, derived from aerial photography or satellite imagery provides an efficient tool for a large-scale landscape classification, but in many aspects these data must be combined with, or complemented by, field inventories to provide a more complete picture. The spatial and thematic resolution of a data set must be adjusted for each specific case: the accuracy of analysis does not necessarily increase with a higher resolution. The techniques relating to the acquisition and analysis of remotely sensed data are continuously improving, putting an increasing demand on the accuracy of ecological background data.

As long as the basic ecological information relating to the response variable, *i.e.* the species, is insufficient, interpretation of spatial indicators, fragmentation indices, or GIS models remains nothing but guesswork. What is needed is an integrated development of simulation models, evaluation criteria and indices, resulting in a reliable empirical database that allows for generalisations and extrapolations. Computer models can be sufficiently complex to make reliable predictions, but at the same time, they should also be simple enough for application in SEA. To accomplish this, further international and interdisciplinary research is needed.

6.5. Indicators and indexes of fragmentation

Indicators are quantified information which help to explain how things are changing over time. They are broad-brush, aggregated statistics which give an overall picture. The three basic functions of indicators are simplification, quantification and communication. When reference data (the maximum that can be realised) or target data (policy goals) are linked to indicators, it gives them a gradient-measuring function (Hinsberg *et al*., 1999). Indicators can be used for planning purposes as well for comparing the values in different planning scenarios.

The fragmentation of the natural environment has effects on the continued existence of species in the natural landscape. Populations disappear and are no longer compensated for by migration from neighbouring areas. This results in the appearance of gaps in the relationships between the various species (*e.g.* predator/prey relationships) disturbing the balance to an even greater extent. It is almost impossible to chart or to predict the final effects of this process on the biodiversity. Nevertheless, in order to make statements about the fragmentation effects caused by the construction and use of infrastructure, indicators are an extremely valuable tool which should be utilised.

It appears that indicators for habitat fragmentation due to infrastructure are not widely used in the countries participating in COST 341. Only two countries (Norway, and The Netherlands) mention the yearly application of an indicator for monitoring (de)fragmentation on a national level. In The Netherlands this indicator has been adopted officially and the latest policy documents have included goals based on this indicator (Ministerie van Verkeer en Waterstaat, 1999). Some other countries *e.g.* France, the Czech Republic, Estonia, Hungary, Switzerland and the United Kingdom have undertaken surveys in which some kind of indicator has been utilised. It is not clear whether these indicators will continue to be used for monitoring in the future. In the National Reports, some figures are given which can also be considered as indicators for the degree of habitat fragmentation but which may not have been utilised for this purpose up until now.

Table 6-2 gives an overview of the various indicators that are used in the contributing countries. They may be classified according to the various scales to which they apply *i.e.* regional, national and European. The European Environment Agency (EEA) has pioneered work at the European level. One such project has been set up for identifying indicators that can be tracked and compared with concrete policy objectives - The Transport and Environment Reporting Mechanism (TERM). The European indicators given below come from the first indicator-based TERM report (EEA, 2000).

Figure 6-2 compares one of the indicators *i.e.* the landtake by infrastructure as percentage of total country area, for different European countries.

Table 6-2 - Overview of the various indicators that are used across Europe.

Type of Indicator	Country	Scale	Used For	Frequency of Use	References
Density of infrastructure	F	n	Assessing fragmentation of forests	single survey	F-SoA, 5.6
idem	N, DK, CH, E, B, S, CZ, EE	r, n	Describing habitat fragmentation	single survey	N-SoA, 4.1 DK-SoA, 5.4.1 CH-SoA, 5.3 E-SoA, 5.3 B-SoA, 5.1 S-SoA, 5.3 CZ-SoA, 3.2 EE-SoA
Mesh-width between infrastructure	NL, S	r, n	Describing habitat fragmentation	single survey	NL-SoA, 5.2 S-SoA 5.4.1
Fragmentation Index = length of linear infrastructure/area of red deer zone	F	n	Expressing area of habitat fragmentation for red deer	single survey	F-SoA, 5.6
Disturbance-free natural areas (based on distance to nearest human-made installation)	N	n	Monitoring habitat fragmentation on a national level	yearly	N-SoA, 4.3 and 8.3
Number of intersections between infrastructure network and supraregional biocorridors	CZ	n	Evaluation of permeability	single survey	CZ-SoA, 6.3
Percentage of supraregional wildlife corridors disrupted	CH	n	Assessing condition of supraregional wildlife corridors	single survey	SGW, 1999
Length of intersections between infrastructure and nature areas	UK	r	Assessing loss of peatland	single survey	UK-SoA, 5.4.1
idem	NL	n	Policy evaluation	yearly	Ministerie van Verkeer en Waterstaat, 1999
Length of unsolved intersections reproduced as a percentage of the total length of intersections	NL	n	Policy evaluation	yearly	Ministerie van Verkeer en Waterstaat, 1999
Average size of landuse areas or size and number of landuse areas with and without infrastructure	NL, S	n	Describing habitat fragmentation	single survey	NL-SoA, 5.3.1 S-SoA, 5.4.1
idem	H	n	Describing habitat fragmentation	single survey	H-SoA, 5.3.1
idem	EE	n	Determining pressure of transport sector on natural diversity and evaluating changes	research recently being launched	EE-SoA
idem	Europe	Eu	Policy evaluation	regularly	EEA, 2000
Area:contour ratio of habitat patches with and without infrastructure	H	n	Describing habitat fragmentation	single survey	H-SoA, 5.3.4

(Cont'd...)

Type of Indicator	Country	Scale	Used For	Frequency of Use	References
					(...Cont'd)
Landtake by infrastructure as a percentage of total country area	E, S, DK, EE	n	Describing habitat fragmentation	single survey	E-SoA, 5.3 S-SoA, 5.4.1 DK-SoA, 5.4.1 EE-SoA
idem	Europe	n	Policy evaluation	regularly	EEA, 2000
Number of SPA's* and Ramsar wetland areas with infrastructure within 5 km of their centre	Europe	Eu	Policy evaluation	regularly	EEA, 2000

* SPA - special bird area. Special bird areas are those designed by the EC Birds Directive; Ramsar wetlands are those designated in the global Ramsar Convention for the protection of wetlands.

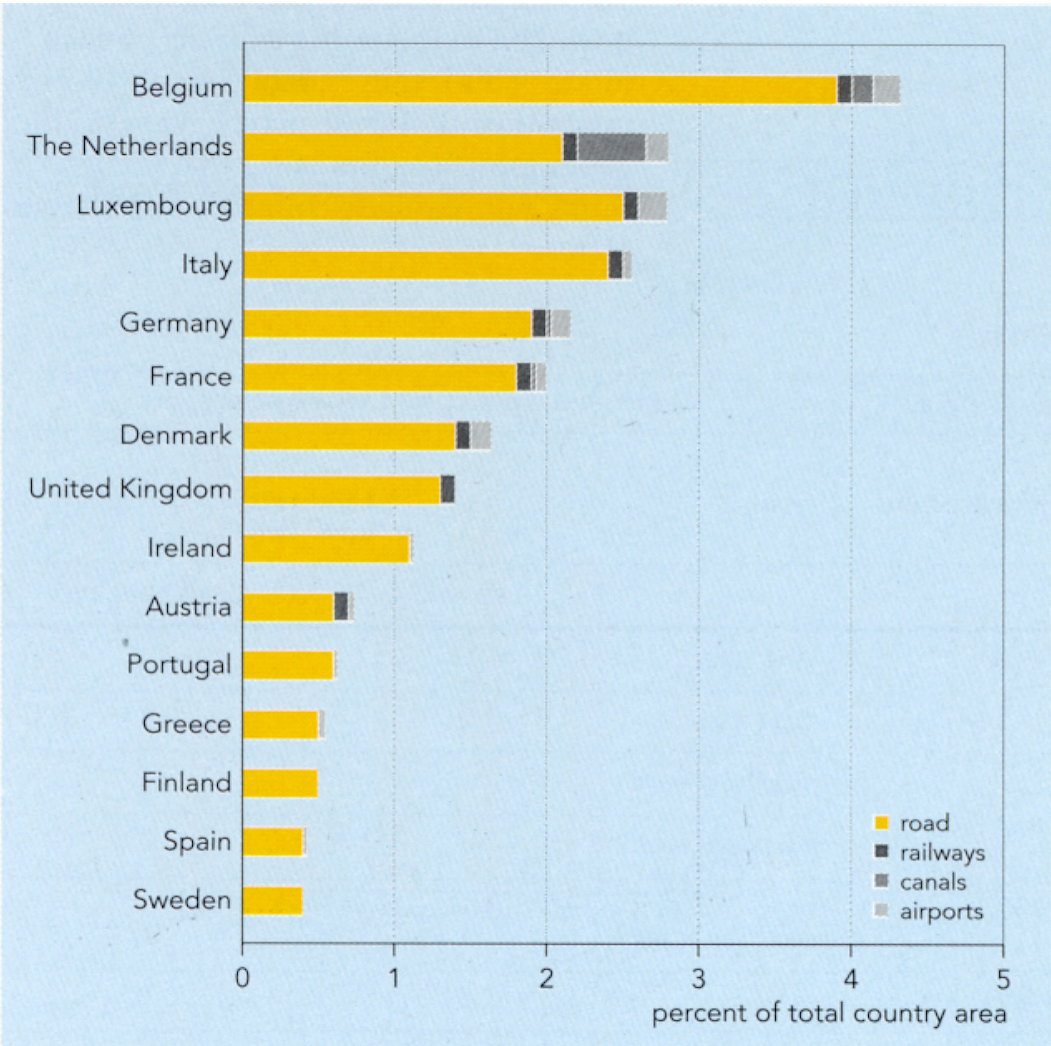

Figure 6.2 - Landtake by infrastructure in 1996 as a percentage of total country area for different European countries. (From EEA, 2000)

Examples of indicators cited in the National Reports and suggested to be of potential future use for measuring fragmentation are included in Table 6-3.

Table 6-3 - Overview of potential new indicators for measuring fragmentation.

Type of Indicator	Country	Scale	Target	References
Density of infrastructure weighted by traffic intensity	NL, E, F	r, n	Determining effects of mobility scenario's, reflecting changes in degree of pressure	NL-SoA, 9.3 E-SoA, 8.3 F-SoA, 8.3
Average distance between same landuse areas or habitat patches	F	r, n	Monitoring increase of isolation	F-SoA, 8.3
Average number of neighbouring habitat patches per habitat patch	F	r	Quantifying spatial context	F-SoA, 8.3
Length of parallel infrastructure[#]	CZ	r, n	Measuring multiplied fragmentation	J. Dufek (*pers. comm.*)

parallel infrastructure = 0.3 km to 1 km distance between *e.g.* new motorway and original road

Ideally, a good indicator of habitat fragmentation should take the following aspects into consideration (Infra Eco Network Europe, 1999):

- size of land units;
- quality of land units;
- location of intersection;
- vulnerability of land units; and
- degree of connectivity between land units.

The density of infrastructure is useful for allowing comparison at a national level with other countries, but it really only indicates the degree of physical fragmentation of territory and does not consider the natural matrix on which the infrastructure network is superimposed (E-SoA, 8.3). Other indicators do have an ecological component, but none of those on Tables 6-2 and 6-3 integrates all the five relevant aspects stated above. This is a task for the future: to develop indicators that integrate as many aspects as possible and yet are simple and pragmatic. Recent research in Germany represents the first step towards this goal. Jaeger (2001) has developed three new, coherent indicators of fragmentation: i) degree of landscape division; ii) effective mesh number and iii) effective mesh size. Together these reflect the chance that two animals released at two different locations in one unit, will meet each other: the more barriers the unit contains, the smaller this chance.

Because some species are much more sensitive to fragmentation at a particular scale than others due to variations in mobility, behaviour and habitat requirement, indicator species will be selected for assessing the effects of fragmentation in Denmark (*e.g.* Hammershøj and Madsen, 1998). Estonia and Sweden are following the example of The Netherlands, Switzerland and the Czech Republic by determining the conflict points between the infrastructure network and nature areas and corridors (EE-SoA; Seiler, 1999). In order to make more effective use of the available information on countryside change, including satellite cover data, and to have a more co-ordinated approach, countryside indicators are being developed in the United Kingdom (UK-SoA, 8.6.1). In Norway, more detailed indicators will be developed based on the indicator that is used for monitoring habitat fragmentation on a national level, *i.e.* disturbance-free natural areas, for specific animal species, since the degree to which animals are disturbed by man-made installations varies greatly between species (N-SoA, 8.3).

6.6. SUMMARY

The principles of the 1992 Convention on Biological Diversity underline the importance of avoiding, mitigating and compensating for nature conservation impacts associated with transportation infrastructure. There are different instruments to avoid habitat fragmentation in the planning phase:

- Recommendations and codes of good practice have been published by different European institutions to promote the mitigation of the effects caused by transport networks on nature in the early stages of their development;
- Regional planning (particularly that utilising European Funds) must aim to balance the objectives, economic cohesion and environmental protection in decision-making;
- The procedures of EIA and SEA are important tools which should help project developers, planners and decision makers;
- National and regional nature protection instruments (e.g. nature reserves, maps of the ecological networks) as well as urban and territorial planning procedures are used;
- The Natura 2000 European network and the related European Directives aimed at the protection of habitats are formal documents that should oblige the integration of sustainable criteria and ecological considerations in infrastructure planning.

Simulation models that can be used for the analysis and evaluation of fragmentation impacts can be divided into three categories: dispersion models, metapopulation models and expert systems.

Computer models can be sufficiently complex to make reliable predictions, but at the same time, they should also be simple enough to reach an implementation in SEA planning routines. To accomplish this task, further international and interdisciplinary research is needed.

It appears that indicators for habitat fragmentation due to infrastructure are not widely used in the countries participating in COST 341. Only two countries (Norway, and The Netherlands) mention the yearly application of an indicator for monitoring (de)fragmentation on a national level.

Density of infrastructure is useful for allowing comparison at a national level with other countries, but it really only indicates the degree of physical fragmentation of territory and does not consider the natural matrix on which the infrastructure network is superimposed.

Chapter 6

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