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Habitat Fragmentation due to Transport Infrastructure

the Netherlands State of the Art Report

European Commission
Directorate General Transport

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Chapter 1 Introduction

Contribution by: Annette Piepers

Fragmentation by infrastructure and defragmentation of infrastructure – both these terms have taken a firm hold in modern Dutch society. A relatively short while ago, in the 1970s, this was certainly not the case. Only a handful of people thought that something should be done for badgers. It was at their initiative that the Directorate-General for Public Works and Water Management started building tunnels under the roads it was responsible for so that badgers could cross safely to the other side. At present, more than 500 tunnels have been built and not just under motorways, but under main roads, secondary roads and railway lines as well. Things did not stop with tunnels for badgers. The measures that have now been implemented include eco-ducts, eco-culverts, walls of tree-stumps, fauna-exits, replacement of habitat, walkways, ecological roadside verge management, nature-friendly (canal) banks. Further to the Directorate-General, the Dutch Railways, research institutes, water boards and the provincial and local authorities have also become involved.

The Netherlands is not the only country where fragmentation of the natural environment through the construction and use of infrastructure is recognised as being a problem. This was made clear in 1995 during an inspirational congress that was organised by the Road and Hydraulic Engineering Division of the Directorate General for Public Works and Water Management. Because there was apparently a large need to exchange knowledge and experience, not long after the congress, an international network of experts was set up – the Infra Eco Network Europe (IENE). This network initiated in turn a new plan of action in the framework of COST (Cooperation in the field of Scientific and Technical research) – COST 341 “Habitat fragmentation due to transportation infrastructure”. The objective of the plan is to devise a number of products that can be used in the defragmentation of Europe, such as:

- An overview of the current state of affairs with respect to fragmentation and defragmentation in Europe;
- a European handbook containing guidelines, methods and measures for dealing with fragmentation;
- a database with information about publications, current projects, measures and a list of other databases related to the subject;
- a report describing the plan of action and follow-up activities.

The European Commission is contributing financially to the plan and providing secretarial support.

At present, fourteen countries are officially taking part in this initiative – Austria, Belgium, Cyprus, the Czech Republic, Denmark, France, Great Britain, Hungary, the Netherlands, Norway, Romania, Spain, Sweden and Switzerland. The European Centre for Nature Conservation is also an official participant. One country, Estonia, is actively involved in the initiative as well, but has not yet officially signed the agreement. The Road and Hydraulic Engineering Division is chairing the initiative and as such is responsible for its success. The Division also has a seat on the Management Committee and various workgroups. The initiative was started in September 1998 and will continue until March 2003. The products are mainly meant for the designers of and building contractors involved in infrastructure projects. Planners, researchers, policymakers, the European Commission and nature conservation organisations form a secondary target group.

First of all, the European overview of the current state of affairs will be published. This has been scheduled to take place in September 2001. The European overview will be compiled from the data supplied by the participating countries. This report shows the situation in the Netherlands. All the national reports will be built up along the same lines. The reports will first discuss the theoretical background of fragmentation (chapters 2 and 3). After this in chapter 4, an outline will be given of the situation in the country concerned – a description of the ecosystems; occurring plant and animal species; policy, legislation and procedures relevant to (de)fragmentation; and the seriousness of fragmentation due to other causes than infrastructure. Chapter 5 will provide information on what is known about the current situation – data on infrastructure networks (motorways, main and secondary roads, railway lines, artificial waterways).

Road safety with respect to collisions with animals will be dealt with separately (chapter 6). The way in which fragmentation is to be dealt with, in other words, the measures that are being taken is described in chapter 7. In the Dutch report, the management of the measures and the evaluation of their effectiveness is included in a separate chapter (chapter 8) instead of being added to chapter 7. Future scenarios are outlined in chapter 9 – what will future policy regarding (de)fragmentation be, how will the indicators and models be used, what infrastructure remains to be built and what research is taking place? The financing and the costs of the measures are detailed in chapter 10. Each national overview will end with conclusions and recommendations (chapter 11). Lastly, each report will have several appendixes containing, amongst other things, maps of infrastructure networks.

The contributions to the Dutch overview originate from the following instances – the Ministry of Agriculture, Nature Management and Fisheries, the Dutch Railways Infrastructure Management Board, Alterra Research Institute (the former Institute for Forestry and Nature research and Winand Staring Centre), Wageningen University and the Road and Hydraulic Engineering Division. The Division is also responsible for the final editing. The Dutch overview will not only serve as a foundation for the European report, but will also be published as a separate document. It is the first time in the history of defragmentation that information from so may different sources has been combined. This has made it possible for us to reflect on the issues involved – what do we now know about the scale of the problem "fragmentation caused by the construction and use of infrastructure" and are we dealing with this problem in the right way? In advance of the conclusions and recommendations, we can state at this juncture that the scale of the problem justifies the attention it is receiving. However, more inventiveness is needed in finding solutions. Defragmentation means more than building fauna passages. Measures that tackle the sources of the problem such as the use of low-noise road surfacing and combing traffic flows to help nature conservation are just a few of the possibilities that deserve more attention. Rigorous defragmentation is required.

Chapter 2 Ecological concepts

Contributions by: R.H.G. Jongman, D. Kamphorst

2.1 Landscape ecology

Landscapes are complex systems made up of spatially organised ecosystems. Within these systems, there are a large number of functional relationships between organisms and their environment. In order to understand the way in which landscapes function as a whole, it is necessary to integrate the principles of various scientific disciplines, such as bio-geography, the science of vegetation, population dynamics, hydrology and the flow of currents of material and energy. People also play a major role in landscapes. Using landscape ecology, it is possible to study the physical, biotic and human effects on landscape in space and time. Landscape ecology focuses on studying the relationships between ecological communities and the environment and ecological patterns and processes within a landscape. These patterns and processes take place within a landscape at different levels of space and time. There are patterns on the surface of the earth that are visible on a world-wide scale, such as climate zones, which are largely determined by the degree of latitude, ocean currents, mountain range patterns, etc, but they are also visible on a regional or local scale. On a European scale, processes are taking place that can be seen in various bio-graphical regions and at the borders in between. Organisms move about at all levels. In Europe, this involves, for example, migratory birds (geese), and migratory fish (salmon, eels). The migration of birds is bound to seasonal patterns and has a yearly rhythm. Alterations in patterns resulting from natural processes in ecosystems can also be found at various levels. Climate changes take place on a large scale over decades or even centuries; succession can be seen locally within a period of a few years; seasonal changes take place within a year and the movements of the tide can be seen within a matter of hours.

Landscape ecological terms

Landscape ecology is the study of the interaction between abiotic and biotic landscape components in space and time and the related flora and fauna (Vink, 1980; Naveh and Lieberman, 1984; Forman and Godron, 1986). Landscape ecology can be approached from various starting points. One of these involves focusing on processes and patterns in landscapes - the landscape as an ecosystem (Opdam, 1993; Zonneveld, 1995; Forman, 1995).

An ecosystem is a spatially cohesive biological community of interacting organisms (the biotic part) and their relationship to their physical environment (the abiotic part).

On a small spatial scale, e.g., in the Netherlands, the landscape is determined by different types of ecosystems within a climatic zone and geological entity (e.g., the Rhine delta, the Maas river valley and the Scheldt estuary), landscape types and ratios of fresh/salt, dry/wet, abundance/scarcity of food. Landscape patterns and relationships play a role here. The hierarchical relationships between, for example, fauna, vegetation and soil demonstrate mutual dependency and influence as well as a stream of energy and material (Klijn, 1997). Species move along or in between the gradients of the landscape. For example, in natural situations, red deer and boars move – depending upon the season – from high, dry locations to places alongside rivers where there is an abundance of food. Migratory fish, such as salmon and eels, migrate in the direction of freshwater to reproduce. In the winter, toads leave their sleeping places in dry woods to go to pools.

The Netherlands has a large variety of landscapes and the variation within these landscapes is extremely diverse. Each landscape comprises a mosaic of various landscape elements, which function as building bricks, e.g., various different sorts of woods, grasslands, fields, verges, ditches, wooded banks, etc. The separate elements form an aggregated pattern and these patterns can be found on various scales ranging from a number of kilometres to dozens of kilometres. The smallest more or less homogenous parts of the landscape are known as ecotopes. Ecotopes are more or less independent spatial units that are characterised by a specific ecological community and the corresponding physical environment. (Stevers *et al*, 1987; Groen *et al*, 1993). A spatial unit that is suitable as the natural home for an individual or population of a species can be defined as a habitat. Landscape elements have various functions for flora and fauna. Each species makes its own demands on its habitat – certain conditions are optimal, others are less favourable or even entirely unsuitable. Each species makes specific demands on environmental conditions and on spatial dimensions such as size and distance. The populations of one species are satisfied with a smaller area than populations of another species.

[figure 1: foto landschap]

Figure 1: A scour-hole in the river forelands.

Various sub-areas can be distinguished in landscapes based upon their function, including their function for animals, such as the function of general home, feeding grounds, breeding grounds, a place to sleep and a refuge. The locations of these functions in the landscape can be spread over a geographical distance. Animals move about between the elements in a landscape for various reasons. A distinction can be drawn between movements within populations and between populations.

Movements within populations:
- daily movements from sleeping places to feeding grounds or a refuge
- movements from summer to winter habitat and
- annual movements for the purposes of reproduction

Movements between populations and to new populations:
- the one-off undirected movement of organisms to find a new place to reproduce (=dispersion) (Opdam, 1987)
- dissemination – enables plants and animal species to colonise new areas. Areas where the species is not (or is no longer) present can be (re-)colonised, as long as they can be reached (Logeman and Schoorl, 1988).

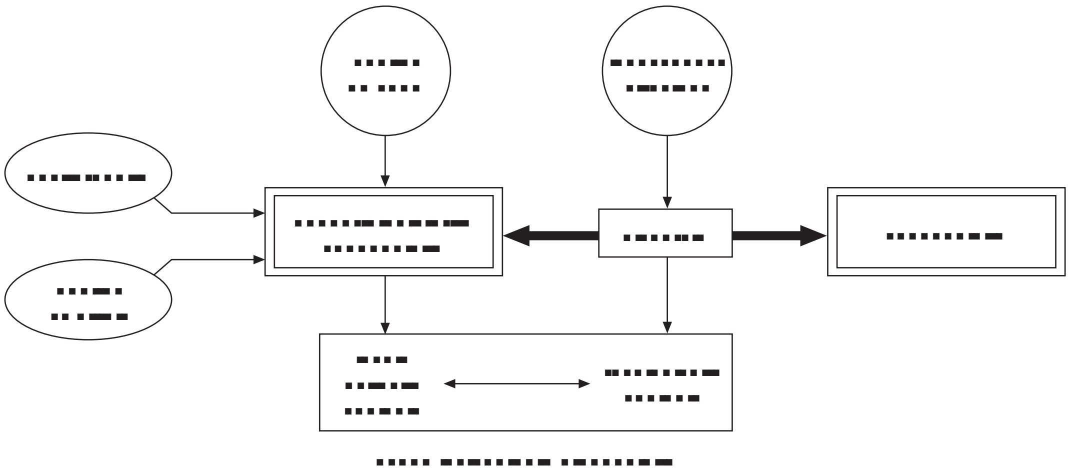
These forms of movement are restricted in a cultivated landscape that is dominated by people. Different sub-areas in a habitat become more or less isolated from one another due to barriers and unsuitable types of terrain that are imposed on the natural surroundings, such as buildings and roads.

[figure 2: foto bord paddentrek]

Figure 2: In springtime toads collectively migrate to their breeding grounds.

An important landscape-ecological concept on population dynamics and dispersion in a landscape that is dominated by people is the metapopulation theory (Opdam, 1991). A metapopulation is a collection of populations of a species that intermix in a certain area, each population of which is too small to survive alone. This is why these sub-populations are referred to as metapopulations. The metapopulation theory applies to cultural landscapes where habitats have become fragmented as a result of large-scale human intervention and have become more or less isolated (see §2.2 for fragmentation of the landscape). In the small and isolated habitat sub-areas, the continued survival or a sub-population of a species can be threatened. However, if exchange is possible between the sub-areas, sub-populations can support one another and thus allow the metapopulation to survive in the form of a cohesive group of sub-populations.

The quality of the habitat, its size of the habitat and the presence of landscape structures for dispersion play a role in the survival of a metapopulation (see fig. 3).



size of the habitat landscape structure

nest predation birth and death-rate sub-population dispersion sub-population

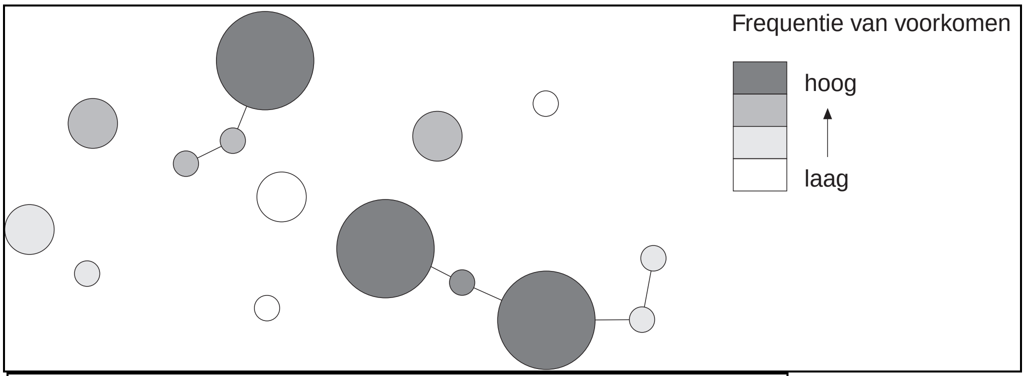
quality of the habitat

rapidity of local extinction rapidity of re-colonisation

Fig. 3. Dynamics of a metapopulation (from Opdam, 1991)

The quality of the habitat is the major factor that determines whether a species will be found in a specific area. The availability of food, a place for refuge and the right conditions for reproduction determine whether a species can survive. The size of a habitat is the most important factor in this respect. The optimum conditions and size of the habitat vary per species. External factors also affect the presence of a species in a habitat – optimum availability of water, food, energy, other organisms and minimum disruption by people.

Dispersion is necessary in order to access new habitats. Successful dispersion leads to an increase in the number of individuals in the new habitat, thus decreasing the chance of extinction of the local population and increasing the chance of re-colonisation of deserted locations. As a result of the internal dynamics of local populations and dispersion between habitat sites, local extinction or departure from a site may occur, whilst allowing re-colonisation to take place sooner or later. The habitat sites can thus be alternatively occupied and deserted (see fig. 4). Dispersion movements can compensate the extinction of local populations.



Frequency of occurrence

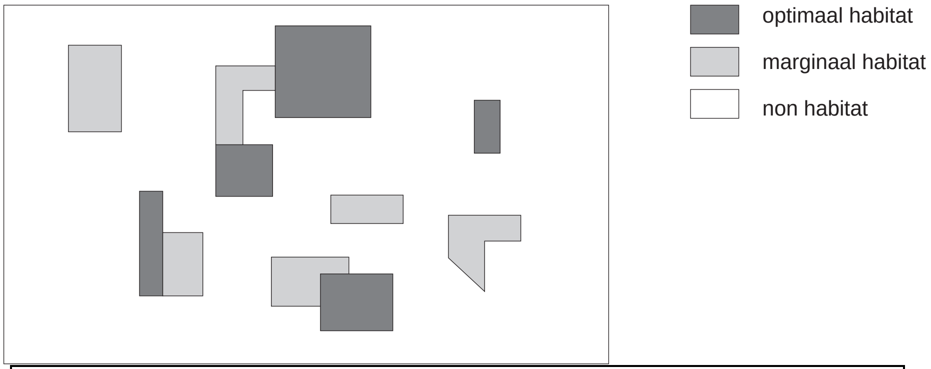
high
↑
low

Figure 4. Spatial dynamics of a metapopulation: alteration in the colonisation of habitat sites (from: Opdam, 1987).

2.2 Habitat fragmentation

In the Netherlands, people have taken centuries to alter the land to meet their own requirements. In comparison with the surrounding countries, the Netherlands has a limited amount of nature reserves and forests. At the same time, land is used intensively because of the high population density, intensive industrial activity, large-scale agricultural production and the large amount of traffic and transportation. The use of land and direct human influence has led to enormous alterations in natural and semi-natural ecosystems. In the second half of the 20th century in particular, the increased scale and intensity of human interference led to a deterioration in biodiversity as quantified in a diminishing number of plants and animal species. In the Netherlands and other parts of Northwest Europe, the most important causes of this deterioration are fragmentation, dehydration, slurry and acidification (Jaarsma and van der Knaap, 1998). Increases in scale and intensification of agriculture have led to monocultures and the disappearance of small landscape elements such as groups of trees, coppices and hedgerows, that are important to many animal species.

Fragmentation of nature reserves in terms of being a spatial problem is defined as “the fragmentation of the habitat of a species in a series of separate fragments” (Opdam and Hengeveld, 1990; H+N+S, 1996; Opdam, 1987; see fig. 5). Fragmentation concerns the reduction of nature reserves and the creation of or increase in spatial discontinuity. Fragmentation is caused by the creation of a form of barrier, such as roads, buildings or impassable farmland, or because of the disappearance of elements from the agricultural landscape that facilitate the dispersion of a species, such as small landscape elements (like coppices and overhanging vegetation on river banks). These barriers restrict movement between various habitats or make movement impossible. This can result in an increase in the effect of external negative influences and a reduction in the quality of habitat sites.



optimum habitat
marginal habitat
non-habitable

Figure 5. Fragmentation of the landscape from the viewpoint of a hypothetical species (Opdam, 1987)

Both the reduction in functional surface area of the habitat territory and isolation increase the chance of local extinction of populations and reduce the chance of a spontaneous return of a species to that location (see §2.1 on metapopulation theory). Populations disintegrate due to isolation or a reduction of available space. The populations that remain are less durable than larger populations and are less able to recover from extreme conditions, because there are fewer individuals capable of reproducing. A wide range of natural processes such as seasonal fluctuations, fire, storm and predation are more likely to have a fatal effect on an isolated population that is relatively small in size than on a larger population.

The functional surface area that individuals and populations require differs per species. Ground beetles, for example, require a habitat of a few dozen square metres, while a species such as wild boar can easily require a few hundred hectares. The size of the habitat is determined by the specific requirements that it needs to fulfil, for example, foraging in fields and sleeping in the surrounding vegetation. The habitat of migratory species can vary greatly from place to place during the year (see §2.1). Apart from effects on size and the connections between the habitats of species, fragmentation makes natural reserves too small to allow processes such as drifting sand, woodland fires and river dynamics to take place in a natural way. This means, in the long run, a loss of variation in the natural environment, which will also lead to a reduction in the number of species.

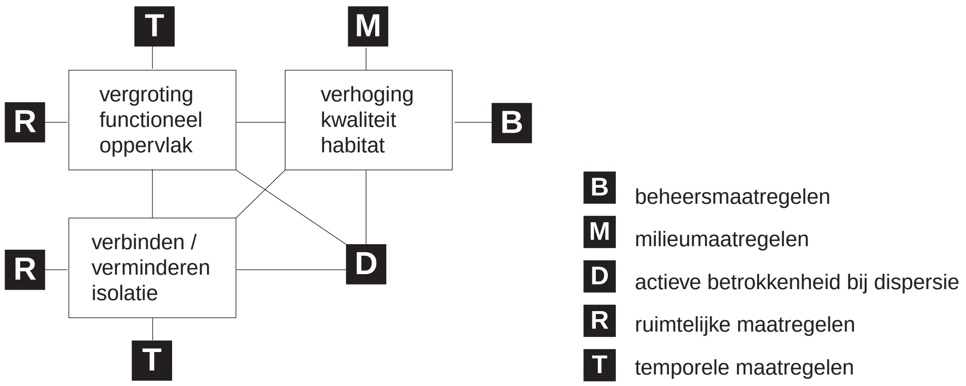
The degree of isolation of a habitat is determined by the presence or absence of connecting elements between the habitats, the distance between them, the density of the habitat and resistance to using the space between the habitats for connecting them. In particular, fragmentation restricts the possibilities for movement (daily movement, season-related movement, dispersion of offspring and migration) of less mobile species. The effects of fragmentation are species-specific (many species suffer, some profit from changes) and depend on the functional surface area required (territory, surface area for population) and the mobility of a species in relation to the isolating effect of unsuitable terrain and barriers such as roads, housing and canals. The isolation of small populations can lead to inbreeding. Generic deterioration can also occur, which can increase a population’s vulnerability (Van Dongen and Hoogenstein, 1996).

2.3 Ecological networks

Policymakers and planners have translated landscape-ecological theory into a conceptual ecological network. An ecological network is a structure made up of key areas, buffer zones and ecological connection routes. The point of departure for this concept is that a landscape with sufficient habitat sub-areas of a specific size and quality, connected where necessary by corridors, will raise the persistence of the metapopulation of a certain species (Jaarsma and van der Knaap, 1998). Within a habitat network, certain stable landscape streams, such as air-currents, flowing water and the migration of species, are important to create optimum habitat conditions (Jongman, 1999). A small habitat is sensitive to external influences. Buffer zones can help to cushion the disturbing effect of these influences. Buffer zones are aimed at curbing human activities on the land surrounding the key area through responsible management of the whole area. Ecological connection zones are landscape structures that maintain or repair the natural connection points in the landscape (Jongman and Troumbis, 1995). Stepping-stones are places in the landscape that can serve as a temporary home or refuge whilst travelling from one key area to another. Ecological connection zones can be regarded as a series of interconnected stepping stones.

Five different types of measure can be used in designing an ecological network (H+N+S, 1996; Jaarsma and Van der Knaap, 1998). These measures are intended to improve the quality of the habitat, increase the habitat surface area or connect habitats.

1. Improving the quality of the habitat. The quality of the habitat is an extremely important factor that determines the occurrence of a species. Measures for improving the quality of a habitat can be divided into measures related to nature management (e.g., making room for ecological processes that can raise or reintroduce variation at different levels of scale) and measures for raising the quality of an environment (to counter disturbance, acidification, slurry, etc.)
2. Designing buffer zones to counter detrimental external influences.
3. Increasing the functional surface area. Acquiring and organising adjoining land and bringing it under the same management creates a larger uninterrupted area. This reduces the chance of local extinction of a species and can create differentiation in ecological communities.
4. Increasing the number of habitat sites. The numbers of a species that a landscape can support can be increased by developing new habitats (see the metapopulation theory).
5. Connection zones. Connection zones reduce the isolation of habitats. Measures for making it possible to bridge distances and points of resistance between habitats can decrease the resistance of the landscape or eliminate or reduce the barrier effects (H+N+S, 1996).



increase in functional surface area	increase in quality of the habitat	B=management measures M=environmental measures D=active involvement in dispersion R=spatial measures T=measures involving time
connection/reduction of isolation		

Fig. 7. Ways of finding solutions to fragmentation and types of measures to realise this (H+N+S, 1996).

Since the start of the 1990s, the national ecological network of protected areas has been the focus of Dutch nature policy (see § 4.4). The Netherlands is a densely populated country with a compact network of buildings, farmland and infrastructure. The numbers and the size of large uninterrupted nature areas are dwindling. With the national ecological network, the government is attempting to improve the natural environment by forming an uninterrupted network of nature reserves joined to one another by ecological connection zones and protected by buffer zones.

Chapter 3 The effects of infrastructure on nature

Contributions by: R.H.G. Jongman, D. Kamphorst

3.1 The direct effects of infrastructure on nature

Fragmentation in terms of being a problem in spatial planning is defined as “the fragmentation of the habitat of an organism in a series of separate fragments”. In addition to urban development and agriculture, infrastructure also plays a role in this process. The actual construction of infrastructure – roads, railways and canals – and vehicles that use it both affect nature.
The effects on nature caused by interference due to the presence of infrastructure can be divided into three categories (from Cuperus *et al*., 1993; Jaarsma and Van Langevelde, 1998).

1. Damage to the abiotic environment caused by the presence of excavation work, asphalt, ballast beds with rails, hard shoulder, etc. and noise pollution, vibrations, xenobiotic substances, etc.;
2. Damage to the biotic environment (affecting individual and populations of organisms as well as changes in the biodiversity of ecosystems and the variation in biotic communities caused by decreases in organism population levels and local extinction);
3. The provision of space for flora and fauna in track/roadside verges.

The damage to the biotic environment can be divided into the following four categories (from Jaarsma and Van Langevelde, 1998, Reijnen *et al.*, 1992) – habitat destruction, habitat disturbance (resulting in the reduction of habitat quality), the forming of physical barriers by infrastructure and road accidents caused by the presence of traffic or drowning because of sheer banks along canals.

Habitat destruction

In this context, habitat destruction means a loss of habitat surface area because of the construction or extension of infrastructure. Destruction is defined as the absolute, quantitative loss of habitat surface area through the physical presence of a road, railway or canal and related facilities that take up a substantial amount of space (Cuperus *et al.*, 1993). In road building, natural habitat disappears under the asphalt of carriageways, hard shoulder and access and exit ramps. A motorway with 2x2 carriageways can easily take up in excess of 5 ha per km. Railway lines take up much less space (see table 1).

Table 1: The global amount of space taken up by different types of infrastructure at surface level.

Mode of transport	Type	Width (m)	Surface area (ha/km)
Railway	Conventional	26	2.6
	HSL upgrade	32	3.2
	HSL new	35	3,5
Road	2x1 carriageways	20	2
	2x2 carriageways	54	5.4
	2x3 carriageways	60	6
	2x4 carriageways	72	7.2

Habitat disturbance

Infrastructure can disturb the surroundings in various ways for example noise and chemical pollution, vibration, visual perceptibility and smell. These effects can assume such proportions that along a road, railway or canal, for example, zones are formed where species that are sensitive to disturbance are either no longer found or only found in low numbers (Cuperus *et al.*, 1993; Oord, 1995). Because of the related reduction in quality, what would normally be considered as an optimum living environment can be transformed into a sub-optimum habitat. It is generally accepted that noise pollution from traffic in the habitats of birds and mammals is the most significant disruptive factor (Cuperus *et al.*, 1993, Van Dongen en Hoogenstein, 1996).

The physical barrier effect

Roads, railways and canals with steep banks can separate different functional habitat areas (breeding grounds and normal habitat, rest areas and feeding grounds, etc.). In addition, if infrastructure cuts through a habitat, it can become too small to be able to house a viable population of a specific species of plant or animal. If habitats become isolated because of infrastructure, they can also become more inaccessible for re-colonisation. Because of this, areas that would normally be considered good biotopes remain devoid of those species that would be particularly suited to them (Van Dongen en Hoogenstein, 1996). The extent to which infrastructure can form a barrier depends amongst other things on its width, the traffic density and the species that has to cross it. In general terms, the greater the traffic density and the wider the road or railway, the greater the barrier effect (Oord, 1995). The extent of the barrier effect also depends on the type of animal that has to cross it. Smaller animals (such as ground beetles, mice, etc.) are frequently unable to cross infrastructure barriers. For these animals, infrastructure constitutes a (virtually) absolute barrier.

Accidents and drowning
For larger animals, roads or railway lines are not absolute barriers, but there is a chance that they might be run over by oncoming vehicles (Van Dongen and Hoogenstein, 1996). The ability of animals to cross a road unscathed depends on various factors such as the traffic density; the width of the road where the animals cross; the animals' body size and crossing speed; the gap between vehicles (in seconds) required to cross over and the likelihood of gaps in the traffic occurring of this length of time (Van Eupen and Van der Veen, 1995; Van Langevelde and Jaarsma, 1997). Inland waterways can also form a barrier for animals. Canals are often built with sheer banks and because of this; animals and young birds that can get into the water can no longer get out and drown.

[figure 7: photograph of a canal with steep banks]

Figure 7:

The role of railway embankments/roadside verges
Although railways, hardened road surfaces and canals form a barrier for many species, embankments and roadside verges can on the other hand link or form ideal habitats for other species. According to figures produced by the Central Bureau of Statistics (CBS), the area of roadside verges in the Netherlands amounts to 52,000 hectares. This is 1.24% of the total land surface area of the country; by way of comparison, only 3.58% consists of natural terrain (Jaarsma and van der Knaap, 1998). The variation of flora and fauna can strongly differ depending on the situation, soil characteristics and the width and slope of the road/track-side. Various types of roadside verges will be favourable for different types of animal. Road/track-sides with a large amount of and varied vegetation can provide food and shelter for a wide range of insects, amphibians, birds and mice. In wide verges, the environmental diversity can be increased further through cultivation or allowing the spontaneous development of brush. Planting thorn bushes, for example, gives a thick cover of vegetation that can be used by animals such as Mustelidae, hedgehogs, hares and various species of mice (Logemann and Schoorl, 1988). Animals can use verges and related vegetation to move around in and between habitats. For these animals, verges serve as links in the ecological main structure (Jaarsma and van der Knaap, 1998).

3.2 The effects of infrastructure on population levels and ecosystems
Habitat fragmentation affects (meta) population levels. For example, if a large number of a particular species are killed in traffic (direct effect), the (meta) population will be affected; the chances of survival for the meta population will decrease. The quantification of effects caused by infrastructure is complicated by the large number of other environmental factors that can influence a (meta) population in addition to the internal circumstances of the population and external factors such as building, land-use and recreation.

The effects of disturbance on the willow warbler *Phylloscopus trochilus*

It is generally thought that roadsides are likely to be less suitable for summer birds than other areas. Detailed research of the willow warbler supports this statement. Studies have shown that the difference between a roadside and a quieter reference area in the willow warblers' success in reproduction is mainly dependent on the proportion of year-old male birds in the total population. Relatively more year-old male birds are found along roadsides. The reason for this is that males that reached sexual maturity in previous year stay away because they did not mate successfully. Territories by roadsides are therefore likely to remain unoccupied for a longer period and are for this reason usually taken in by inexperienced year-old males. The reduction of the quality of breeding grounds is likely to have a negative effect on the size and durability of a population. If a population's habitat becomes completely disturbed, there is a large chance that the population will disappear. In general, with partial disturbance of a habitat, the higher the quality of the disturbed area the greater the effect will be. The population in a disturbed area will in such cases not be able to function as source for colonising and populating areas with a lower quality. This will subsequently drastically reduce the numbers of a species in these areas and will probably also have a detrimental effect on the numbers in areas with a high quality (Reijnen, 1995).

Habitat fragmentation dramatically increases the chance of local population extinction and can instigate a domino effect involving other species in the same ecosystem. Species that are higher up in the food chain like carnivores and birds of prey are the most vulnerable to local extinction. The populations of these species are usually small and therefore recover more slowly from negative influences. The removal of these species from an ecosystem can have a profound effect on species lower down the food chain, which can in turn be a determining factor in the existence of species of a higher level, etc. The gaps that this process creates in the biotic community can also be filled by species from surrounding often completely different environments. In this type of situation, it is relatively easy for foreign species to invade a biotic community and push out the original species and thus disturb the balance of nature.

Lastly, habitat fragmentation leading to the local extinction of one species can in turn herald the extinction of several more species. This can create favourable conditions for invasions by competitive species resulting in more local extinction. The outcome will be a new ecological balance that will be less complex than the original. The new balance is generally considered less valuable because it usually does not have as much biodiversity. A number of species that are characteristic of the original ecosystem disappear; furthermore, the type of ecosystem that disappears is often more characteristic of a particular landscape than the ecosystem that replaces it (Van Dongen and Hoogenstein, 1996).

Chapter 4 Context

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4.1 Introduction

The subject of fragmentation of natural areas as a result of the construction and use of infrastructure brings two different worlds together: the world of nature conservationists and the world of infrastructure managers. The former is concerned with ecosystems and flora and fauna species, with occurrence and numbers, with rarity and characteristics. The infrastructure manager is more involved in facilitating the mobility of both people and goods, traffic flows and density. This chapter describes the natural environment in the Netherlands - the ecosystems and species that are occur and their national and international significance. It also discusses how the natural environment is protected or further developed – the existing policy documents, legislation and guidelines and their consequences. It concludes by looking at how the natural environment is approached in spatial planning, the way in which policy is translated into concrete terms in different areas and the instruments available to protect the natural environment. The infrastructure networks and their respective impact on the natural environment are described in the next chapter.

4.2 Biogeografical description

The Netherlands is part of the Northwest European lowland plain and consists primarily of the delta areas of the Rhine, Maas and the estuary of the Scheldt rivers. The natural environment and landscape in these characteristic lowlands feature a wide variety of ecosystems in which the environmental conditions vary from salt to fresh and wet to dry habitats and in the types of soil – peat, clay and sand. To the west is the North Sea, a saltwater ecosystem with fish and many types of seabirds, but which is also home to sea mammals such as sperm whales and seals. The North Sea has a major influence on the Dutch coastal zone, which consists of a wide band of sand dunes alternating with tidal waters in the North and Southwest. These tidal waters are influenced by the North Sea and the river estuaries and form the brackish water ecosystems on the coast so characteristic for the landscape, flora and fauna. This area, where quiet and space are relatively abundant compared to the rest of the Netherlands, which is subject to such intensive use, is the site of important spawning grounds for the sea fish. Seals visit regularly and the vast expanses of salt marshes, mud flats, sandbanks and shallows, with their plentiful supply of food, form vital feeding grounds and homes for the wide variety of seabirds that migrate along the coast or come here to breed every year.

Behind the dunes and coastal waters are the clay and fenlands, parts of which are below sea level. Most of these clay and fenlands are agricultural land, but are characterised more and more by a close-knit network of towns, cities, industrial estates and infrastructure, particularly in the densely populated west of the Netherlands. People in this region have always had a great deal of influence on the natural environment and landscape, primarily due to intensive water management, which has resulted in the unique man-made Dutch landscape with its countless polders. In an international context, the inland polder 'De Beemster' in the province of North Holland has recently been included on the 'World Heritage' list (see the Belvedere Policy Document, 1999).

In this region, which has been so intensively cultivated by its population, the original natural environment of peat marshes and woodland has only been preserved in widely dispersed relatively small nature reserves. The wet, extensively managed, man-made grasslands are an important habitat for meadow birds like the black-tailed godwit *Limosa limosa*. These wet grasslands combined with various stretches of water in the coastal zone are known as the wetlands, which are afforded international protection as habitats for a wide variety of water birds, which include the spoonbill *Platalea leucorodia* and the cormorant *Phalacrocorax carbo*. Furthermore, large groups of geese, ducks and swans migrate here for the winter after spending the summer in the North-European arctic region. The wetlands also attract different kinds of birds that stop over on their way to spending the winter in southern Europe or Africa.

The higher sandy regions start in the middle of the Netherlands, and stretch to the east and south. This is where the badger *Meles meles* is found, the largest carnivore that still occurs in the Netherlands. Heaths, sand drifts and deciduous forests are the ecosystems that are characteristic of the landscape. The heath vegetation found in these sandy regions with hairy greenweed *Genista pilosa,* root lathyrus *Lathyrus linifolius* and the grayling *Hipparchia semele* are valuable ecosystems for North-western Europe, but the acreage has diminished drastically in recent years. From the early twentieth century onwards, large tracts of these ecosystems, which were known as 'wastelands', have been reclaimed and are used for farming. In addition to a radical increase in the extent of building development and the density of the infrastructure network in these areas, the intensification of agriculture has had the foremost impact on these ecosystems in recent decades. Drainage of wetlands and soil enrichment with nitrogen and phosphate are the primary reasons that both wet and dry grassland vegetation in nutrient-poor environments in this sandy soil have all but disappeared. It is precisely these grasslands that require international protection, since they are under threat all over Northwest Europe. A characteristic of these nutrient-poor grasslands is the high level of biodiversity that may occur, including a variety of higher plants, mosses and lichens, whose habitats have decreased dramatically in recent years, and various species of ground beetles. Imported tree-types like the spar and the American oak have replaced the original trees in the woods and forests to boost timber production. Deciduous forests with oak and beech trees that are native to the Netherlands can still be found in a few small areas. However, the quality is not up to that of the type of forest that occurs across the country's eastern border towards Central Europe, which is generally far better developed (see Ellenberg et al., 1982).

[figuur 8: foto voedselarm ven]

Figure 8: A nutrient-poor mere with *Eriophorum angustifolium*

The extreme south of the Netherlands (South Limburg) has the highest elevation in the country and is typified by hills that reach a maximum height of 300 m above sea level. The soil is loessial and the subsoil contains a large amount of limestone. Characteristic ecosystems in this region are the fertile chalk-slope woodland and the limestone grassland vegetation, which extend into similar ecosystems in Germany and Belgium. The limestone grasslands or chalk-slope grasslands are rich in various species of both plants (including orchids) and animals. Together with similar calcareous grasslands in the dunes and calcareous habitats in the Maas river valley, these ecosystems are known to have the largest degree of biodiversity in the Netherlands. As a result of the large population and the intensive farming of this highly productive land, the remains of these grasslands and woodlands, with their rich variety of flora and fauna are now only found in widely dispersed, relatively small nature reserves. In South Limburg, a number of animal species occur that are not found anywhere else in the country such as the hamster *Cricetus cricetus* and the nurse-toad *Alytes obstreticans*.

The major rivers form yet another unique region: the Rhine, the Maas and the Scheldt, which cut through the higher sandy soils, the hill country and the fenlands and clay areas as they flow from east to west. The river forelands with sandy levees, natural banks and meandering tributaries that flow into marshes and willow thickets form the river landscape so typical of the Dutch delta region. As in the rest of the Netherlands, people here have also had a considerable impact on the original character of the river landscape. Over the years, the courses of the rivers have been regulated and the fertile forelands have been used for a long time as intensive agricultural grassland.

In order to restore the natural environment and landscape, a number of nature development projects are currently underway in the river forelands. These projects use as much of the dynamic character of the rivers (soil erosion and sedimentation, for example) as possible to form the landscape and create new habitats for plants and animals. As part of this development work, international attention should be drawn to the habitats for water and marsh birds and particularly to the restoration of the plant habitats in the sandy calcareous river dunes. These two ecosystems are home to species that are endangered in both the Netherlands and in Europe as a whole.

The river dune grasslands with their wide variety of plants and animals, the dry grasslands of the dunes, the higher sandy soils and the hill country are some of the most endangered grasslands on the north-west European lowland plain (see Schaminee *et al*. 1996).

To sum up, we can conclude that apart from the North Sea as an open salt-water ecosystem, there are six characteristic ecosystems in the Netherlands:

1. The coastal ecosystem, with salt water, mud flats, salt marshes and meadows;
2. The wetlands, open water, wet grass lands and marshes;
3. The dune ecosystem, with pioneer vegetation, grasslands, dune scrub and dune woodland;
4. The grasslands, primarily wet grasslands and a relatively small acreage of dry grasslands;
5. The heath ecosystem with dry and wet heathland vegetation and
6. The forest ecosystem.

The spread of these ecosystems is partly related to the 9 physical geographical regions which the Netherlands can be divided into on the basis of situation, soil type and (geo)hydrology (dry-wet, salt-fresh). Particularly the semi-natural ecosystems such as grasslands, heaths and forests can be found in several physical geographical regions (see Table 2).

Table 2: The spread of the most important main ecosystems in the Netherlands for the 9 established physical geographical regions.

Physical Geographical region	Coastal ecosystem	Wetlands	Dunes	Grasslands wet	Grasslands dry	Heaths	Woodland
North Sea	+						
Tidal areas	+ +	+					
Closed sea inlets		++		+			
Dunes			+ +	+	+	+	+
Clay areas		+		++			
Fenlands		+		++			
River area		+		++	+		+
Higher sandy soils				+	+	++	++
Hill country				+	++		++

In recent years, a great deal of research has been conducted into the threat to and deterioration of European ecosystems. Studies have often defined ecosystems at different scale levels, making it difficult to come up with a clear indication of the international significance of the Dutch ecosystems (Bal, 1999). If the surface area of the most natural ecosystems at the scale level of the physical geographical regions is taken as the standard, the Netherlands, with its ecosystems in the coastal zone, including the North Sea, the dunes and the tidal waters, currently makes a valuable contribution to European biodiversity (RIVM *et al* 1997). Looking at it like this, the Netherlands contributes 7% of the entire European acreage of dunes and salt marshes. The Wadden Sea tidal flats comprise 13% of the entire acreage of similar systems in Northwest Europe and West Africa.

[figuur 9: Duinlandschap]

Figure 9: Dune area

In addition to applying the natural quality criterion for ecosystems, it is possible to use the species level to determine the international significance of the Dutch natural environment. As part of the Handbook “Model Ecosystem Types” (Bal *et al*, 1995), the Institute for Forestry and Nature Research has conducted extensive research to this end (from Beers *et al*. ,1993, Siepel *et al.*, 1993). Species of international importance come under the i-criterion, i.e. they have to be native and their natural habitat in the Netherlands makes a reasonable contribution to the European acreage occupied by a particular species. The Handbook “Model Ecosystem Types” contains lists of i-species for various salient species groups, such as mammals, birds, amphibians, reptiles, butterflies and vascular plants. These lists are regularly updated and improved on the basis of recently acquired data on the acreage on which the various species occur in the Netherlands and Europe as a whole. For 12 species groups, Table 3 indicates the extent of the international significance of the Netherlands in terms of the numbers of i-species. One striking feature is that for both the vascular plants and the various animal groups, a reasonable, albeit varying number of i-species occurs in each group. Of the total number of species, over 20% contribute to the natural environment considered to be of international importance.

Table 3: Number of species in the Netherlands, including species of international importance (from Burrough 1996).

species group	number of native species	number of i-species
higher plants	1448	223
mammals	76	12
birds	296	17
reptiles	7	3
amphibians	16	7
fish	126	59
echinoderms	15	10
crustaceans	52	24
butterflies	76	12
dragonflies	60	3
ground beetles	378	177
grasshoppers	42	5

A study of the spread of i-species in the Netherlands shows that a number of species of international importance occur in all physical geographical regions. For the species selected in Table 3, the number of i-species varies from approximately 100 for the North Sea (aquatic species in particular) or for the fenland to 200 species for areas such as the dunes or higher sandy soils (RIVM *et al*. 1997). The diversity of vascular plants of international importance is at its highest in the dunes where there is dry grassland vegetation that thrives in a warm environment. This runs parallel to the relatively high level of naturalness found in the dune ecosystems in the Netherlands. It also turns out that the diversity of species in the relatively nutrient-poor grasslands of wet and dry habitats is not only high for the Netherlands, but also comprises a reasonable number of vascular plants of international importance. The i-species mammals that occur in the Netherlands include the pine marten *Martes martes*, the hamster *Cricetus cricetus* and the northern vole *Microtus oeconomus*. The birds include the nuthatch *Sitta europaea*, the black-tailed godwit *Limosa limosa*, the dark-breasted barn owl *Tyto alba*, Bewick's swan *Cygnus bewickii* and the common redshank *Tringa totanus.* The amphibians and reptiles include the grass snake *Natrix natrix* and the warty newt *Triturus cristatus*. The grayling *Hipparche semele* is also a species of international importance.

[figure 10: foto grutto]

Figure 10: More than 50% of the world population of the black-tailed godwit *Limosa limosa* breeds during summer in the Netherlands.

4.3 Fragmentation as a result of urbanisation, intensive agriculture

The surface area of natural land and woodland in the Netherlands has almost halved in this century as a result of the cultivation of 'wasteland' and intensification of land use on marginal farmland. In 1900, the Netherlands had approximately 90,000 ha of natural land. In 1990, this figure had fallen to approximately 450,000 ha (see Figure 10). The most dramatic decrease has taken place in the heath ecosystem with dry and wet heathland vegetation.

[Figure 10: graph showing total surface area of natural land and woodland]

Figure 10: Surface area (x 1000 ha) woodland and natural land in the Netherlands in the period 1900-1997 (source: RIVM/DLO, 1997).

The numbers of species reliant on this ecosystem have fallen drastically as a result. The Dutch population of black grouse, for example, has been decimated from approximately 30,000 in the 1930s to about 100 today. The decline of the black grouse *Tetrao tetrix*, a species whose habitat is covered by the European Bird Directive (see next section) provides a useful indication of how loss of habitat can cause large populations to be split up into small, isolated sub-populations, which accelerates their decline. Until the 1970s, the total number of birds declined faster than the number of different populations: the sub-populations shrunk. From the middle of the 70s, many of the small populations were no longer able to survive and the decline gained momentum (see Figure 11). Only a highly isolated population remains today.

[figuur 11: grafiek korhoen]

Figure 11: Decline of the black grouse *Tetrao tetrix* in the Netherlands (source: Niewold, 1990)
a: total number of cocks; b: number of populations

There are not enough detailed historical maps for a complete analysis of the shift in land use. The development of detailed satellite photographs has created an accurate picture of the current situation, which can be analysed with the aid of geographical information systems (GIS).

Figure 12 (see appendix) shows a countrywide picture of the land cover of the Netherlands in 1995 (resolution 25x25m, source LGN3). The overall impression is one of a highly urbanised landscape in which the rural areas are dominated by agricultural land use (grassland and arable land). This 'ocean' of cultivated land is dotted with 'islands' of woods and natural land. The drawback of the satellite photograph is that no distinction can be made between nutrient-poor grassland with a high level of biodiversity (in undeveloped areas) and the intensively used rye grass fields with hardly any species of flora and fauna. It is therefore difficult to determine the acreage of natural land directly from the satellite picture. For this reason, figure 13 (appendix) shows the boundaries of natural land according to Dutch nature conservation policy. This map also shows what ambitions the Dutch government has with regard to the creation of new natural land and the struggle against further fragmentation. (National Ecological Network, see also §4.4).

Table 4. Level of fragmentation of land use in the Netherlands (calculated for the Netherlands as a whole and the National Ecological Network).

	total surface area in ha	**number of units**	**average surface area in ha (x)**	**standard deviation**	**average distance between areas in m (y)**	**index* relationship (x/x_{max} / y/y_{max})**
The Netherlands total						
grassland	1372725	93256	15	142	85	7.5
arable land	965966	111415	9	84	118	3.2
deciduous woods	181447	183280	1	9	136	0.3
coniferous wood	175903	45219	4	61	205	0.8
heath	13415	7098	2	20	132	0.6

without vegetation	17615	8428	2	43	489	0.2
other natural land	122471	67292	2	35	188	0.4
fresh water	342032	51745	7	832	166	1.7
National Ecological Network						
grassland	173931	35301	5		162	1.3
arable and	46891	19458	2		244	0.4
deciduous wood	119570	37332	3		145	0.9
coniferous wood	164404	15550	11		189	2.5
heath	13321	1967	7		109	2.8
without vegetation	13449	3572	4		649	0.3
other natural land	106154	22895	5		196	1.1
fresh water	27371	11664	2		274	0.3

** This index is a standard for the fragmentation in which the size of the units and the distance between them are taken into account. To make sure that one of either factor does not weigh heavier in the final result, the actual values have been related to the respective maximums, so in fact the percentage of the maximum score is used in the calculations. The ultimate index value increases as the average surface area grows and/or the distances between them decrease. A low value, therefore, means a high level of fragmentation.*

Table 4 shows the results of a quantitative analysis of the spatial configuration of land use according to Figure 12. The natural units are highly disintegrated in comparison to arable land and grassland. The situation is most unfavourable for deciduous wood and pioneer communities (category 'without vegetation'). The category 'other' refers to heterogeneous areas; it has been included for the purposes effective assessment. The distribution around the average varies somewhat for the different units. The category 'fresh water' has an immense standard deviation due to the existence of several large bodies of water such as the IJsselmeer. Similar peaks also exist for coniferous woodland (Veluwe national park) and in the categories 'without vegetation' and 'other natural land' (dunes, salt marshes). Deciduous woodland has a relatively small surface area variation. Really large deciduous woodland complexes are no longer found in the Netherlands. Heathland is in the middle (see also figure 14 in the appendix).

As expected, the scores for the National Ecological Network are much better. Compared to the Netherlands in its entirety, the average surface area of natural units within the NEN roughly three times the size. The index for spatial relationship for coniferous woodland and heathland within the NEN is much higher that for the Netherlands as a whole. On the other hand, the grassland and arable land are much smaller in the NEN and are more widely dispersed. This is quite logical because primarily small-scale, man-made landscapes and arable reserves with a high level of biodiversity fall within the bounds of the NEN. Nature development will further improve the cohesion of the NEN, but this remains to be seen in the present situation (see also RIVM/DLO, 1997).

4.4 Regulations and policy

Nature
In 1990, the Ministry of Agriculture, Nature Management and Fisheries issued the Nature Policy Plan, which focuses on the conservation and development of ecosystems that occur in the Netherlands by building up a spatial network – the National Ecological Network (NEN). The NEN is made up of existing natural land (the 'core areas'), planned natural land and the connecting zones between them. The National Ecological Network will give plants and animals a better chance for survival. Additional measures have also been taken for a number of species. These measures are partly intended for areas outside the National Ecological Network, e.g. in areas with a lot of meadow birds, geese, wild swans and Berwick's swans.

The 'no-unless' principle was introduced in the Structure Plan for the Rural Areas (Ministry of Agriculture, Nature Management and Fisheries, 1993): areas designated for nature and/or woodland and/or recreation may not be altered unless the initiator can prove that there is a vital social requirement involved. If any changes are made, mitigation measures should be taken, and if these do not suffice, compensatory steps should also be taken. Mitigation measures can be used to soften any detrimental effects (see §7.3). Compensation measures involve the development of new nature conservation areas to replace nature that has been lost (see §7.4). The 'no-unless' principle applies to:

- key areas in the NEN;
- existing nature development areas in the NEN;
- small nature conservation areas outside the NEN which are designated as such in the regional plan, are covered by the Nature Conservation Act or have been laid down in a land-use plan;
- habitats of species of special interest included in regional plans and/or land-use plans on the basis of the species protection plans of the national government;
- woods and landscape vegetation covered by the Forestry Act (i.e. larger than 0.1 ha);
- large-scale public recreational facilities.

In recent years, a number of international treaties and conventions have been signed and decisions made to protect endangered and/or rare species. The Wetlands Convention, the Conventions of Bonn and Bern and the European Habitat and Bird Protection directives are just a few examples (van Opstal, 1999). The signatories, including the Netherlands, are currently incorporating the agreements into their national nature policy. These agreements are primarily concerned with the protection of endangered species, but there are also moves underway to protect the habitats of these species. Lists of endangered species are being compiled and the boundaries of their habitats have to be defined. See figure 15 (in the appendix) for the proposed areas in the Netherlands laid down in the Bird Protection Directive.

Data on the presence and habitats of the relevant species are part of the international agreements that have been made and, in some cases, even have a legal status. For example, the EU Habitat and Bird Protection Directives were issued by the European Commission so they take precedence over national legislation of the member states (van Opstal 1999). This legal status means that the EU Habitat and Bird Protection directives have an important influence on the Dutch nature policy, particularly in places where internationally valued species are endangered. All species in the Netherlands that are covered by the provisions of the EU Habitat and Bird Protection can be designated as species of international importance as a result. Some of these are the same as the i-species listed in the Handbook "Model Ecosystem Types in the Netherlands", but there are differences, however. A species may occur on a small scale in the Netherlands and not have the i-status, but it may be listed as an endangered species in the EU Habitat or Bird Protection directives. The fire-bellied toad *Bombina variegata*, the otter *Lutra lutra* and the beaver *Castor fiber* are examples of species that have no i-status, but are still protected under European law and their habitats are protected under the EU Habitat Protection directive. Seen from this viewpoint, the number of mammals, birds and butterflies of international importance with the i-status (see Table 3) can be increased by 13 mammals, 31 birds and 2 butterflies that are endangered at a European or even global level (Bal 1999). These additional species should be taken into account in national spatial planning policy (including land-use plans).

[figuur 17: foto otter]

Figure 17: The otter *Lutra lutra* has become extinct in the Netherlands partly due to the fragmenting effect of infrastructure. The otter will be reintroduced coming years.

The wetlands and marshy grasslands in the Netherlands are home to a number of endangered bird species of international importance. These areas, which are protected under the Bird Protection guideline, form a vital link in the flyways used by birds between the arctic tundra and parts of southern Europe and Africa. Many waterfowl stay in the Netherlands every year, some of which only temporarily as they migrate. Others winter in the country, such as the barnacle goose *Branta leucopsis* and the white-fronted goose *Anser albifrons*. Still others come to the Netherlands to breed like the lapwing *Vanellus vanellus*, avocet *Recurvirostra avosetta* and common redshank *Tringa totanus*. Of the 127 types of waterfowl that occur, there are 91 species of which at least 1% is in the Netherlands at least temporarily, as are 10% or more of 55 other species (RIVM *et al.*, 1997).

Most treaties and conventions take ‘a species’ as the basic principle. This is different in the Netherlands, where nature policy is based primarily on protection of areas in a cohesive ecological network (NEN). An effective ecosystem offers the species that live in it every chance of survival. Ultimately, both approaches are intended to preserve the biodiversity, but the coordination between the two requires further attention. A step has now been taken in this direction with the formulation of the Pan European Ecological Network as a strategic concept designed to integrate nature conservation, preservation of the biodiversity and landscape conservation at a European level. In 1996, The European Council (Council of Europe, UNEP and EVNC) laid the basis for this move with the presentation of ‘The Pan-European Biological and Landscape Diversity Strategy’ (van Opstal 1999).

Traffic and Transport

The Second Transport Structure Plan (Ministry of Transport, Public Works and Water Management, 1990) is the policy document concerned with transport and infrastructure. In addition to accessibility, the plan also looks at amenity. The target in the fight against fragmentation is: in the short term, further fragmentation of nature and landscape has ceased; in the long term, the fragmentation has been forced back. Fragmentation can be prevented by practising caution in the construction of new infrastructure and by tailoring new infrastructure to the landscape in question. Fragmentation will be countered by taking mitigation and compensation measures and restricting the construction of scenic routes.

Water

In the beginning of the 1990s, the Third Policy Document on Water Management (NW3) provided an extra impetus to the construction of environment-friendly banks (Ministry of Transport, Public Works and Water Management, 1990). Nature-friendly banks along canals were a clear spearhead in this document. The implementation has been guaranteed, both financially and pragmatically, via the Long-term Recovery Plan (MJPH) and via the Long-term River and Canal Bank Plan (MPO). The policy laid down in the Third Policy Document on Water Management was further refined by the Directorate-General for Public Works and Water Management in the "Management Plan for State-Administered Waters 1992 - 1996" and the "Management Plan for State-Administered Waters 1997 - 2000". The scheme has been developed still further in Regional Management Plans and the Management Plans for Wet Infrastructure (BPN). This has resulted in an increase in the construction of nature-friendly banks along canals and rivers.

The Fourth Policy Document on Water Management (NW4) continues along the lines laid down in NW3 with a slight shift in the theme (Ministry of Transport, Public Works and Water Management, Ministry of Housing, Spatial Planning and the Environment and the Ministry of Agriculture, Nature Management and Fisheries, 1998). Nature-friendly banks play a less prominent role than in NW3. An important aspect of the policy in NW4 is the restoration of the natural resilience of surface waters in the Netherlands, with bank restoration as one of the priorities. The Fourth Policy Document on Water Management and its predecessor the Third Policy Document both emphasise the natural value of the many types of inland waterways, including canals. They look at the water quality as well as the restoration of natural bank-forming processes and the restoration of migration and spawning possibilities for fish. The NW4 is expected to be worked out in more detail this year in the Supplement to the Fourth Policy Document on Water Management.

4.5 Planning, procedures and area-specific elaboration

Nature
Until recently, the division into physical geographical regions with the primary ecosystems was the highest level on which a description of nature and landscape in the Netherlands could be based. However, a more accurate definition of the ecosystems to be preserved and/or developed is essential to the planning, the implementation and the evaluation of nature policy. After all, concrete questions regarding the intended goals of nature policy have to be answered, such as what quality of nature is targeted where on the basis of the given environmental conditions and how can the relationship between the ecosystem approach and the endangered plant and animal species which the nature policy is designed to protect be put into practice? The handbook Model Ecosystem Types in the Netherlands (Bal *et al*, 1995) provides a systematic description per physical geographical region of the main ecosystems on the basis of clear-cut base ecosystems or "model ecosystem types". A total of 132 of these model ecosystem types have been distinguished. Based on the criterion "naturalness", defined as the extent to which people influence the model ecosystem type, these ecosystem types have been classified one step further into four separate categories: 1. Almost natural ecosystems; 2. Managed-natural ecosystems; 3. Semi-natural ecosystems and 4, Multifunctional ecosystems. Using the criterion "biodiversity", the quality of the model ecosystem type has been detailed still further. For each ecosystem type, there is an indication of what characteristic, rare and/or endangered plants and animals may be present. These species are referred to as "target species". Initially, the species used were those for which enough information on their national distribution was available. The species groups in question were: higher plants, mammals, birds, reptiles, amphibians, butterflies and dragonflies. In later years, the list was extended with useful information on moths, beetles, fish, crustaceans and echinoderms (Bal, 1999).

In the document “Ecosystems in the Netherlands” (Ministry of Agriculture, Nature Management and Fisheries, 1995), the national government gives an indication of what ecosystems in terms of model ecosystem types have priority when it comes to the conservation and development of new nature as part of the planned National Ecological Network. The document also deals with required quality of nature and its magnitude. The most concrete terms concern its goals regarding the natural environment, for which the government considers itself responsible, and particularly the goals for the most natural ecosystems in categories 1 to 3 in the handbook "Model Ecosystem Types in the Netherlands". The actual allocation of model ecosystem types in a particular region is the responsibility of the regional and local authorities such as provincial and municipal councils and water boards. By delineating the boundaries of the relevant model ecosystem types in area-specific plans and maps, they implement the national policy in general terms. The bounded National Ecological Network is also referred to as the Provincial Ecological Network (PEN).

In the Dutch situation, important habitats of internationally endangered species, like the dunes and wetlands, usually correspond to the bounded areas in the NEN, but this does not always have to be the case. The instrument for species protection, including the habitat of the species, may also be in effect outside the NEN. For the spatial planning of all kinds of civil engineering activities, such as housing, industrial and infrastructure construction, species protection plays an important role. Outside the NEN, this is one of the main instruments of nature policy, while many people believe that nature only takes precedence within the NEN. Examples of species protection include fire salamanders along the railway line in South Limburg and the abundance of provisions made along national highways for the badger. The strong legal foundation of the EU Habitat and Bird Protection directives will in the future result in a situation where European legislation regarding species protection will have a steadily increasing influence on Dutch nature policy (see the lecture given by Professor Verschuuren of the University of Brabant in Tilburg, 2000). The influence of international treaties and conventions will then have to be examined more explicitly in the obligatory environmental impact assessments (see below).

Traffic and transport

The infrastructure planning/EIA procedure (EIA = environmental impact assessment), which is based on the Infrastructure (Planning Procedure) Act and the Environmental Management Act, provides the framework for decision-making on certain activities, including the construction and reconstruction of main infrastructure (Klink *et al*., 1999). In this procedure, it is compulsory to draw up certain documents such as a Planning paper/EIA. This Planning paper/ EIA is a public document containing an objective description of what environmental impact the activity and the alternatives will have and what measures can be taken to prevent, minimise or compensate for that impact. The Planning Paper/ EIA is a tool that can be used by the government when making a deciding on the activity in question. In the case of main infrastructure, it concerns the Infrastructure (Planning Procedures) Act drawn up by the ministers for Transport and Communications and for Housing, Spatial Planning and the Environment. The provincial and/or municipal authorities decide on the underlying road network. In these cases, the EIA procedure is not linked to the Infrastructure (Planning Procedures) Act but to a regional plan or land-use plan procedure laid down in the Spatial Planning Act. Figure 15 shows the process that has to be followed when carrying out the planning/EIA procedure.

[Figure 15: process related to the Infrastructure (Planning Procedures) Act]

In addition to the legal decision-making procedure, there is also a financial decision-making procedure. This procedure, which is not governed by law, establishes whether and, if so, how much and when funds for a particular project should be set aside. The funding decisions are laid down in the Long-term Programme for Infrastructure and Transport (MIT). A project can only be carried out if it is legally and financially viable. The MIT is issued annually as part of the budget of the Ministry of Transport, Public Works and Water Management. It provides an up-to-date overview of the planned or current infrastructure projects in the Netherlands in which the Ministry of Transport, Public Works and Water Management is involved. These are projects that concern the main road network, the main waterways network, the rail network and the regional and local infrastructure that are expected to cost more than 25 million guilders and are to be funded partly or in full by the Ministry of Transport, Public Works and Water Management from the Infrastructure Fund. Not all projects in the MIT are governed by the Infrastructure (Planning Procedures) Act. This applies to local infrastructure, for example.

In 1993, the compensation principle, linked to large-scale spatial construction projects, came into effect in the Netherlands (the Ministry of Agriculture, Nature Management and Fisheries and the Ministry of Housing, Spatial Planning and the Environment, 1993). This principle requires that certain damage to the natural environment that cannot be prevented or mitigated must be compensated by replacing and developing the damaged nature values elsewhere. Physical compensation involves reconstruction and management of (compensation) areas, preceded if necessary by acquisition of the required land.

The compensation principle is binding when the state is the initiator of spatial construction projects. It serves two purposes: reinforcement of the nature conservation interests when weighing up the pros and cons of a spatial intervention and the actual compensation of the damage caused to the natural environment by a particular project. The elaboration of the compensation principle is not supported by any specific national laws and regulations, as is the case in Germany (*Eingriffsregelung*) and the USA (*no-net-loss* for wetlands). As a result, compensation in the Netherlands takes place on a purely voluntary basis between the parties concerned (cf. the Canadian *no-net-loss* principle for the federal wetlands: Rubec 1994).

The principle is applied when one of the area categories in the Structure Plan for the Rural Areas (see §4.4) is damaged. The following guidelines have also been drawn up: (1) the initiator is responsible for applying the compensation; (2) the legitimacy of a project must be established before compensation comes into play; (3) once the project has been approved, any impact first has to be prevented and mitigated, and only compensated as a last resort; (4) damage to nature should be physically compensated in terms of the same acreage and the same quality and, if the latter proves impossible, of similar quality; (5) if physical compensation is not possible, financial compensation is required (Ministry of Agriculture, Nature Management and Fisheries and Ministry of Housing, Spatial Planning and the Environment, 1993; Ministry of Agriculture, Nature Management and Fisheries, 1995). The model ecosystem types are used to determine the quality of nature.

For the national road network, the Directorate-General for Public Works and Water Management has translated the policy goals in the Second Transport Structure Plan regarding fragmentation (see §4.4) into the following, more concrete goals:

- prevent new transections of the (Provincial) Ecological Network;
- if that is not possible, fragmentation can be minimised or mitigated by land-use adaptation and fauna passages;
- remaining damage to areas protected under the Structure Plan for the Rural Areas has to be compensated;
- fragmentation on the existing road network has to be cut (this can be seen as a repair of existing damage): in 2000, 40% of the bottlenecks between the national road network and the (Provincial) Ecological Network will be cleared up; in 2010, this figure will rise to 90%;
- optimisation of layout, structure and management will help counter fragmentation;

in the vicinity, existing nature areas will be protected, linked up, and reinforced and developed where possible.

Chapter 5 Fragmentation by existing infrastructure

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5.1 Introduction

The national report distinguishes four types of infrastructure, i.e. national trunk roads, secondary roads, railroads and waterways (canalised rivers and canals). Other forms of infrastructure— such as airfields, high-tension lines and pipelines — are not taken into consideration. Some characteristics relevant to the fragmentation effect (e.g. length, density, traffic intensity) are described for the existing Dutch situation. The known facts about the effects on nature caused by each type of infrastructure are also described in this chapter. In this context, the four aspects of fragmentation—i.e. destruction, disturbance, barrier effect and traffic kills (see § 3.1)—are discussed separately. The available knowledge comes from experimental research, literature studies and/or computer models. Depending on the information available, the effects are described at various levels, i.e. at that of the individual, of the population or of the ecosystem/landscape. The positive effect of infrastructure—that is, the corridor function of road verges and banks—is described in a separate paragraph. Paragraph 5.3.8 describes fragmentation as the number of bottlenecks with respect to nature caused by the infrastructure network. This is a more pragmatic approach to the problem, which establishes a relationship with the approach in Chapter 7. Finally, a short description is provided concerning the secondary effects of infrastructure.

[figuur 16: foto snelweg]; [figuur 17: foto provinciale weg];
[figuur 18: foto spoorlijn]; [figuur 19: foto kanaal]

5.2 Infrastructure networks

Motorways, main roads and secondary roads

The RONA (Guidelines for the Design of Non-Motorways) Commission has drawn up guidelines for dividing roads outside built-up areas into categories. Based on function and design, the following are the four main categories: (A) motorways, (B) roads with limited access, (C) roads designated as ‘fully or partially closed’ (roads where e.g. agricultural vehicles or mopeds/bicycles are not allowed) and (D) roads open to all traffic. Each main category in its turn is divided into two subgroups. This is indicated by Roman ciphers. Figure 20 shows the major road and traffic characteristics in each category.

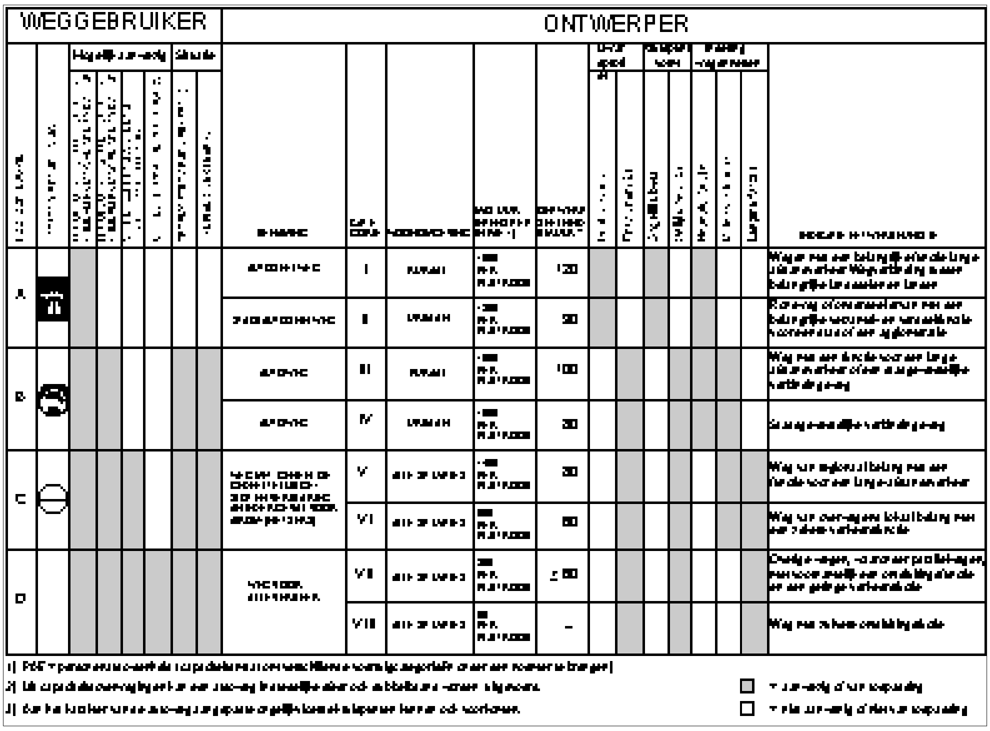

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Figure 20 Category division of roads outside built-up areas with an indication of the road and traffic characteristics and the network function (RONA, 1992)

The road system outside built-up areas is managed by various governmental bodies, i.e. the state (mainly roads in category A), the provinces (especially roads in category B and a large part of category C), and the local authorities. In the western part of the country, some local authorities have transferred their road management tasks outside built-up areas to water district boards (Jaarsma et al., 1999). All roads managed by local authorities and water district boards are referred to as rural/ roads. These include all roads from RONA category D and some from category C.

The most recent CBS Statistics of the Road (1 Jan. 1996) gives the total hardened surface road length outside built-up areas as 58,202 km. Of this, 3,143 km (5%) are managed by the state (national trunk roads). The provinces manage 11%, i.e. 6,360 km (provincial roads). The remaining 48,700 km are rural roads, managed by water district boards (6,555 km, or 11% of the total) and local authorities (42,145 km, or 73%). Provincial roads and rural roads taken collectively in the group ‘secondary roads’ comprise 95% of the total road system. The remaining 5% are roads of a higher order, i.e. the state-managed system of motorways/roads with limited access. Over time, the length of the hardened surface road network has increased markedly, from 47,777 km in 1970 to 58,202 km in 1996. In addition to hardened surface rural roads, there were an additional 10,012 km of unpaved rural roads on 1 Jan. 1996. This length has especially decreased: in 1979, the total length was 20,500 km.

Not only the length of the road system but also its density are illustrative of the fragmentation. This is simple to compute by dividing the road length by the land-surface area. The land surface area (minus the large water surface areas of the Wadden Sea, Eems-Dollard, the North Sea, the IJsselmeer, Oosterschelde and Westerschelde) is 35,513.49 km2. Much more meaningful is the concept of ‘mesh’, which can serve as a frame of reference for the number of encounters with roads when moving through the landscape. The mesh is computed by imagining that the full length of the road system has been spread over the country in a square (Jaarsma & Monderman, 1995). This computation, performed for the totality of the Netherlands, shows that in 1996 the mesh of motorways was approx. 32 km; that of all national trunk roads and provincial roads 7.5 km and that of all hardened surface roads (national trunk roads, provincial roads and hardened surface rural roads) 1.2 km. Figure 21 shows the mesh in the period 1970-1996. It distinguishes between national trunk roads, provincial roads and rural roads.

The growth of the state-managed network of motorways/roads with limited access translates into a considerable reduction of the mesh. Although the mesh for motorways was 75 km in 1970, in 1986 it had decreased to 37 km and in 1996 to 32 km. By 1993, the mesh for national trunk roads and provincial roads collectively appeared to have increased. This, however, was due to an administrative effect, since in that year 1,300 km of provincial roads were taken over by local authorities (also national trunk roads became province managed). For national trunk roads and provincial roads collectively, the mesh in 1970 was 6.9 km, in 1986 it was 6.2 km and in 1996 it was 7.5 km. The mesh of all hardened surface roads in 1996 was 1.2 km. In 1986, this was 1.3 km and in 1970, it was 1.5 km.

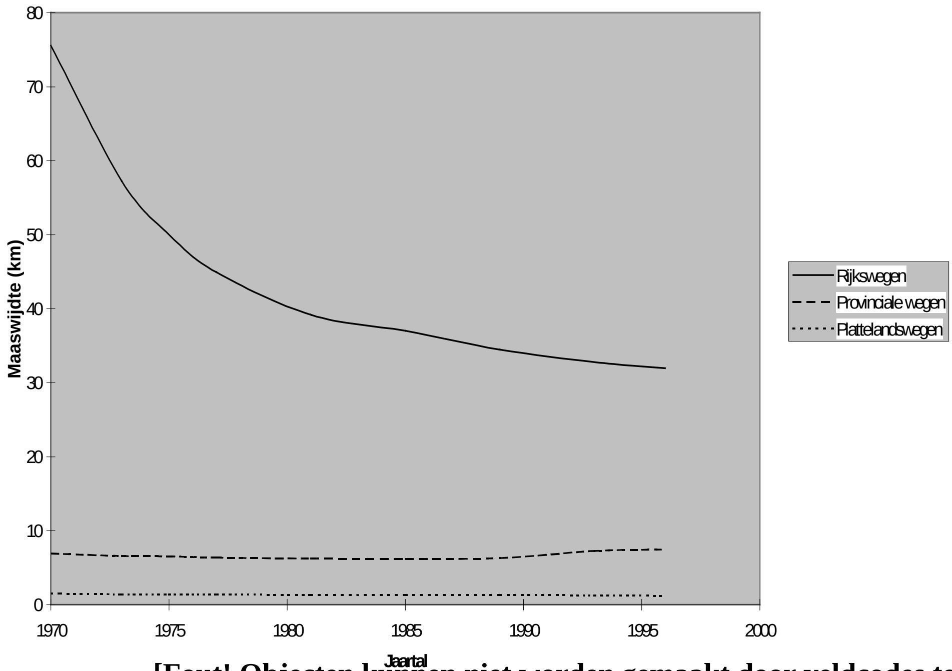

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Figure 21. Mesh development for each hardened surface road category in the period 1970-1996

Seen from the viewpoint of fragmentation, an important factor is that roads are widened when their length is increased. Although there is no hard statistical evidence corroborating such, it is evident that over time the average road has become wider. It is an established fact that—due to the adaptation of the existing roads to expanding traffic flows—many roads have been widened over time. Also the norms have been made more strict: while new rural roads in 1969 were based on a minimum hardened surface width of 2.5 m, over time this was increased to 3 m, and the current target is 3.5 m.

In addition to the presence of a road, its utilisation is important. Computed over a full year, the average use varies from some tens of cars per day (on a limited number of very quiet rural roads), via several hundred to some thousands of cars per day (on most rural roads). Main roads are busier: usually in the range of 5,000 to 15,000 cars per day. On some quiet motorways, the car count is 15,000 to 30,000 cars a day. The busiest motorways reach averages of 200,000 cars a day.

Each year, the CBS estimates the total distance driven on roads in the various categories. If this so-called vehicle performance is related to road length, the average intensity per road category can be derived. This is a theoretical average, which in actuality does not occur exactly as such in any road section. It is, however, suitable for comparing categories and following developments over time. Figure 22 provides a picture of this for the period 1970-1996.

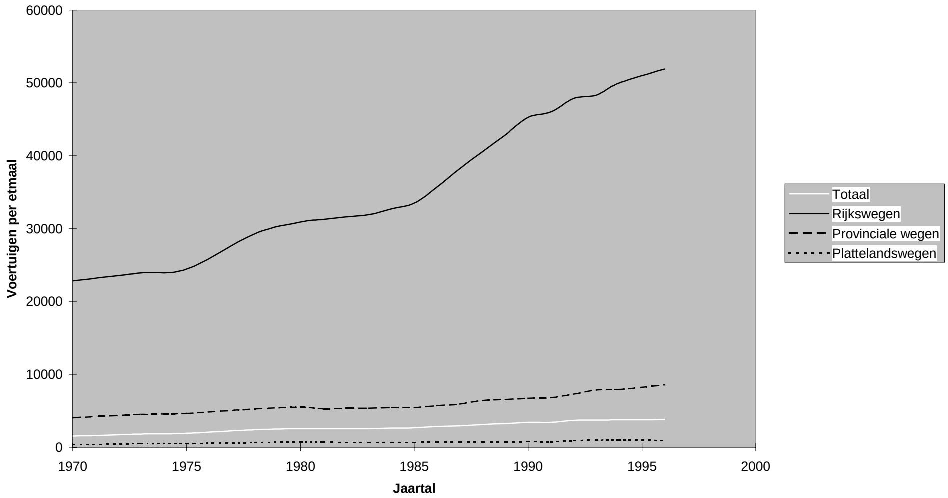

Figure 22. The daily average (JEG) for each road category per year in the period 1970-1996

During this period, the average intensity on national trunk roads more than doubled. The absolute levels on secondary roads were of course much lower. However, they too increased markedly. This is shown more clearly by using the outcome expressed in index numbers. Figure 23 shows the results as compared to 1986=100.

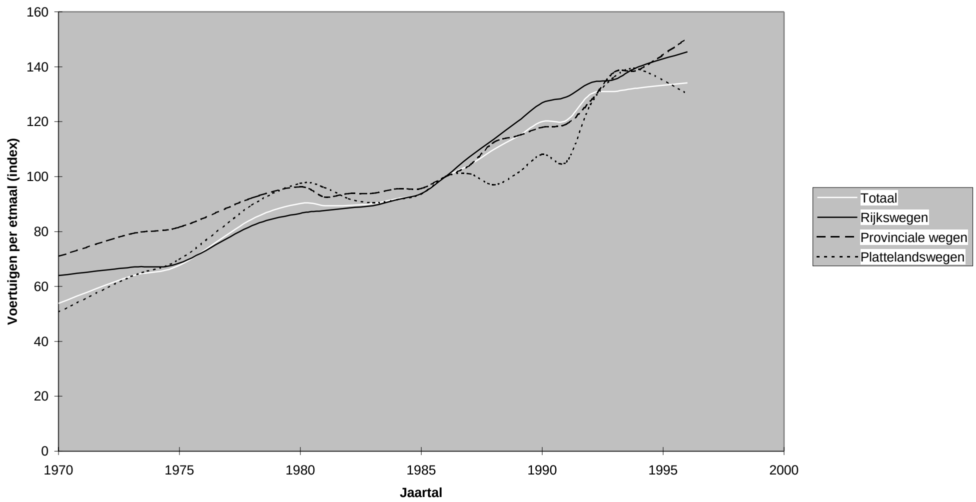

Figure 23. The daily average (JEG) for each road category per year in the period 1970-1996 (index: 1986=100)

What is striking in this figure is the irregular trend of the index for rural roads. The marked increase in 1993 was probably due to changes in road management (compare § 9.5). It is probable that the other fluctuations are an inherent part of the statistical random process used in taking random sample surveys of observations made on these quiet roads.

Railroads

There are 2,805 km of railroad in the Netherlands (on 31 Dec. 1997; see Table 5). This means an average density of 79 m of railroad per km2 of land-surface area (minus the large water-surface areas), with a global mesh of 25 km on average. The density of the rail network in the western part of the Netherlands is relatively high, whereas it is relatively low in the north and south-west. Annex III shows the existing railroad system.

Table 5. Properties of the existing rail infrastructure.

Total length	2,805 km
Single track	952 km
Two or more tracks	1,853 km
Electrified	2,058 km
Not electrified	747 km

The rail infrastructure of the Netherlands is managed by NS Railinfrabeheer (the Dutch Railways Infrastructure Management Board), a executive organisation of the Ministry of Transport and Communications.

The railroad system is intensively used for transporting passengers. On most lines, each hour several trains ride in each direction. The maximum train speed is 160 km/hr. Part of the rail network is regularly used by freight trains. The main traffic flows are between the Rotterdam harbour area and the German Ruhr area, and between Antwerp and northern France. The majority of freight trains travel these lines.

Waterways

Based on transport volumes, navigable waterways have been subdivided into main transport axes, main navigable waterways and other navigable waterways. The dimensions of the cross profiles and man-made constructions and the capacities of the sluices in navigable waterways up to CEMT class V are based on the Guidelines for Navigable Waterways. A summary of the CEMT division is provided in Table 6. For instance, canal class I means that the canal must be suitable for navigation in two directions by ships with a length of 39 m, a width of 5.1 m and a draught of 2.2 m. These are the maximum dimensions of ships allowed to use the canal. The classes from CEMT II and above result in the fragmentation of state waterways. At the provincial level, already class I is of importance (what is meant by this?).

Table 6: CEMT classification of waterways (Commission for Fairway Management, 1996)

CEMT class	**Tonnage**	**Length of ship (m)**	**Width of ship (m)**	**Draught (m) (with load)**
I	400	39	5.1	2.2
II	650	55	6.6	2.5
III	1,000	80	8.2	2.5
IV	1,500	85	9.5	2.8
Va	3,000	110	11.4	3.5
Vb	---	187	11.4	4.0

In annex IV the national waterway network is shown.

An impression of the intensity of river and canal use is provided by the freight transported, for instance as compared to the quantity of freight transported by road and rail (see Table 7).

Table 7: Freight transported by various means of transportation (Ministry of Transport, Public Works and Water Managment, 1995).

Transport volume (million tonnes/yr)	**National**	**International**	**Total**
Road	410	132	542
Inland waterway	68	146	214
Rail	5	12	17
Total	483	290	773

5.3 Effects of the existing infrastructure network on nature

5.3.1 Loss of habitat

National trunk roads and railroads
The most direct consequence of the creation of infrastructure is the destruction of habitats. However, there are no data available concerning the area of destroyed habitat for each species. Nor is it possible to provide the exact number at a landscape scale. This is because it is not exactly known which type of growth existed where there are now main roads and railroads. An analysis of the historical development based on consecutive topographical maps would clear this up, but this is outside the scope of this context. It is however possible to estimate this effect using GIS processing of the satellite picture from Figure 12 (see insert). On the raster map, all 'road pixels' were redefined and the dominant value of the adjacent pixels were provided in order to obtain an estimate of the percentage of the currently used land that disappeared under a road (see Table 8). This of course is a gross underestimate, since many nature areas, which formerly were crossed by new roads/railroads, have by now disappeared altogether. The figures, however, provide an impression of the degree to which the current units are intersected.

Table 8. Estimated area loss due to the creation of the main road and railroad network

	With roads*	**Without**	**Difference**	**Difference**
Grassland	1,372,725	1,405,741	33,017	2.3
Arable land	965,966	987,429	21,463	2.2
Deciduous forest	181,447	184,485	3,038	1.6
Perennial forest	175,903	178,512	2,610	1.5
Heathland	13,415	13,463	47	0.4
Not covered	17,615	17,642	27	0.2
Other nature areas	122,471	123,342	871	0.7
Fresh water	342,032	343,633	1,600	0.5
Saltwater	431,943	432,117	174	0.04
Urban areas	429,089	451,623	22,534	5.0
Main roads and	100,101	14,720**	-85,381	

** Main road and railroad network, see Map 1a*
***The fact that this value is not 0 is due to the dominant environment of the transformed pixels apparently also being made up of road. The area losses for each unit are therefore slightly underestimated.*

The ‘difference’ percentages show that the density of main roads and railroads in nature areas is relatively low. Nonetheless, the total area of deciduous and perennial forest probably decreased by at least a couple of thousand hectares as a direct consequence of the creation of roads/railroads. The direct loss of heathland and other natural growth types seems marginal, certainly as compared to e.g. the area loss due to land reclamation (see also Section 4.3).

Secondary roads
The total length of secondary roads is much larger than that of motorways/roads with restricted access. Collectively, these provincial and rural roads comprise at least 95% of the total road system (see also Section 5.2.1 about road networks). Despite their more narrow cross profile, the length of secondary roads makes them more destructive of habitat than motorways/roads with restricted access (Jaarsma & Van Langevelde, 1998).

Waterways
The creation of canals destroys habitats, especially in the case of class V canals (see Table 6), where the bank is usually made of steel sheet piling and where the water is very turbulent. There are no figures available about lost habitat area.

5.3.2 Disturbance

Motorways
In the period 1984-1991, the Institute for Forest and Nature Research by order of the Road and Hydraulic Engineering Division of the Directorate-General for Public Works and Water Management made extensive studies of the effect of road traffic on populations of breeding birds (Reijnen et al., 1992; Reijnen, 1995a). This study was carried out along motorways/roads with restricted access with traffic intensities ranging from approx. 5,000 to 60,000 motor vehicles a day. Two types of landscapes were studied: forest areas (Reijnen et al., 1995b) and open moist grassland areas (Reijnen et al., 1996). The effect was studied by comparing the densities of breeding bird species in areas subject to different traffic intensities. The study covered areas adjacent to roads as well as those at a greater distance from the road network. As a measure for the disturbance by road traffic, the sound load (emission) was used, since it has the largest reach. The test areas were selected in such a way that other factors affecting the density of breeding birds were the same everywhere; where such was not possible, a correction was made for the differences. This is why the vegetation structure in forests and the agricultural management of grasslands were measured in order to correct their effects in the analysis.

In 33 of the 45 studied species in forests and in seven of twelve studied species in open grassland areas, a road traffic effect was established. In forests, effects were established for birds of prey, pigeon, woodpecker, thrush, tit, songbirds and crow-like birds, and in open grassland for duck, wading birds and songbirds. In addition, road traffic has an effect on the total density of all species. There are clear indications that traffic noise is the main disturbing factor, rather than the visual disturbance of traffic driving by.

Figure 24 (see insert) indicates the zones in which road traffic leads to disturbance in the two types of landscape studied. In the forest landscape type, this zone generally speaking is narrower than in grassland, since the vegetation structure in the forest (mainly tree trunks) has a muffling effect on road traffic noise. The sound therefore reaches less far, so that the zone of disturbance is narrower. The application of these research results is described in a manual (Reijnen et al., 1992) for environmental impact reports.

In 1995, an orienting study was made in fir forests of the possible disturbance of squirrels by the sound emission from road traffic. The choice was made in favour of the squirrel (*Sciurus vulgaris*)—a target species from nature policy—in order to establish also the relation between disturbance and mammals, and because the squirrel as a species is easy to survey. In this type of habitat, no effect was found on the density of squirrel nests (Nieuwenhuizen & Van Apeldoorn, 1995).

In 1996, an extensive literature study was made into the effects of light and lights on nature. The effect of lights on animals is found especially in the possible disturbance of hormonally controlled processes (such as procreation), spatial orientation and the distribution of activities over the day. However, knowledge from field experiments is rare (De Molenaar et al., 1997). Based on this literature study, some possible field experiments based follow-up studies were proposed (De Molenaar & Jonkers, 1997), from which the study of the influence of road lights on a godwit population was selected as the first to be carried out. The godwit (*Limosa limosa*) is a species for which the Netherlands is of much international importance. The first preliminary results seem to suggest that road lights have an adverse effect on the breeding behaviour and breeding density of the godwit. Research has shown that the breeding density in a zone of 200-250 m around the lights is lower and that nests built there were the last to be built (De Molenaar et al., 2000).

Roadside ditches are often excavated to keep the road structure dry. Depending on their depth, these ditches can also have a dehydration effect on the surrounding area. Soil and water levels are especially effected on sunken roads. A kind of ‘chain reaction’ often occurs. With sunken roads, drainage has to be laid to keep tunnel basins dray. Drainage entails discharge onto surface water and causes a decrease in the groundwater level in local situations. This can in turn cause the soil to reset. Furthermore, because of changes in the groundwater level and its direction of flow, isolated contaminants in the soil and groundwater can become mobilised and migrate. This will affect the soil and groundwater quality. The dehydration effects are particularly significant with construction projects in the river valleys of the higher sandy regions and with the construction of (half) sunken roads in the naturally draining polder areas of the fenlands. The effects are also large in the sand dune regions (Grontmij, 1995).

Secondary roads

Secondary roads are less intensively used than motorways/roads with restricted access, although there are considerable differences between provincial roads and rural roads (see § 5.2.1). On secondary roads (especially rural roads) periods with vehicle traffic alternate with periods that are relatively quiet. The highly varying intensity and composition of the traffic on secondary roads leads to irregular disturbances. This could lead to the fauna being slower in becoming accustomed to such disturbance. So far, it has not been studied whether this hypothesis is correct; however, this could be done by establishing the consequences for population density.

Railroads

Bergers (1997) tried to gain an understanding of the relative extent of the fragmentation effects of railroads as compared to motorways. In this context, he studied the infrastructure factors that were relevant to the fragmentation effects, i.e. dimensions and shape, width and height, intensity of use, sound emission, barrier elements, lights, etc. The sound emission near a railroad is discontinuous. As yet, it is not clear whether this—as compared to the disturbance effect of the continuous sound emission from motorways, which was studied—leads to a larger or smaller disturbance effect on nearby animals. On the one hand, there are long periods of silence (and therefore reduced stress) along railroads; on the other hand, a continuous sound could lead to the animals becoming accustomed to it. When estimating the effects of disturbances on animal groups, for birds Bergers (1997) used the study of motorways made by Reijnen & Foppen (1991). For estimating the sensitivity of other animal species, assumptions were made or anecdotal data was used.

Table 9. The expected disturbance caused by sound near railroads for various species groups (after Bergers, 1997)

Disturbance	Species (groups)
Large	Common buzzard, willow warbler, goldcrest, godwit, wood pigeon,

	lapwing, cuckoo, partridge, oyster catcher, shoveller, skylark, golden oriole, wren
Medium	various bird species, fallow deer, red deer, wild boar, frog and toad, grasshopper
Probably	various bird species
none	newt, butterfly, spider, ground beetle
Unknown	many bird species, marten, small mammals, reptiles

A study is currently in progress to establish the effects of disturbance by train traffic on birds by empirical means. It is assumed that sound is the most disturbing factor in that context. The results will soon be available.

The construction of rail infrastructure can produce changes in groundwater and surface water systems, which can have an adverse effect on the habitats of vegetation and animal species. There are effect-related risks in the creation of lowered line sections, tunnels and tunnel basins. Also railroad ditches, which ensure that the railroad body remains dry, can desiccate the immediate environment. The visual presence of a railroad with overhead wires is relatively marked. The visual presence of trains is very discontinuous, but this can perhaps produce a more frightening effect (perhaps intensified by the conspicuous colours of most Dutch trains).

Along electrified railroads, especially on braking sections, there can be increased copper concentrations in the soil due to the wear of overhead wires. Further emission of dangerous substances is not found there. Diesel trains produce exhaust gas emissions and slightly pollute the air with CO_2, NO_x and SO_2. The effects of these emissions on the adjacent nature have not been examined, and are therefore unknown.

Vibration levels near railroads are higher than near motorways, and have a discontinuous character. However, it is unknown to what degree vibrations disturb specific species.

Waterways
Disturbance along waterways takes the shape of waves hitting the bank when ships sail by, in the worst case abrading the bank. As from the beginning of the twentieth century, the Gelderland river region has seen an ever increasing defence against erosion, first using gravel (start of the century) and then with rocks when the number and size of ships increased (as from the 1960s). The consequences were the disappearance of natural banks along with their vegetation and fauna. The vegetation of rock-defended banks is usually made up scrub growth poor in species.

An important source of disturbance is created by canals, which connect various water systems and supply water from area-foreign waters. For instance, agriculture in Limburg is supplied with water via the Noordervaart, where the water is taken in from the upper courses of various brooks. The disturbance is then especially expressed in the composition of vegetation and the macrofauna. The best known disturbance is the creation of an improved canal connection between the Rhine and the Danube, which allowed all sorts of new fish species to arrive in the rivers of the Netherlands.

The peace is disturbed by the intensive use of water surfaces (recreation and inland navigation) and of banks (fishing, beach recreation). Nothing is known about the scope of such disturbances.

Lastly, the dehydration of the surroundings through the drainage effects of man-made waterways is a form of disturbance. In 1996, 100,000 m^3 groundwater flowed into the Amsterdam-Rhine Canal. This is equal to approximately 36 million cubic metres of groundwater per year. A considerable proportion of this was deep seepage water from the Utrechts Hill Ridge that is now drained directly (Schmitz, 1996).

5.3.3 Fauna victims

National trunk roads
Data about traffic kills on national trunk roads are gathered by inspectors working for service districts of the Directorate-General of Public Works and Water Management, who check the condition of the road system each day. Having detected a traffic kill, they fill in the date, location (road number and hectometre marks) and species/species group on a specially designed registration form. The data are then entered into a computer. Most inspectors will have attended a special training course in how to register and why, and how to recognise species. They also have a booklet available, showing the animals they may find (Ministry of Transport, Public Works and Water Management, 1995). Not all service districts and inspectors are involved in registration. Such involvement depends on traffic safety and the interest in green aspects. The Road and Hydraulic Engineering Division records and updates the traffic kill data in a national database.

In 1996, the rabbit *Oryctolagus cuniculus* was the species most frequently found as a traffic kill on motorways. Since by far not all traffic kills were found, and since the data of not all national trunk roads are known, extrapolation was used to obtain an estimate of the total number of rabbits concerned (i.e. over 47,000). This estimate is perhaps too high, because hares may have been taken for rabbits. The hedgehog *Erinaceus europaeus* came a close second, with an estimated 17,000 kills. Of the dark-breasted barn owl *Tyto alba*—a species for which the Netherlands is of international importance—an estimated 1,200+ individuals were victims of traffic on motorways (see fig. 28). Compare this with the following: in 1997, the number of breeding couples was 796 (verbal communication from De Jong, 2000). In 1997, the total number of traffic kills was hundreds of thousands.

[figuur 28: foto dode kerkuil]

Figure 28: The dark-breasted barn owl *Tyto alba* becomes victim of traffic frequently.

Secondary roads
In the Province of Flevoland, road workers monitored traffic kills for approx. 5-7 years. This produced a good picture of the bottlenecks to the National Ecological Network (‘EHS’) caused by the infrastructure of the province. The Province of Overijssel registers traffic kills recorded by various bodies, including Badger and Tree Association and Association for Mammal Science & Mammal Preservation. Also gamekeepers submit reports. These data form the basis for the designation of EHS bottlenecks caused by the provincial road system and other secondary roads. If there appear to be bottlenecks caused by provincial roads, rural roads or bicycle paths, provisions are made. In Friesland, information about traffic kills on provincial roads is recorded and kept up to date by the provincial department. These data form a basis for determining the locations of fauna passages to be created. Records were made of the average number of kills per year on the provincial road Balk-Hindeloopen-Boksom (length: 60 km) (see Table 10).

Table 10: Average number of traffic kills on the main road Wagenaar, Leyenaar, W&M in: The Province of Friesland, 1991).

Roe deer	5
Badger	2
Stoat, weasel, polecat	5
Hare, musk rat	137
Hedgehog, mole, rat	47
Birds	768
Pets	58

In North Holland, traffic kills are not registered systematically; the data are not gathered centrally, but on a project basis. Data are often gathered by local groups and road managers. The Province of Limburg subsidises the Badger and Tree Association so that it can record traffic kills. Each year, Badger and Tree supply an atlas showing the bottlenecks, including those caused by municipal roads (Badger and Tree Association, 1998). The Province of Utrecht does not structurally record traffic kills. In as far as mammals are concerned, in the past, some traffic kills were recorded, but only succinctly. This only produced data about larger animals, which remained there longer. In the Province of Gelderland, the Badger and Tree Association records the number of badgers killed by road traffic and indicates the main bottlenecks to the badger caused by roads.

The way in which traffic kills are recorded for rural roads is more difficult to ascertain than for provicial roads. The provinces usually have no knowledge of this. As suggested by the provinces, a very small number of water district boards and local authorities were approached on this subject. The information gathered does not, however, produce a general picture.

National trunk roads and secondary roads

In 1998, the Badger and Tree Association recorded the number of badgers *Meles meles*—a target species in nature policy—killed by road traffic in each province and for each road-managing body. In that year, over half of all traffic kills occurred on municipal roads (see Table 11). The category ‘other roads’ comprised kills on private roads or roads managed by bodies other than those at the three governmental levels (Badger and Tree Association, 1998).

Table 11. Badgers killed by road traffic in 1998, per province and road-managing body

	Nat. roads	Prov. roads	Mun. roads	Other roads	Total
Limburg	37	70	109	8	224
North Brabant	5	10	51	1	67
Gelderland	13	45	45	6	109
Utrecht	-	-	3	-	3
North Holland	1	-	-	-	1
Overijssel	1	4	4	1	10
Drenthe	3	3	3	1	10
Friesland	2	2	12	-	16
Flevoland	-	-	2	-	2
Total	62	134	229	17	442
%	14%	30%	52%	4%	

(Source: Badger and Tree Association, 1998.)

That in 1998 there were many more kills on secondary roads than on motorways/roads with restricted access is due to the larger total length of secondary roads. Data from the Badger and Tree Association for the period 1990-1996 shows that the number of badgers killed per 100 km of municipal road is much lower than the number killed on national trunk roads. This is connected with the lower traffic intensity on secondary roads.

Badgers and traffic
In the period 1981-1993, the Institute for Forestry and Nature Research collected 523 badgers killed by traffic in order to study their procreation. These traffic kills came from the entire area of distribution of the badger. The study referred to above and data from the beginning of the century proved that the litter size has for years been the largest in Europe. The probable cause is little competition within the group, which may be a consequence of hunting in former days and traffic mortality these days. The capacity of the population to compensate for the high mortality by maximising the litter size perhaps is already being used to the fullest (Broekhuizen *et al*. 1994).

The pressure on the badger population in the Netherlands is fairly high. At least 11% of all litters are lost because the mother has a traffic-caused accident. Further compensation for traffic mortality by litter increase is improbable. In some social groups there is only one female present. If that female dies, the loss of reproductive capacity can only be remedied by the immigration of a new female. The number of traffic kills compared to the total size of the population is very high. Each year, 18-20% of the population is killed (Broekhuizen *et al*., 1994). Figure 26 (see insert) shows the locations of the badgers killed in the period 1991 to now. Model computations show that a high local mortality of adult animals markedly reduces the survival potential of local populations (Lankester *et al*., 1991; Verboom *et al*., 1991). Mitigation measures (such as the installation of fences with tunnels) reduce mortality, and a lack of tunnels can hinder the exchange and separate foraging areas from procreation and sleeping spots.

Based on a combination of research methods, the effect of roads (all categories) on hedgehog mortality and hedgehog populations was established. The hedgehog *Erinaceus europaeus* is a species found everywhere in the Netherlands, also as a frequent victim of traffic. Traffic kills were counted on regular routes and incidental observations were noted. Figure 26 (see insert) shows the 2,550 observations of hedgehog road kills reported in the period 1995-1997. In order to determine the effect of roads on population size, the capture-mark-return method and track studies were used to determine the relative hedgehog density in various areas (Huijser & Bergers, 1997). Each year, 6-9% of the hedgehog population is killed by traffic. Due to traffic effects, the total size of hedgehog populations can be up to 30% lower than the size of comparable populations not subjected to traffic effects. These results are not significant, probably because the size of the sample survey was not big enough. Especially males are killed in traffic. The species is not monogamous, so there is no threat to procreation. Near very high road densities, local populations can become extinct and networks can become less durable (Huijser & Bergers, 1997).

A 1993 literature study of the effects on amphibians and reptiles, and of the mitigation and compensation measures concerning these, brought to the fore that the main effect of roads on amphibians is road kills (Vos & Chardon, 1994). In view of the high traffic intensity on the Dutch road system, highways and many of the secondary roads must therefore be regarded as absolute barriers for crossing amphibians (Vos, 1997).

Fewer birds are killed by traffic on secondary roads than on motorways/roads with limited access. Dutch Bird Protection Society estimates the number of traffic kills on roads to be two million per year, of which half occur on motorways (5% of all roads) and the other half on all other roads (Van den Tempel, 1993). For the dark-breasted barn owl *Tyto alba*, traffic—especially on motorways—is one of the main causes of death (Ministry of Agriculture, Nature Management and Fisheries, 1996). Research in the Netherlands showed that 41.5% of dark-breasted barn owls found dead in the Netherlands were killed in traffic. This high mortality is ascribed to the frequent hunting activities of the owls on the verges of motorways, which are often excellent habitats for the field mouse (Van den Tempel, 1993).

Railroads
Animal mortality due to train kills is determined by the animal's chances of safely reaching the other side of a track. The relative low intensity of train traffic makes this chance relatively high. Bergers (1997) computed a chance of 96% during the day and of almost 100% at night. Near rail infrastructure, birds are regularly killed, for instance because they fly into overhead wires. Also mammals, amphibians and reptiles often seem to be the victims of train kills (see Table 12). Train

kills of larger mammals lead to safety risks. These incidents are usually effectively registered. Train kills, however, constitute just a small part of the yearly mortality of large mammals. NS data show that animal kills relate especially to roe deer and swans, and to a lesser degree to other large mammals and birds.

Table 12. Expected mortality caused by railroads for various groups species (after Bergers, 1997)

Mortality	Species (groups)
Many/large	Owl, nightjar, amphibians, reptiles
Medium	Mammals, various birds species
None	Most bird species, spiders, ground beetles, grasshoppers
Unknown	Bats, butterflies

Within the scope of the defragmentation study by the Dutch Railways Infrastructure Management Board, a more extensive survey of animal mortality is being drawn up. The results will soon be available.

Waterways

Despite the fact that there are no national figures available, it can be assumed that thousands of animals drown each year because they cannot climb out of canals with steep banks. A good example are the Twenthe canals, where in the period 1987-1994 over a canal section of 63 km, at least 210 roe deer were killed (Heinen, 1995). The roe deer *Capreolus capreolus* as a species is fairly common. A study over a 14 km canal section (Twenthe canal near Twickel), in which not only roe deer were studied, showed how many mammals were killed each year, on average, over the entire section (see Figure 27) (Heinen, 1995).

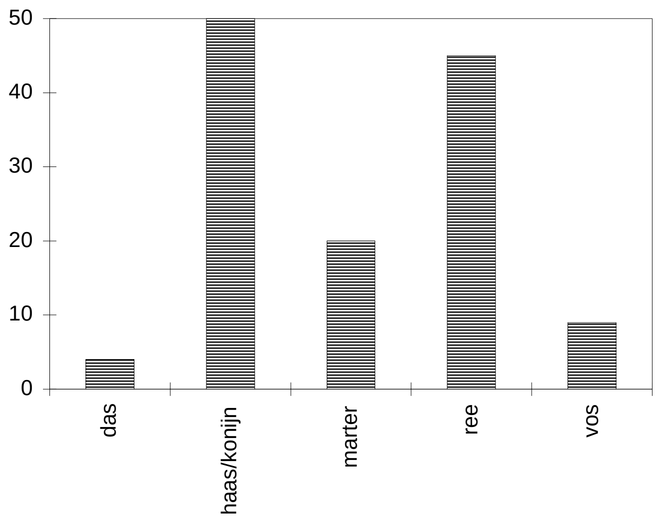

Figure 27. Converted average number of victims of drowning in the Twenthe canal per year (after Heinen, 1995)

Usually, the bodies of small mammals are not found, since they decay quickly, are eaten or remain unnoticed. For roe deer, the number of victims is not evenly distributed over the year (see Figure 28). Especially in the rutting season, the number of victims increases.

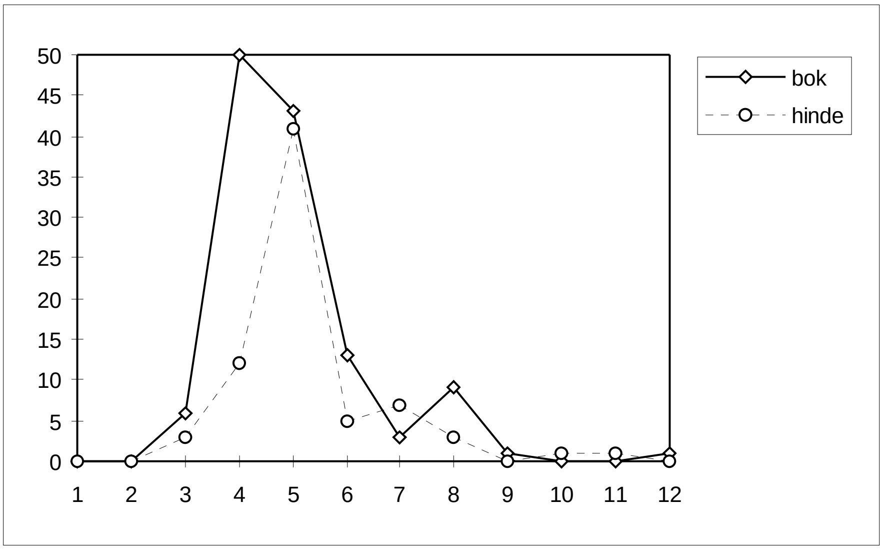

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Figure 28: Number of drowned roe deer (*Capreolus capreolus*) found each month in the Twenthe canals, in the period 1987-1994 (Heinen, 1995).

5.3.4 Barrier effect

National trunk roads and secondary roads

Until now, not very much field research has been conducted of the barrier effects of roads (i.e. not being able to cross over) in the Netherlands. The migration pattern of mice in roadside verges along several motorways and main roads has been mapped out. Mice appeared not to cross the roads included in the study (Van der Reest, 1989). In research of the use of roadside verges along motorways as a habitat and corridor by a number species of ground beetles that occur in sparse vegetation, none of these insects were found in the first few metres stretching back from the road. In view of this, it can be assumed that the first strip of verge next to a motorway that is kept short and thick for safety reasons also forms a barrier for these species (Vermeulen, 1995). Assumptions about the barrier effect of roads for certain species are mainly based on research in other countries or logical deduction.

Barrier effects are evident in places where motorways are built along dams that cut through large expanses of water. This applies amongst others to the IJselmeer Dam, which transformed the saltwater Zuider Zee into the sweet water IJsselmeer, and the dike between Enkhuizen and Lelystad. Fish and other water organisms cannot traverse these structures.

Secondary roads (especially in rural areas) are not as wide as motorways or main roads and as such are presumably less likely to form an absolute barrier for fauna. The consequence of this is that animals are more likely to attempt to cross over.

Barrier effect of infrastructure on mammals in forests
The forest area of the Netherlands is not one single uninterrupted area, but a collection of larger and smaller wood fragments intersected by the local infrastructure. Mammals that mainly live in forests (e.g. the pine marten *Martes martes* and red-backed mouse C*lethrionomys glareolus*) must sometimes cover large distances and overcome such barriers as roads in order to move from one area to another. One of the limiting factors for reaching a habitat location is therefore the distance that can be travelled by dispersing individuals. This distance differs from species to species. The dispersion distance is maximal in a landscape with little resistance, meaning no barriers, where the landscape elements that are not part of the habitat do not form an obstacle to the dispersing species. If the resistance increases, the chance that an individual will occupy a new habitat decreases. In the case of an absolute barrier, the resistance can be referred to as maximal. The chance that the individual in such a situation will reach a new habitat is regarded as minimal. For some species, part of the infrastructure is perceived as an absolute barrier.

Barriers are distinguished at two scale levels (Buit et al, 1999). Certain barriers are such especially for the daily movements (home range) of individuals. These so-called local barriers therefore make up obstacles at a local population level. At a network population level (where dispersion plays a role), they can however be passed. This is because dispersing individuals are more inclined to tackle certain barriers when seeking a new habitat. However, there are also barriers that are a serious obstacle to dispersing individuals. For instance, for many smaller mammals, busy highways can be regarded as a part of these so-called network barriers.

The Institute for Forestry and Nature Research has developed a spatial expert system, which computes the sustainability of populations based on support capacity and the spatial layout of habitat and the location of barriers. This system (LARCH; Landscape ecological Analysis and Rules for Layout of Habitat) distinguishes barriers at two levels (see also § 9.4). When determining local populations, barrier maps are used at the local population level. LARCH divides habitat spots within the local population distance, but separated by barriers, into different subpopulations. The same methodology is used to divide network populations, including of course network barriers.

Figure 29 (see insert) shows the situation for a hypothetical animal species for which mainly food-rich deciduous and mixed forest is regarded as habitat. This hypothetical species is based on a small mammal with a dispersion distance of 1,000 m. The left-hand map shows the potential sustainability of the habitat networks in which barriers play no part. In the right-hand map, all roads and rivers are local level barriers, and the busier (i.e. provincial and national) roads and the rivers are network level barriers. The difference between the sustainability of these two networks illustrates the effect of infrastructure on the survival chances of certain species, which perceive this infrastructure as a barrier.

Railroads

Important barrier elements of rail infrastructure are the ballast bed supporting the rails, aerial contact lines (birds and bats), noise-reducing construction methods, fencing, track-side ditches and in some cases the radically elevated or sunken track. No specific field research has been carried out of the barrier effects of railways. In 1987, an inventory was made of the colonisation of seven new pools in South Limburg by four species of newts. In this study, attention was also devoted to migration patterns. It appeared that no migration took place between the pools located on opposite sides of the railway line located in the research area, but this did occur between pools on the same side of the tracks (Lenders, 1996). The following statements are based on research carried out by Bergers (1997). Railway lines can be expected to have a large barrier effect for smaller, crawling animals (insects, spiders, amphibians, reptiles and small mammals). Birds are apparently not hindered very much by railway lines. In general, large mammals (roe deer, red deer, wild boar, badger) are able to cross railway lines (that are not fenced off) without difficulty (see table 13).

Table 13. Expected barrier effect caused by railroads for various groups species (after Bergers, 1997)

Barrier effect	Species (groups)
Absolute	Grasshoppers, ground beetles
Strong	Mice, newts, spiders, ants
Weak	Marten, hedgehog, squirrel, reptiles, frogs, toads, butterflies
None	Deer, wild boar, hare, birds

Unknown	Bats

Waterways

In the Netherlands, the natural environment is fragmented by canals, which throughout the country intersect the National Ecological Network, brook valleys, marsh areas, etc. For instance, the Wilhelmina canal divides the brook valleys in North Brabant into two parts, cutting off the upper courses from the central and lower ones. Culverts, rather than banks or open water, are then the only way to allow for exchange between upper course and central course. For various fish species, passing through the culverts is a problem (Kemker, 1998). The Wilhelmina canal is also a barrier to species of the moist heathland found on either side of a canal, for instance, the crested newt *Triturus cristatus*. In the longitudinal direction of the Wilhelmina canal, the slopes due to too intensive or extensive management form a barrier to butterfly species of poor open vegetation, such as the >>groentje>> *Callophrys rubi* or >>oranje zandoogje>> *Pyronia tithonus*.

5.3.5 Combined effects

National trunk roads and secondary roads

In 1993, it was studied whether the occurrence of *Rana arvalis*— a heathland frog and endangered species whose habitat comes under the European Habitat Directive—in the fen pool of southwestern Drenthe is influenced by fragmentation in general. In addition, also the possible effect of the entire road network was looked into. The probability that the frog is present in these fen pools decreased markedly as the road density near such a fen pool was larger (Vos, 1997, Vos & Chardon, 1998).

In 1995, the Institute for Forestry and Nature Research carried out a slightly comparable study based on the existing distribution data of some fairly general amphibian species in fen pools in some study areas in Gelderland and North Brabant. It was established whether amphibians are absent more often from relatively small road-locked areas than from larger areas. In Gelderland, it was found that the number of species decreased as road fragmentation increased. In North Brabant, however, this correlation was not found, possibly due to the much lower fen-pool density in this area: amphibian habitats may already have been too fragmented even without road effects (Van de Sluis & Vos, 1996).

5.3.6 Corridor function

National trunk roads and secondary roads

Ecological management (see § 8.1) has led to road verges, which are rich in flowers and species. Over half of all Dutch plant species can be found on road verges (see Figure 31). Especially the species that used to be general in grasslands and extensively used fields, but are no longer there due to the intensification of agriculture, still find good habitat conditions in road verges (see Table 14). The current method of mowing and disposal is not much different from conventional haymaking. Many animal species profit from such management, including diurnal butterflies, ground beetles and bees.

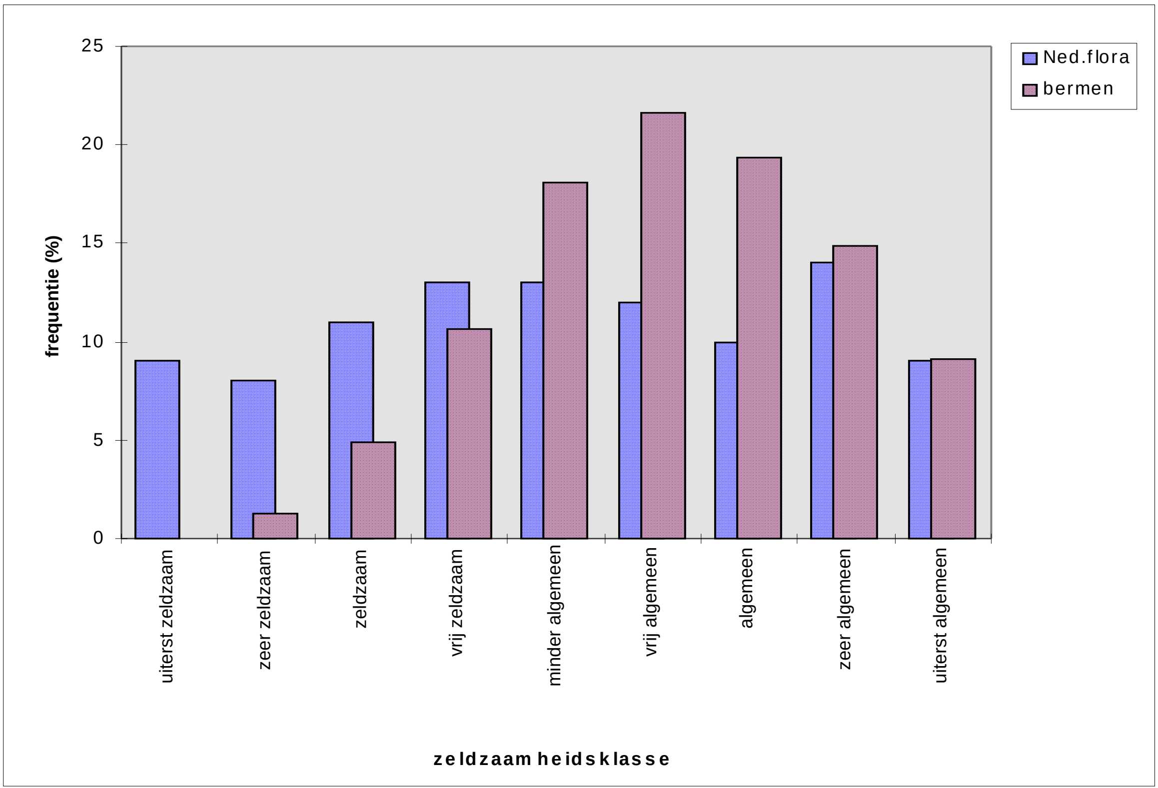

Figure 31. Rarity of plant species on verges alongside roads as compared to national rarity (source: Sýkora et al., 1992)

Table 14: Growing locations of plant species in the Netherlands, which flourish in road verges

Plants of moderately fertilised grasslands	29%
Plants of highly fertilised grasslands	16%
Plants of fringes, wooded dykes, forest edges	14%
Cropland weeds	10%
Pioneers on dry sandy soil	10%
Salt plants	2%
Plants of rough growths	19%

Between 1989 and 1993, studies were made of the possible corridor function of verges alongside motorways for ground beetles found on poor sand soils (Vemeulen, 1995). The survival of these ground beetle species is threatened by the fragmentation of their habitats (see § 4.2). The studies showed that a road verge can under certain conditions function as a corridor between habitats, allowing ground beetle populations to maintain themselves. However, the verge must include a zone that is sufficiently wide and has the same properties as the habitat; the total verge must have a width of fifteen to thirty metres.

Railroads

Also growth-covered parts of the track (ramps, verges, ditches, etc.) can create special plant and animal habitats. Some 1,100 plant species have been found alongside Dutch railroads (75% of the Dutch flora), including many rare and endangered species. In addition, fauna surveys alongside tracks found a large variety of animals, especially reptiles and insects (Koster, 1991). As well as resulting in the loss of habitats, the presence of a railroad can therefore also lead to an increase in habitat-specific species.

Waterways
In the Nature Policy Plan, (canal) banks play a crucial role as connection zones between various nature zones. The banks form structures, which allow the exchange of organisms between various areas. Species use the banks that during dispersion are, for instance, the grass snake *Natrix natrix*, beaver *Castor fiber*, otter *Lutra lutra*, water shrew *Neomys fodiens*, Daubenton's bat *Myotis daubentonii*, dragonflies and small reed birds. The beaver *Castor fiber* moves by swimming along a bank at a distance of several metres, the white-legged damselfly *Platycnemis pennipes* needs vegetation for cover since it is not a very good flyer, and the grass snake will move along a bank if the bank provides enough cover.

5.3.7 Defragmentation on a landscape scale

Figure 32 shows the consequences of the infrastructure network (national trunk roads, railroads and most provincial roads) for the fragmentation of land use in the Netherlands. Figure 32 compares the manipulated map image that is basic to Table 8 (see § 5.3.1) with Figure 12 (see insert). The average surface area of the units is of course smaller if the infrastructure concerned is regarded as a border. However, the figures show this only weakly, since the extra fragmentation due to the infrastructure is slight. Usually, very small units (of which there are a great many) are not intersected by the infrastructure concerned. Only larger units that are intersected contribute to the increase of the average size. In coniferous forests with relatively many large units (the Veluwe National Park), this has a clear effect. For the other types of nature, the average growth of the units increases only marginally. Heathland, for instance, increased from 2.09 to 2.10 ha, which is a smaller increment than could be shown on the bar graph. The analysis however, does not give insight into the intersection of relations between areas with different land use. These relations, e.g. between the Veluwe with forests and the forelands along the large rivers with grassland, can be of great ecological importance.

[Figure 32: bar graph of size classes]

Figure 32: Comparison of average surface units in land use with and without roads/main roads.

5.3.8 Summary of bottlenecks

National trunk roads
In the 1990s, all regional boards of the Directorate-General for Public Works and Water Management conducted a survey of the bottlenecks to nature within their management area caused by the national trunk road system. Usually, a bottleneck is defined as an intersection of the National Ecological Network or a provincially detailed counterpart. However, there are also boards that looked into the intersection of the habitats of certain species or into the presence of locations with fauna victims. The Road and Hydraulic Engineering Division records and updates the traffic kill data in a national database. Since this information is not yet complete, no map can be presented showing the location of bottlenecks. However, the number of bottlenecks and the total bottleneck length are generally known. The total length of bottlenecks is approx. 834 kilometres, of which 688 kilometres is situated in the National Ecological Network and 146 kilometres is situated in the so-called white areas (areas outside the National Ecological Network).

Secondary roads
The analysis of the fragmenting effects of the existing infrastructure/provincial infrastructure is focused on determining where fauna facilities in the road system are desirable. Some provinces have mapped the fragmenting effects by surveying the bottlenecks to the National Ecological Network caused by the provincial road/fairway network. In the provinces, these surveys were done in various ways (see annex V). In some provinces, the spatial coupling of the proposed provincial National Ecological Network is the basis in, for instance, North Holland, Limburg and Groningen. In the provinces of Groningen and Limburg, this study was extended by further evaluating the selected possible bottlenecks based on,

among other things, the distribution areas of species, which are to receive attention. In Limburg, some fragmenting effects of provincial and national trunk roads are distinguished, i.e. the probability of collisions and disturbance, and the isolation and limitation of habitats (Bugter, 1993). In South Holland, the bottlenecks were surveyed based on the surface area of the most relevant animal species and the main ecological connection zones. As some of the fragmenting effects of the provincial fairway/road network in South Holland are the reduction of habitats and the negative effects of said reduction on populations and mortality due to the presence of barriers in habitats and across migration routes. Apart from traffic kills, animals drown in navigable waterways with steep sheet piling. The disappearance of the otter *Lutra lutra* from South Holland in the 1970s was also due to the excessive mortality on roads near the Nieuwkoop Lakes (Province of South Holland, 1994). In the Province of Gelderland, policy is especially active for the badger *Meles meles*. The transition area from the Veluwe to the Achterhoek has priority in the realisation of fauna measures. For the provincial roads, these are carried out by the province, and for municipal roads the province provides subsidies. For the future there are plans to make some roads on the Veluwe low-car intensity. The Province of Utrecht had a study carried out into the fragmenting effects of the infrastructure on the Utrecht Hill Ridge (see the box below and Fig. 33).

Bottleneck survey in the Province of Utrecht

The Province of Utrecht surveyed and defined the bottlenecks to nature in the Utrecht Hill Ridge caused by the national and provincial roads in that area (Bureau Waardenburg, 1993). For provincial roads and rural roads, three road categories were established, i.e. local roads with low traffic intensity (class 1), two-lane roads with a relatively low traffic intensity (class 2a), and two-lane roads with high traffic intensity (class 2b). The barrier effect of these roads has been divided into three types: physical barrier (the road comprises a limitation of the habitat on both sides of the road), landscape barrier (the road—comprising road top and any configured road verges—forms such an unattractive habitat for the animal species that the species does not traverse it or does so only incidentally) and a risk factor for crossing animals. These three aspects can be simultaneously present. For instance, a motorway is a physical barrier to soil-bound organisms (such as the vole, slow-worm and ground beetle); the open character, the six traffic lanes and the wide verges form a landscape barrier to forest fauna; and the intensive traffic is a big risk for crossing game (risk barrier).

For all provincial roads, it has been mapped which areas of the National Ecological Network they intersect and which type of barrier they produce. This has resulted in the following global picture. Class 2 roads form a landscape barrier to species, which have a small action radius (small mammals, amphibians, lizards and invertebrate soil fauna). The road isolates the populations of these species. The dispersion of this group is therefore very limited or is excluded. Roads of class 2a will be frequently crossed by animals with a large action radius (pine marten, fox and badger) (see Figure 33). Class 2b roads form a physical barrier. Populations on either side of the road are practically isolated from each other. For animals with a large action radius, the risk under high traffic intensity is so high that the road is crossed only incidentally (see Figure 33). Class 1 roads form a physical barrier to animals with a small action radius. For animals with a large action radius, the road is a risk barrier. Local roads, of which there are six, are used as a short cut for through traffic. Thirteen bottlenecks were caused by provincial roads, and two by local roads (Bureau Waardenburg, 1993).

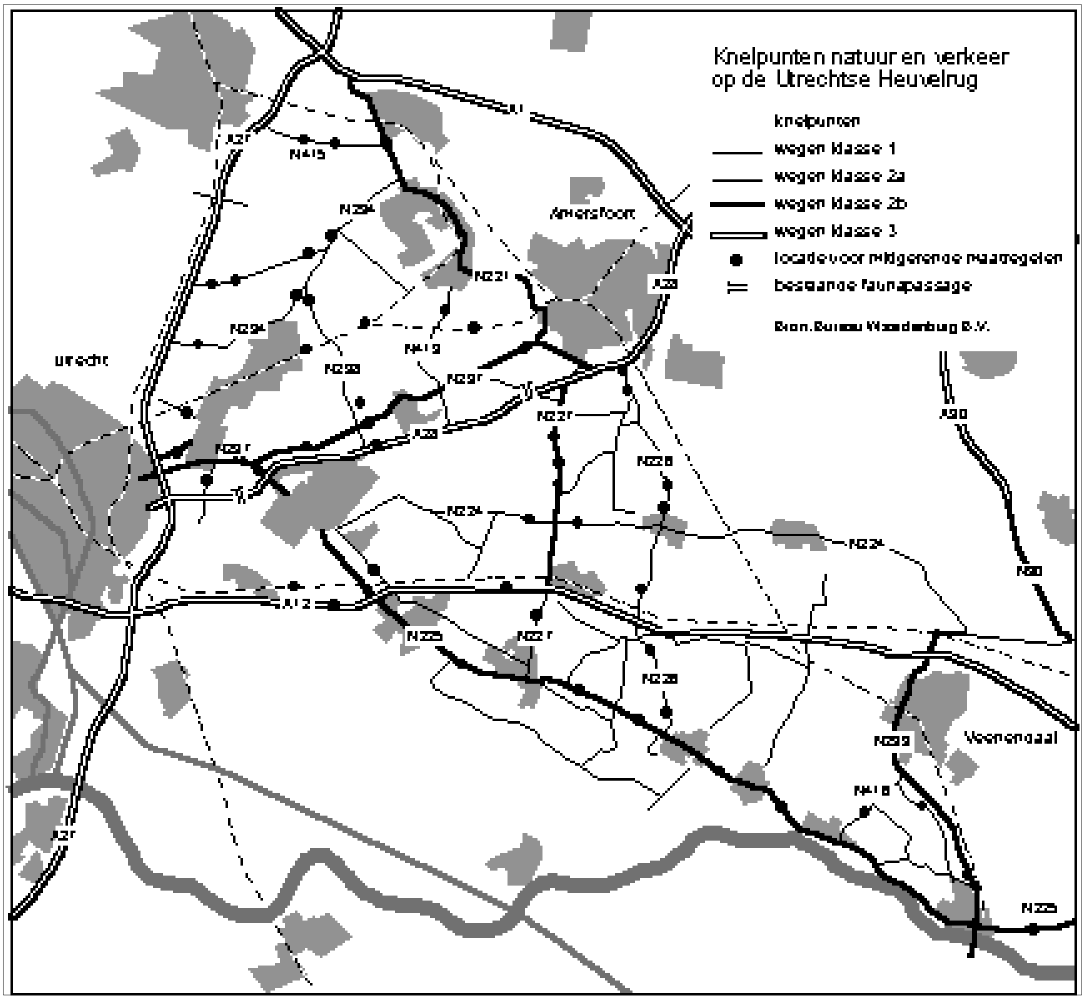

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Figure 33. Bottleneck map for Utrecht Hill Ridge (Bureau Waardenburg, 1993)

Railroads

Any intersection of a nature area by rail infrastructure can be regarded as a bottleneck. Even if measures have been taken to make the track passable for certain animal species, the presence and use of the railroad will continue to effect the environment. For some animal species, the track will remain an insurmountable barrier. Trains disturb the environment and regularly hit animals.

Various analyses were made in order to produce a picture of the number and seriousness of the bottlenecks, in which the existing network of railroads was provided with a spatial ecological structure in the Netherlands (by, among others, TNO in 1992 and IKC Nature Management in 1996-1998).

In an analysis for this report, the existing railroad network was compared with all nature and forest areas within the National Ecological Network, Nature Protection Act areas, nature areas in regional and zoning plans and public recreational facilities. These are all areas provided with basic protection under governmental policy (see §4.4). For each province, Table 15 provides a summary of the number of intersections of these protected areas by rail infrastructure, and the total length of the intersections.

Table 15. Bottlenecks caused by rail infrastructure in nature areas

	Number	Kilometres
Gelderland	42	154
Limburg	44	81

North Brabant	50	80
Overijssel	26	69
North Holland	28	56
Utrecht	28	48
Drenthe	7	31
South Holland	24	28
Groningen	12	25
Friesland	8	18
Flevoland	5	11
Zealand	7	9
Total	281	610

For the time being, each intersection is regarded as a potential bottleneck. This brings the number of potential bottlenecks to nature and forest areas caused by rail infrastructure in the Netherlands to 281. In this context, nature and forest areas are intersected over a total distance of 610 kilometres. The seriousness of the bottlenecks varies markedly, and depends on such factors as the width and height of the track, the shielding of the track by means of ditches or fences, the intensity of train traffic and the species found on either side of the track. The regions of NS Rail Infra management, which manages the Dutch railroad network, have worked out and are further working out detailed plans, in which these bottlenecks were further surveyed and their seriousness judged, and in which measures are proposed.

National trunk roads and railroads

Within the scope of an evaluation study of the defragmentation of the infrastructure (Arcadis, 1999), a summary was made of 20 priority areas for large-scale defragmentation. These areas are in the larger units of dry and wet ecosystems, or form essential spatial links in between. Table 16 shows in which of these areas national trunk road and/or rail infrastructures are one of the potential bottlenecks. Also new infrastructure is included.

Table 16. Rail infrastructure in priority areas for robust defragmentation

no.	Robust connection	Track section
1	Wet axis Friesland	A7, A32, line Zwolle-Leeuwarden
2	Lindevallei	A32, line Zwolle-Leeuwarden
3	Connection Friese Wouden-Drentse Aa	A28, line Zwolle-Groningen
4	Zwarte meer	A50
5	Connection Northern/Eastern sand regions	N34, line Zwolle-Hardenberg
6	IJmeer	A1, A2, A6, A7, line Amsterdam-Utrecht, line Amsterdam-Hilversum, line Amsterdam-Lelystad
7	Northern Heuvelrug	A27, A28, line Utrecht-Hilversum, line Utrecht-Amersfoort, line Hilversum-Amersfoort
8	Northern Valley	A1, A30, line Amersfoort-Apeldoorn, line Amersfoort-Ede
9	Connection Veluwe/Eastern sand regions	A1, line Apeldoorn-Zutphen, line Zutphen-Deventer, line Apeldoorn-Deventer
10	Southern Valley	A12, line Utrecht-Arnhem (HSRL East)
11	Connection Rijk van Nijmegen-Maashorst	A73, line Nijmegen-Venlo
12	Connection Brabantse Wal-Markiezaat/Westerschelde	A58, A4, line Bergen-op-Zoom - Middelburg, freight line Roosendaal-Antwerpen (VERA)
13	Connection North/South Kempen	A58, A2, N65, line Den Bosch-Tilburg, line Den Bosch-Eindhoven, line Eindhoven-Tilburg
14	Peel	A67, line Eindhoven-Venlo
15	Connection Veluwe-Oostvaardersplassen	A6, A28, line Amersfoort-Zwolle, line Amsterdam-Lelystad
16	Connection East Twente - Salland	A1, A35, line Almelo-Hengelo

17	Connection NH dunes-Zaanstreek-Waterland	A7, A9, line Amsterdam-Alkmaar, line Amsterdam-Hoorn
18	South Kempen	A2, A67, A69, A69, line Eindhoven-Weert
19	South Veluwe	A12, A50, A48, line Utrecht-Arnhem (HSRL East), line Arnhem-Zutphen
20	Brabant-Oostelijke Maasoever	A73, line Nijmegen-Venlo
-	Connection Central Veluwe - South Veluwe	A1 (already defragmented)
-	Connection Central Veluwe - East Veluwe	A50 (already defragmented)

Waterways
For the fragmentation of the National Ecological Network caused by the wet infrastructure, the Fragmentation Series of the Road and Hydraulic Engineering Division has published a summary of all state waters, and for each water the relationship with the National Ecological Network and the bottlenecks for nature development (Duel, 1992). For each province, the basic information has been established in that series.

5.4 Secondary effects of infrastructure

The previous sections concerned the direct fragmenting effect of the infrastructure. However, there are also indirect effects. The creation of infrastructure accelerates the economic development of regions, and thereby the urbanisation process. The pattern of reclamation is highly determinative of further urbanisation and the use of the landscape. Generally speaking, however, this development is not autonomous. The final effect is determined by the direction given to the urbanisation process by regional planning.

By order of the State Planological Department, a study was made of the effects of four urbanisation scenarios. The nature development model LEDESS (Harms *et al*., 1995b, see §9.4). In a fully autonomous development, the urbanisation process is more or less diffuse. This means a relatively large loss of habitat for fauna and the biggest fragmenting effect on the landscape. The second scenario is based on guided development along the main infrastructure, giving rise to urbanised corridors. This requires a relatively low degree of control. Such linear urbanisation leads to a smaller loss of habitat, but means a more intense compartmentation of the landscape. The consequence of this is isolated habitats. The other two scenarios relate to compact urbanisation, in which in one case the accent is on the Randstad (the central, urbanised area of the Netherlands) and in the other on the string of cities in Brabant. The first option (continuation of VINEX policy) would have relatively large consequences, since supra-regional connections are severed ('green' axis Veluwe-dunes and 'blue' axis Biesbosch-IJsselmeer). Compact urbanisation in the string of cities in Brabant requires a high degree of governmental intervention, but provides the best prospects for nature and the landscape. This is the best way to maintain robust units of nature and green landscape veins (Harms et al., 1995).

Chapter 6 Road safety with respect to accidents with animals

Contributions by: C.F. Jaarsma, D. Kamphorst, R.J.M. Kleijberg

6.1 Introduction

In this chapter, the theme is illuminated from the perspective of traffic instead of nature. To what extent do accidents involving animals pose a threat to road safety? If this is the case, all the more reason there is for implementing measures to limit the number of human and animal victims.

6.2 Accidents with animals

National trunk roads and secondary roads

Road safety is a relative term used in referring to the probability of material and immaterial damage resulting from (near) accidents and the danger caused by traffic (NPV, 1983). Damage with respect to road safety is expressed in the annual amount of fatalities, serious and minor injuries and economic loss.

Accidents resulting from collisions between a moving vehicle and an animal crossing the road are registered by the Central Bureau for Statistics (CBS). Figures produced by the CBS and the Transport Research Centre (AVV) over 1998 (AVV/CBS, 1999) are used in this chapter to illustrate several facts related to collisions between moving vehicles and animals crossing roads. A distinction is made in this respect between wild animals and pets. Several relevant details that are not included in the 1998 statistics are explained using the Statistics for Road Accidents on Public Highways produced by the CBS for 1995 (CBS, 1996) and 1997 (CBS, 1998).

Table 17. The total number of accidents resulting in injuries per year, the total number of accidents caused by collisions with animals per year and the number of accidents involving animals as a percentage of the total number of accidents in the period from 1991-1998.

Year	**Total number of accidents**	**Accidents involving collisions with animals**	**Percentage of accidents involving collisions with animals**
1991	11 734	36	0.3%
1992	11 364	26	0.2%
1993	11 227	30	0.3%
1994	11 469	-	-
1995	11 437	26	0.2%
1996	11 561	-	-
1997	11 238	-	-
1998	11 124	29	0.3%

(Source: CBS, 1992; CBS, 1993; CBS, 1994; CBS, 1996; AVV/CBS, 1999)

In 1998, the total number of accidents resulting in injuries (i.e. road accidents resulting in deaths and accidents resulting in people being taken to hospital for treatment of injuries was 11,124. The number of accidents caused by collisions with animals was 29 (AVV/CBS, 1999). 0.3% of the total number of accidents in 1998 were therefore caused by collisions with animals. The proportion of accidents resulting in injury that were caused by collisions with animals was also considerably below 1% (see table 17) in other years during the period from 1991 to 1998. These figures show that collisions with animals are not significant in terms of the total number of accidents resulting in injury. In this respect, it should, however, be remarked that collisions with objects such as trees or crash barriers could be caused by swerving to avoid animals crossing the road. The figures for this have, however, not been included in the statistics. Furthermore, nearly all the red deer *(Cervus elaphus)* in the Netherlands, which constitute the greatest danger for motorists, are located in fenced off areas, mainly in the Veluwe National Park.

Evasive manoeuvres

A short article in the North Holland daily newspaper of 20 October 1999 is a good example in this respect. In the article, it is reported that, during their investigation of the cause of a fatal collision between a car and a tree, the police found the remains of a duck at the start of the skid marks. Because of this, it is presumed that unsuccessful evasive manoeuvres were the cause of this fatal accident.

The accident figures for two-wheeled vehicles (bicycles, mopeds and motorcycles) have been registered for 1997. The figures show the difference between the number of accidents with other vehicles and so-called one-sided accidents (accidents involving only one vehicle). Table 18 (CBS, 1998) shows that the proportion of one-sided accidents with motorcycles is significant. Animals were involved in 10% of these accidents, in other words; in other words, in 5.6% of all accidents with motorcycles resulting in injury. The percentage for mopeds of approximately 2% (8% of 22%) is much lower. The 1997 figures for one-sided accidents involving two-wheeled vehicles with or without collisions with objects also show that accidents are seldom caused by collisions with animals. The proportion of accidents caused by colliding with an animal is significantly less than collisions with other objects. It should however be reiterated that accidents with or without collisions with other objects could be caused by swerving to avoid animals crossing the road.

Table 18. Percentage of accidents in 1997 in which no other vehicle was involved (one-sided collisions) of the total number of accidents and the percentages of different types of object that road-users collided with.

	Bicycle	Moped	Motor-cycle
% accidents with another vehicle	71	78	44
% one-sided accidents (without another vehicle)	29	22	56
object collided with:			
Nothing	28	66	64
Animal	2	8	10
Other	70	26	25

(CBS, 1998)

The 1995 figures show that most collisions occurred on roads with a speed limit of 80/90 km per hour (see table 19), i.e. in rural areas. 12 (of the total of 26) collisions with animals were registered on this type of road. Roads with speed limits of 50 km per hour or lower are located in built-up areas and are not included in the problems related to habitat fragmentation. It can also be safely assumed that the animals involved in accidents in built-up areas are (mainly) dogs and cats.

Table 19. Number of collisions between moving vehicles and animals crossing the road for each category of speed limit in 1995.

Speed limit	**Number of collisions between moving vehicles and animals**
< 50 km per hour	3
50 km per hour	8
60/70 km per hour	-
80/90 km per hour	12
100 km per hour	1
120 km per hour	2

(CBS, 1996)

In 1995, just as many accidents with animals occurred during the day as at night – 12 each. Only two accidents were registered for the twilight hours (CBS, 1996). In 1998, there were 17 collisions with animals during the day and 12 during the hours of darkness (in the statistics for 1998, there is no distinction between twilight and night-time) (AVV/CBS, 1999).

Figure 35 also shows that the number of collisions that occurred in the dark is not, as could be expected, much higher than the number that occurred during the day. 12 (of the 29) accidents occurred during the daylight hours (10.00 to 16.00); this is approximately 40% of the total.

Figure 35. Total number of collisions with animals crossing the road at different times of the day in 1998 (source AVV/CBS, 1999)

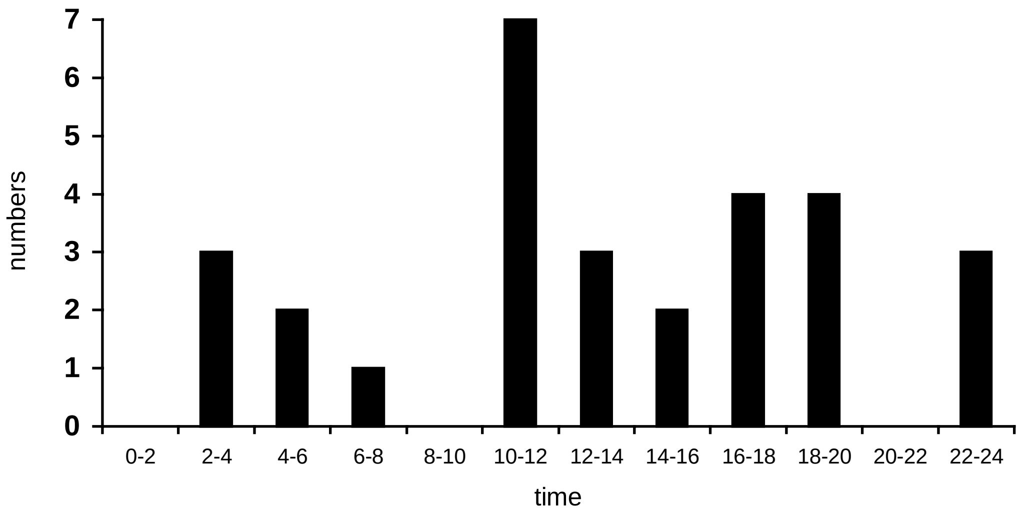

Figure 35 shows that not very many accidents caused by collisions with animals occur during the morning rush hour from 7.00 to 9.00. An explanation for this could be that animals are aware of the high traffic density and do not cross the road during this time.

The question can be asked whether weather conditions play a role in collisions between vehicles and animals. In the statistics, a distinction is made between dry weather and poor weather conditions. A general rule is that it rains in the Netherlands 6% of the time. In 1995, 5 of the 26 collisions with animals (19%) took place under poor weather conditions (CBS, 1996). In 1998, this was 2 of the 29 collisions (7%) (AVV/CBS, 1999). From these figures, it can be concluded that slightly more accidents occur in poor weather conditions.

The proportion of accidents caused by collisions with animals is not significantly different in any of the provinces of the Netherlands. In each province, the number of accidents caused by collisions with animals is below 1% (see table 20). The number varies from 0% in Groningen to 0.49% in South Holland and 0.50% in Flevoland.

Table 20. Absolute numbers of road accidents and road accidents caused by collisions with animals and the percentage of collisions with animals of the total number of road accidents in the provinces of the Netherlands in 1998.

Province	**Total number of road accidents**	**Total number of road accidents caused by collisions with animals**	**% of collisions with animals of the total number of road accidents**
Groningen	419	0	0
Friesland	352	1	0.28

Drenthe	403	2	0.49
Overijssel	853	3	0.35
Gelderland	1 517	7	0.46
Flevoland	200	1	0.50
Utrecht	883	3	0.34
North Holland	1 560	3	0.19
South Holland	1 929	2	0.10
Zeeland	347	1	0.29
North Brabant	1 862	5	0.27
Limburg	799	1	0.13

(AVV/CBS, 1999)

Railway lines
At present, not very much is known about the types and numbers of animals that are run over by trains. There is no systematic registration of animal deaths. Collisions with animals or observations of dead animals on railway lines are, however, reported as part of the system for monitoring line faults. In general, this mainly concerns the larger or noticeable species of wild mammals and birds.

With the way the Dutch railway network is used at the present time, there is little risk to safety though possible collisions with wild animals. Railway lines are for this reason not specifically fenced off against animals. The future high speed rail links will be fenced off from the surroundings for safety reasons. This is to prevent larger mammals like deer, wild boar and martens as well as people, pets and cattle from causing unsafe situations on the tracks.

The presence of fencing will lead to the forming of a significant barrier in nature reserves and woodland areas. The barrier effects will have to be mitigated with passageways for animals like fauna overpasses and tunnels.

Inland waterways
“Traffic safety with respect to collisions with animals” is not a topic of any significance with respect to canals and inland waterways.

Chapter 7 Dealing with fragmentation – prevention, mitigation and compensation

Contributions by: G.J. Bekker, R. Cuperus, C.F. Jaarsma, D. Kamphorst, R.J.M. Kleijberg

7.1 Introduction

In dealing with habitat fragmentation, a distinction has to be made between fragmentation caused by the existing infrastructure network and fragmentation caused by building new infrastructure and reconstruction. The infrastructure manager is responsible for implementing measures. Depending on the type of infrastructure (see §5.2), this can be the national, provincial or local government or district water board. The prevention of fragmentation is only applicable to new building works and reconstruction projects. Mitigation measures are used in dealing with both existing and new fragmentation and include everything deliberately intended to reduce or cancel out the negative effects of the construction and use of infrastructure on the ecological processes and the nature value in a particular area (Cuperus *et al*., 1993). Mitigation ("alleviating") measures are mainly used for fauna. Until now, compensation measures have only been implemented with new building and reconstruction projects. In this context, compensation means taking measures to encourage the ecological functions and nature value in a particular area to replace the functions and value that are reduced or lost through the construction and use of infrastructure (Cuperus *et al*., 1993).

The analyses of the bottlenecks in §5.3.8 form the starting point in the mitigation of the effects of fragmentation caused by the existing infrastructure network. Drawing up measures for the prevention, mitigation and compensation of the fragmentation effects caused by new infrastructure is part of the planning/EIA procedure (see § 4.5).

This chapter describes the possibilities for defragmentation measures and what has been achieved in this respect to date.

7.2 The prevention of fragmentation

National trunk roads

In a recent study focused on national trunk roads (Jurakic, 1999), it was found that, during the different phases in the infrastructure planning process, insufficient attention is given to alternatives that do not involve construction or extension works. Alternatives aimed at preventing fragmentation effects can, for example, entail improving the way existing infrastructure is used and encouraging public transport. Modifying infrastructure by moving complete sections or building tunnels can prevent the negative effects of cutting through ecosystems. There are various reasons why the prevention of the negative effects of infrastructure on nature values that have been laid down for the national ecological network and other nature reserves that are protected under planning policy does not receive enough attention.

In view of recent experience involving the construction of infrastructure, it is clear that the idea of 'prevention' is still insufficiently developed within the Ministry of Transport and Communications. For example, during the Planning Act procedure (see §4.5), no explicit motivation is provided as to whether and how damage to protected areas (according to Planning) can be avoided via the 'not unless-principle'. This principle prohibits harming these areas unless social interests justify action in exceptional circumstances. And when anything other than constructional and broadening alternatives have not been discussed in the early stages of the planning process, it is impossible to introduce these at a later stage, such as the environmental effects report. There is also insufficient clarity on and attention for the consequences of the (international) Guideline on Birds and Habitats (see §4.4).

These problems are also insufficiently recognised by external monitoring parties. This means that the Ministry that promotes the interests of environmental protection (the Ministry of Agriculture, the Nature Management and Fisheries), in its role of legal advisor within the existing decision-making procedure, is unable to provide guidance in preventing effects on the environment. At the same time other advisors, such as the Environmental Impact Committee, pay too little attention to solutions aimed at preventing infrastructural effects.

Furthermore there are the financial restrictions. Building tunnels or moving sections of road are relatively expensive. This gives economic motives priority over the interests of nature conservation. The study referred to above showed that the ‘most environment-friendly alternative’, which is required by law in the framework of the EIA regulations is virtually always too expensive financially and for this reason is not adopted for ‘dry’ infrastructure (the situation is different for ‘wet’ infrastructure). Whether or not infrastructure or other alternatives designed to prevent effects are ‘realistic’ must be considered in the light of the financial criteria that are set in an early stage of the planning/EIA procedures. Moreover, the ‘most environment-friendly alternative’ is usually developed too late in the development phase of these procedures. Because of this, these alternatives cannot be dealt with at any length during the planning process. This makes the costs higher than necessary.

Another reason is the following: In many planning/EIA reports, the negative effects of the destruction of and cutting through nature reserves are only illustrated qualitatively and not quantitatively. Because of this, the absolute effects of infrastructure on nature value are underestimated.

The last factor is that utilisation and public transport alternatives still fall a long way short of effectively solving bottlenecks in regional traffic planning and road safety. For this reason, these alternatives are often unfavourable compared with construction and expansion projects that do provide solutions.

Secondary roads

Habitat fragmentation caused by building new roads in the provinces of the Netherlands is an integrated element of the EIA. In principle, whether or not fragmentation will occur or whether it can be prevented is taken into consideration in the building or reconstruction of secondary roads. However, the reasons for not proceeding with the construction of infrastructure are by no means always related to considerations regarding the fragmentation effect that construction will have. Road building or reconstruction is not systematically registered in a way in which avoiding fragmentation actually plays a role in the selecting the route and location of (new) roads in any of the provinces. However, in recent years, hardly any new secondary roads have been built. The prevention of fragmentation in building or reconstructing roads therefore does take place in principle, but in practice, few examples of this can be found in the provinces. In weighing up the different interests involved, nature conservation organisations are given the opportunity to speak out about the fragmentation effects caused by building or reconstructing secondary roads. In Utrecht and Gelderland, the organisations that do this include the Provincial Environment Federation and the Badger and Tree Association. In preventing fragmentation in road building and reconstruction projects, cutting through the National Ecological Network has been taken into account in a number of cases in, for example, Friesland and Limburg.

Railways

The “no-unless-principle” from the Structure Plan for the Rural Areas is still virtually never explicitly applied in the Netherlands in support of and as part of the decision-making processes related to major spatial planning projects. The Environmental Impact Assessment Committee recently started to test published EIAs proactively in this respect. The “no-unless-principle” is implicitly raised in the public debate on the “need and necessity” of new rail links and the related effects on nature and the landscape. Examples of this are the intense public debate about the route of the high-speed rail link through the “Green Heart” of South Holland and the construction of the Betuwe Line.

There is no explicit legislation for the routes of and for fitting railway lines in the natural environment. However, the policy of various government departments, public interest groups and project initiators all have the express wish to limit any detrimental effects as much as possible from the outset by choosing the best possible route and by adapting railway lines to their surroundings.

When choosing the route of a rail link, detrimental effects can be avoided by laying horizontal track sections around instead of through (protected) nature reserves. With measures to fit new lines or tracks to be reconstructed into the surroundings, the design can be optimised in such a way that any negative effects on the environment are minimised. The starting points for this are the horizontal and vertical positioning of the track, the cross section, crossing points with ecological networks and a wide range of additional measures (fauna passages, noise barriers, planting vegetation, etc.). The most extreme form of fitting a rail link into the surroundings is the complete tunnelling of sections of track, for example, parts of the Betuwe Line and the high speed rail link through South Holland. Measures like this constitute a gradual transition to mitigation. Many so-called mitigating measures are taken when fitting railways into the environment in anticipation of the probable effects of (re)construction.

In recent years, fitting new railway lines into the environment has taken place on the basis of a strategy that has now been used for four major railway infrastructure projects (HSRL South Holland, HSRL East, the Hanze Line and the line between Roosendaal and Antwerp). The strategy clarifies the choices that can be made in respect of construction projects at an early stage in the planning procedures and the objectives that should be set regarding the rural and urban surroundings of the railway track. The strategy forms the framework for the development process, but also a platform for consultation and discussion with local interest groups.

[figure 35: photo of a railway line fitted into the surroundings]

One of the objectives of the aforementioned major railway infrastructure projects was the optimisation of what eventually became a small number of alternatives. Avoiding negative effects on the environment played, obviously within the scope of technical and financial feasibility, a key role in this. In general, this process entailed first looking for suitable routes. After the routes were selected, the possibilities for fitting them into the environment were examined. The process also involved extensive consultation with different interest groups (local residents, the managers of nature reserves, nature and environmental workgroups and official organisations).

Inland waterways
No information is available about the prevention of habitat fragmentation during the construction and extension of canals and waterways.

7.3 Mitigation measures

7.3.1 Possibilities for mitigation

It is customary to place fragmentation caused by infrastructure and traffic in four categories - habitat destruction (during construction), habitat disturbance, the barrier effect and accidents/drowning. Mitigation measures are specifically designed to save lives, the elimination of barrier effects/isolation and elimination/reduction of disturbance depending on the category of fragmentation. There are no (real) mitigation measures for habitat destruction – this has to be compensated (see §7.4).

Defragmentation measures are based on one or more of the following principles (Figure 36 a-e):
1. restriction (with fencing) of an animal’s ability to move between habitats or making it safer (fencing combined with safe passages) to reduce the number of accidents; Figure 36 a and b);
2. elimination of the barrier effects of a road (modified roadside verges with passageways; Figure 36 c);

3. elimination of habitat isolation (corridors in roadside verges to guide animals to passageways or as a link to a habitat located further away; Figure 36 d);
4. elimination/reduction of disturbance (screens; Figure 36 e).

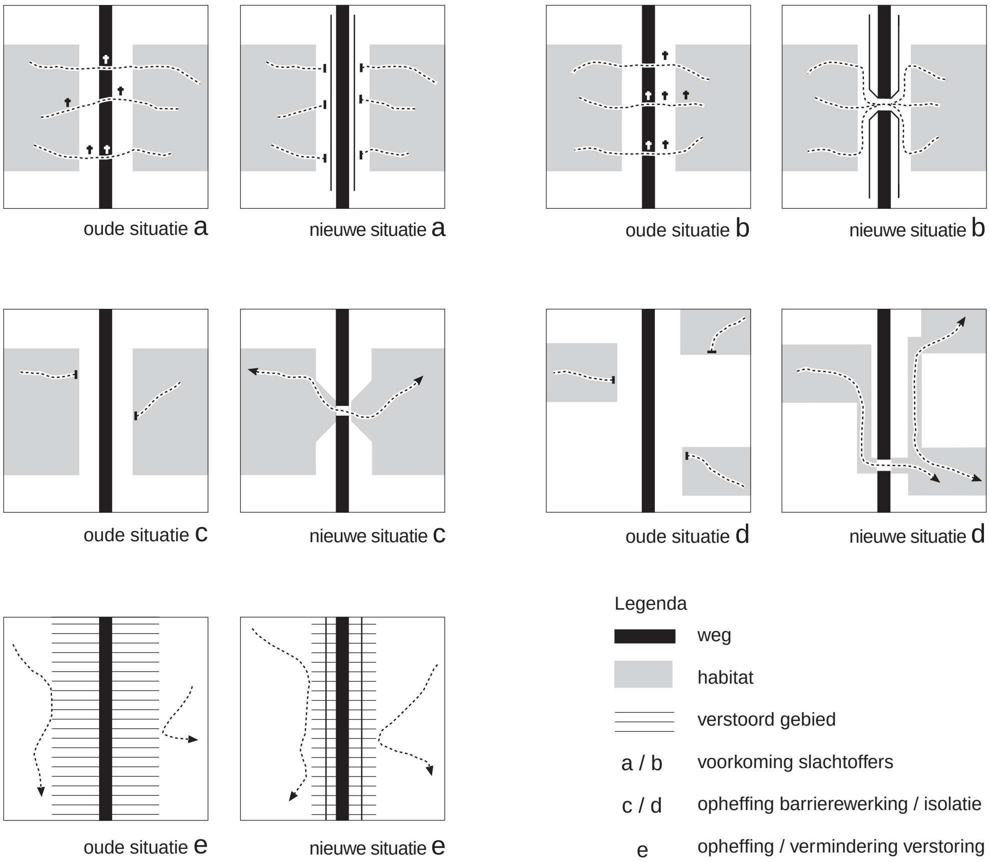

Figure 36. The principles of mitigation measures for accidents, barrier effects, isolation and disturbance (from Oord, 1995).

With mitigation measures, a distinction is made between source-oriented and effect-oriented measures. Source-oriented mitigation measures are concerned with the actual infrastructure or the traffic that uses it. They have a broad scope of operation. Measures that are aimed at specific animal groups such as game reflectors and overpasses for fauna are called effect-oriented.

Various source and effect-oriented mitigation measures are set out in table 21 on the basis of the four fragmentation categories and illustrated with examples. The effect-oriented measures are divided into four subgroups – (1) fencing and screens, (2) passages and (3) roadside verges plus corridors. Fences are (primarily) used to reduce the chance of animals being killed when crossing the road and screens are (primarily) meant to improve the quality of fenced off habitats. Roadside verges can (also) serve as corridors. If more space is needed to link habitats than a normal verge, corridors can be set up.

Table 21 Overview of source and effect-oriented mitigation measures with respect to the various categories of fragmentation

Fragmentation category	Mitigation measures			
	Source-oriented measures	Effect-oriented measures		
		Fencing and screens	Passages	Roadside verges and corridors

1. Prevention of casualties	• reduce traffic density • reduce traffic speed • canal banks with slight inclines (1:10) • fauna-exits	• fencing • guide walls • screens • deterrents (game mirrors) • vegetation/set-up (deterrents, guides and increasing the height at which birds fly over infrastructure)	• specific fauna passages (tunnels, fauna overpasses) • modification of existing or new engineering structures	
2. Elimination of barrier effects	• change the structure of roads/ surfacing • reduce traffic intensity • reduce traffic speed • canal banks with slight inclines (1:10) • fauna-exits	• planting vegetation to guide animals to different habitats and to deter them from crossing roads	• specific fauna passages (tunnels, fauna overpasses) • modification of existing or new engineering structures	• ecological set-up of roadside verges • ecological management of roadside verges
3. Elimination of isolation	• change the structure of roads/ surfacing • reduce traffic density • reduce speed • construction of nature-friendly banks		• specific fauna passages (tunnels, fauna overpasses) • modification of existing or new engineering structures	• ecological set-up of roadside verges • ecological management of roadside verges
4. Elimination/reduction of disturbance	• reduce traffic density • reduce traffic speed • noise absorption (ZOAB = porous asphalt) • (decrease in) street lighting levels	• noise reduction measures (walls, screens) • measures to reduce light and visibility		

With all these measures, the location has to be selected first. Source-oriented mitigation measures not only have a broad scope of operation, they must be implemented over a large area (or, as the case may be, over long stretches of infrastructure). This is different for effect-oriented measures. In this case, the measures have to be tailored for specific locations and closely related to different types of animals. This is usually fairly difficult, because the animals that the measures are designed to help live along entire sections of a road/railway/canal. In practice, bottlenecks usually occur when infrastructure crosses the national or provincial ecological networks or other areas protected under government policy, the provincial animal protection plans and data on animal road accident victims or cases of drowning (see §5.3.8). The great length, the usually narrow verges and the generally short distances between the entrances that have to be kept open to farms and fields cause practical problems in implementing effect-oriented measures along roads in rural areas. This limits the possibilities for placing continuous fencing and screens.

Source-oriented measures for waterways can, for example, include the construction of canal banks with gentle inclines, fauna-exits where animals can get out of the water or nature-friendly banks. Possible measures for motorways and main roads (such as laying ZOAB/porous asphalt) and modifying the levels of lighting. With roads in rural areas, the options include – depending on the local situation – a narrower hardened road surface and (in theory) the removal of hardened road surfaces. This is closely tied in with reducing the traffic density and is further worked out in the framework of the “traffic management in rural areas/combining traffic flows” policy plan. Source-oriented measures in the form of placing speed limits can in principle be used with all categories of road, but the way in which speed limits are enforced will have to be looked into.

Traffic management in rural areas/combining traffic flows
Reducing the traffic density on one road category always leads to more traffic on other road categories. When drawing up measures to modulate traffic flows, the whole region that will be affected has to be taken into consideration. The concept of “traffic management in rural areas” was originally set up to find a solution for unsafe situations on rural roads (Jaarsma, 1997). However, the concept apparently also has beneficial effects for fauna (Van Langevelde & Jaarsma, 1997; Jaarsma & Van Langevelde, 1997), which are related to the density of traffic on a limited number of roads. Figure 37 – the data for a survey area near Oosterwolde (Friesland) – illustrates this.

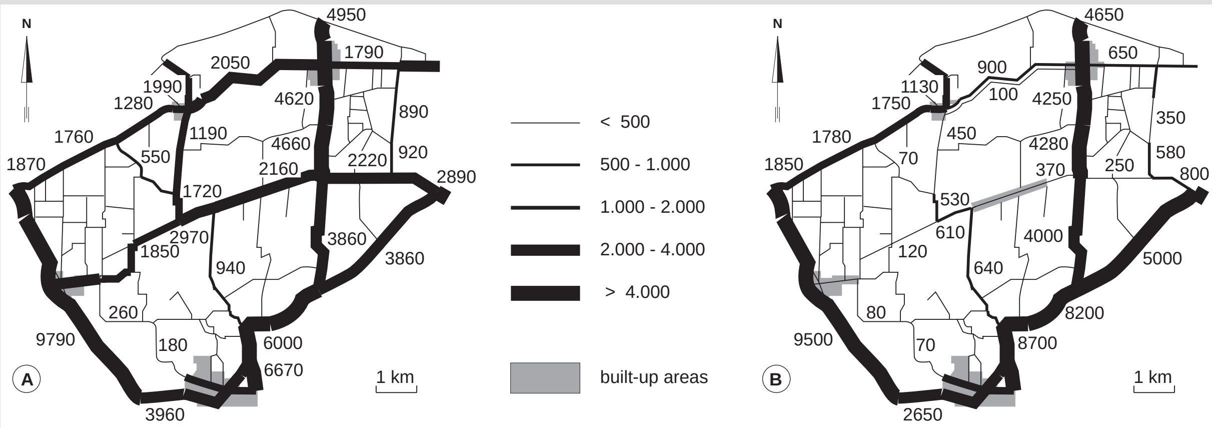

_Figure 37. Average (car) traffic density per 24-hour period in the survey area for (A) autonomous development and (B) planned situation (Jaarsma *et al*., 1995)

In the figure, the traffic densities, which would be expected in around 2005 if there was no redevelopment of the road network are given on the left (so-called autonomous development). On the right, the traffic densities are listed that have been calculated for a structured situation in which a limited number of roads are assigned a special traffic function. These roads are specially designed for to meet a particular requirement, for example by laying cycle paths. All other roads are meant exclusively to be used by local traffic. They have a “modest” level construction in line with the expected low traffic density and driving speeds. The beneficial effect for fauna is produced by the (much) lower traffic density in a large part of the region. Because of this, some of the roads can even be made narrower. The amount of traffic on a small number of roads will actually increase, but effect-oriented measures can be implemented to alleviate the situation in specific places.

The concept of “traffic management in rural areas” received new impetus from the introduction of the traffic safety concept "Sustainable Safety". In this concept, motorised movement has to take place as much as possible on the safest roads, which are motorways. In rural areas, this means concentrating the, at present often diffuse, traffic flows through a given area on a small number of “traffic arteries” – the (main) roads that are generally on the outskirts of the area. In dealing with the traffic per region, it is in principle possible to concentrate traffic on a limited number of main roads. Figure 37 illustrates this. In a study carried out for Northwest Limburg, the traffic density was worked out using the "Sustainable Safety" concept (Jaarsma & Hoogeveen, 1998).
The concentration of traffic flows leads to a situation in which the disturbance in an area as a whole is reduced. Jaarsma and Hoogeveen quantified these effects as much as possible per area. From their calculations, it is apparent that the habitat surface area increases in relatively quiet zones (with a maximum noise level of 40 dB(A); a level that is somewhat higher that the applicable standard for quiet zones of 35 dB(A)). By concentrating traffic flows, the number of animals killed in road accidents can decrease by approximately 20%. In this theoretical calculation using a “crossing-over formula” (see annex VI), only source-oriented measures regarding traffic densities were taken into account. By implementing effect-oriented measures along the roads where traffic is concentrated, further reductions in the number of accident victims can be achieved.

In the guideline “Measures for fauna on roads and waterways” (Oord, 1995), effect-oriented measures to counter habitat fragmentation caused by infrastructure are worked out. Flowcharts are used to indicate which measures can be implemented for different types of animals (the so-called model ecosystem types). The handbook also contains a detailed technical description of the siting/construction of each measure and discusses the required management and maintenance.

Mitigation measures often focus on a specific species. If the defragmentation effect they have is insufficient or if a broader scope of operation is required, compensation measures can be applied. These are discussed in the paragraph below.

To prevent animals from being run over, fencing and guide walls can be placed to conduct them to places where they can cross the road safely (see fig. 42). For birds, planting trees can force them to fly higher over the road so they avoid traffic. In addition to fences and screens, extra measures are often necessary, for example escape routes (for animals that stray onto the wrong side of the fence), service ports and special features where fencing crosses junctions or ditches. Other measures include wildlife mirrors and reflectors (see fig. 43), odour emitters, badger ramps and modified roadside ditch profiles.

A study carried out by the Institute for Forestry and Nature Research could not, however, demonstrate that wildlife mirrors or reflectors had any positive effect (De Molenaar & Henkens, 1998). The so-called fauna-exit is a special type of additional measure. It is used to reduce the barrier effect of steep canal banks (see fig. 44). Nature-friendly canal banks can also be included in this category (see fig. 45). Noise-reducing measures and screens belong in the same category as fencing and guide walls. Their (primary) function is, however, to eliminate or reduce disturbance. Planting vegetation to counter the visual disturbance in an area also belongs to this category. Fencing and screens are less effective along secondary roads in rural areas than along motorways or main roads. This is because of the large number of entrances to farms and fields that have to be kept open. It means that there will always be a large number of gaps in fencing, screens, etc., which radically reduces their effectiveness.

[figuur 42: foto raster]; [figuur 43: foto wildspiegel]; [figuur 44: foto faunauittreeplaats]; [figuur 45: foto natuurvriendelijke oever]

In 1995, Oord drew up a flowchart of the types of passageway that can be used for fourteen different animals (varying from deer to the common toad). A distinction is made between creating specific fauna passageways (for badgers, otters, small fauna and amphibian tunnels, fauna tunnels with an open topside, large fauna tunnels and ecoducts) and modifications to engineering structures ((eco-)culverts, extending canal banks under bridges, traffic tunnels, roadside verges or walkways next to viaducts).

In principle, these measures can be applied to all categories of road. For example, badger tunnels have been built under every category of road in the Netherlands (see table 24 in §7.3.2). Two remarks should be made in this respect. Firstly, it is unlikely that there will be enough space along every secondary road in rural areas for additional fencing. This will reduce the effectiveness of passageways. Secondly, ecoducts are a large-scale and expensive solution that, for the time being, only have been used on motorways.

Fauna passageways used with rail infrastructure are essentially the same as those used for roads. A wide range of ecoducts, game tunnels, badger and amphibian pipes, eco-culverts, etc. can also be used with railways. Other measures that can be used in mitigating the effects of railways include:

- landscaping embankments, track-sides and overhangs in such a way to create favourable growth and living conditions for plants and animals (so that part of the ecological loss is reversed in local situations);
- measures to counter the dehydration effect of the construction and presence of infrastructure (reverse drainage, insulated construction methods, the use of settlement-free slabs, etc.);
- measures to counter disturbance of the environment (noise screens and barriers, the use of low-noise tracks and rolling stock).

7.3.2 Measures that have been implemented

National trunk roads

In the 1970s, the Directorate-General for Public Works and Water Management started building tunnels for badgers (Bekker & Canters, 1997). Several parties were involved in this initiative and it evoked a great deal of discussion. By the 1980s, the construction of badger tunnels became a more normal part of building practices. Since 1990, building badger tunnels has been a standard feature in the planning and design of new motorways. This applies for both areas in which badgers are actually found and for areas where it is known that they lived in the past (see fig. 46). In 1988, the first two ecoducts were built at the same time as the construction of a new motorway – the A50. Both were built in places where the motorway crosses the migration routes of deer. In 1992, a third ecoduct was built over the new section of the A1 near Oldenzaal. A fourth was completed at the end of 1988. It was built over the existing section of the A1 near Kootwijk. Similarly to the first two ecoducts, it links two parts of the Veluwe, one of the largest nature reserves in the Netherlands, that are situated on opposite sides of the motorway (see fig. 47). In the 1990s, a large number of existing engineering structures such as viaducts, bridges and culverts were remodelled so they could function as fauna passageways. Gangplanks and gangways have been placed in culverts (see fig. 48), canal banks have been extended under bridges and rows of tree-stumps (the so-called walls of tree-stumps) have been placed under viaducts (see fig. 49). Table 22 shows the total number of fauna passages that were built on national trunk roads until 1999.

[figuur 46: foto dassentunnel]; [figuur 47: foto ecoduct]; [figuur 48: foto aangepaste duiker]; [figuur 49: foto aangepast viaduct]

Table 22: The number of fauna passages that have been built under and over national trunk roads in the Netherlands until the end of 1999.

Type of fauna passage	number
small fauna tunnels	259
large fauna tunnels	1
ecoducts	4
tunnels for amphibians	0
eco-culverts	8
modified engineering structures	85

Until now, attention has been mainly focused on building fauna passages to decrease the barrier effect of national trunk roads, erecting fencing and placing game reflectors to reduce the number of animals killed in road accidents and to improve ecological management of roadside verges (see §8.2). Other measures, such as reducing the maximum speed limit or placing noise barriers are generally not implemented outside the built-environment. The experiments with modified street lighting to limit disturbance that are currently being carried out form an exception to this. Because wildlife mirrors and reflectors are apparently ineffective (De Molenaar & Henkens, 1998), it is the policy of the Directorate-General for Public Works and Water Management not to use them anymore. They have even been removed on some road sections.

Secondary roads

In the Netherlands, the first tunnels for amphibians were laid under a road near Bergen in North Holland at the transition between the dune area and the polder. Near St. Odiliënberg, fences and pipes were laid to protect toads. A secondary road was also involved in this case. No information is available about the use of these structures. By now almost 80 tunnels for amphibians have been realised under secondary roads. In the "de Meinweg" national park, a tunnel was built under the hardened-over Meinweg with the objective of allowing free-ranging cattle to move from one side of the road to the other safely. This is remarkable because it involved modifying a secondary road. In the beginning of 2000, a large fauna tunnel was completed under a secondary road at Hoog Soeren (see fig. 47). The purpose of the tunnel is to allow large game to move between the northern and southern sections of the national park. The animals are led to the tunnel through a shallow valley.

Measures to improve road safety also benefit fauna

The Zeeland Islands District Water Board is implementing measures to improve road safety that can also benefit fauna. Using roads in rural areas more extensively is reducing the habitat disturbance caused by the road network in general. The Water Board is preparing various similar 'implicit' defragmentation measures. To improve road safety, the speed limit on roads in rural areas will be reduced from 80 km/h to 60 km/h. Because of this, these roads will be less busy, which in turn may reduce the barrier effect they produce. On a narrow road in the countryside near Middelburg, the number of cars is to be reduced to make the area more attractive for cyclists. This will also reduce the barrier effect for fauna. In other places, cattle tracks will be reintroduced. Cattle will be able to roam freely in these places and the roads will be resurfaced, for example, with gravel or loose chippings. This will make it easier for insects and reptiles to cross over.

Railways

In 1999, the Dutch Railways Infrastructure Management Board compiled an overview of the provisions for animals, which it knew about, along the existing rail network that countered the barrier effect. The overview shows that there are a total of 39 provisions for animals and 29 natural structures in 15 different locations (see table 23).

Table 23 Existing ecological provisions along rail infrastructure

track section	number of provisions	type of provisions
Woerden-Harmelen	8	walkways in culverts, small fauna tunnels, passageways, pools, structured overhang
Utrecht-Arnhem	7	wet/dry passage, pools
Boxtel-Eindhoven	13	dry culverts, amphibian tunnels, wildlife tunnels, wet/dry passage
Groningen-Leeuwarden	3	dry culverts, wet/dry passage
Schagen-Heerhugowaard	3	wet/dry passage, new habitat
Meppel-Leeuwarden	3	pools
Lelystad	1	passageways, exit point
Amsterdam-Weesp	7	exit point, "temporary shelter", wet/dry passage, pool, new habitat
Weesp-Lelystad	2	pool, wet/dry passage, new habitat
Zwolle-Wierden	3	dry culverts
Deventer	1	shelter for bats

Zutphen-Hengelo	1	dry culvert
Hilversum-Utrecht-Den Dolder	4	dry culvert, fencing, pool
Dordrecht-Lage Zwaluwe	1	lake berm
Maastricht-Sittard-Schin op Geul	3	pool, structured overhang, new habitat

National trunk roads, secondary roads and railway lines
In the Netherlands, badger tunnels have been built under national trunk roads, secondary roads and railway lines. Table 24 shows the number of tunnels that have been built up to 1998.

Table 24: The number of badger tunnels built in the Netherlands up to 1998.

Province	Nat. trunk roads	Prov. roads	Mun. roads	Railways	Total
Limburg	61	35	38	1	135
North Brabant	73	30	30	2	147
Utrecht	38	35	30	1	104
Gelderland	1	0	4	1	6
North Holland	1	1	0	1	3
Overijssel	75	12	17	0	104
Drenthe	40	7	1	0	48
Friesland	2	9	5	0	16
Total	291	29	137	6	563
	52%	23%	24%	1%	100%

(Source: Badger and Tree Association, 1998)

Waterways
A reliable overview of the number of mitigation measures that have been implemented along canals is not yet available. An inventory of this information will be made during the present policy evaluation. The current state of affairs can, however, be described in global terms.

17 kilometres of lake berm and 50 fauna-exits have become integrated part of the repair and construction programme for widening the Twente Canals. One nature-friendly bank has been laid along the Amsterdam-Rhine canal and 12 more banks have been planned. Along the North Sea Canal, 10 ha of nature-friendly bank have been laid; a follow-up that will involve the creation of a brackish connection zone is being prepared. Along the canalised section of the Hollandsche IJssel, 3 kilometres of nature-friendly bank have been laid and 4.5 kilometres along the North Holland Canal. The Directorate for North Brabant has laid a total of 65 kilometres of nature-friendly banks and 165 fauna-exits. The points where the canals in Brabant cross various small rivers are, in spite of the presence of culverts, still a problem for migratory animals in river valleys.

7.3.3 Design criteria
The design of provisions for fauna is a relatively new field of knowledge combining civil engineering and ecology. The designs are largely based on existing civil engineering expertise. Over the last few years, a specific direction has been seen in the development of many types of passageways. At present, the experience that has been gained is only translated into design criteria on a limited scale. It is, however, clear that a structured work method does benefit designs. Recent studies (see §8.3) provide the main criteria that a particular design has to meet in order to be able to function properly for a target species. The available knowledge from both disciplines provides the initial basis for the dimensions of different passageways. Experiences with various designs, the monitoring of passages to see how they are used by different animals and coincidental discoveries will supplement available information.

In 1995, a guideline was drawn up by order of the Directorate-General for Public Works and Water Management that contains a compilation of the preliminary findings (Oord, 1995) (see §7.3.1). The guideline uses as a background, on the one hand, ecological knowledge and the experiences of field-biology and, on the other hand, practical and theoretical (civil) engineering knowledge. The currently available knowledge of developments, research results and experience can now supplement and improve the guideline. The guideline can be considered as a first, preliminary supportive reference book. It contains no compulsory criteria or requirements. The flow chart 'target species – types of passageway' provides a great deal of insight in the topic. The chart links the most common target species with specific types of passage and indicates if a particular species has a strong preference for one type of passage, whether it has been demonstrated that the species uses or can be expected to use this particular type of passage.

The guideline subsequently describes various types of passage in terms of set characteristics. In addition to an introductory outline, the following aspects are discussed systematically:

- functional requirements and experiences
- situation
- design
- management and maintenance
- cost estimate
- sketched examples

With respect to the work method, it is important in concrete projects to adhere to a broad approach that focuses on regional areas. This involves a total approach aimed, on the one hand, at the relationship between ecological connection zones, corridors and fauna passages and, on the other hand, adequate maintenance and guarantees in planning policy. To help follow this approach, a step by step plan that partially has a cyclical character has been drawn up for implementing measures along infrastructure:

1. compiling an inventory of and establishing the points where nature and infrastructure cross
2. problem analysis and setting objectives based on a regionally oriented approach
3. setting priorities for dealing with the bottlenecks
4. making preliminary designs for the measures for each bottleneck or set of bottlenecks
5. consultation with the relevant parties
6. drawing up project proposals
7. compiling specifications, organising the tender and construction activities
8. evaluation of the use of the measures
9. organising management and maintenance after completion

The co-operation, consultation and co-ordination in respect of implementing defragmentation policy produces additional practical information, innovative global ideas about the approach and design and concrete research results. This occurs through the participation of the large number of parties involved in infrastructure in national, provincial and local government. Because of this, necessary measures, design ideas and standards are tried out on a wider basis, which ultimately leads to them having more support. A prerequisite for this is that the national government formulates a clear-cut unambiguous policy that can be interwoven with different objectives on a national, provincial and local level.

The Dutch Railways Infrastructure Management Board has produced a special reference book for flora and fauna provisions along rail infrastructure to facilitate the implementation of measures (*NS Railinfrabeheer*, 1995).

With the publication of the new 'Handbook for Nature-friendly Canal Banks', a completely updated and supplemented overview is available in which criteria are given for measures that can be implemented as described in §7.3 (CUR, 1999a-e, CUR 2000). Ecological criteria form the basis of the handbook. Various computer models have also been developed (PLONS, EKOS, KIMONO, TURBOVEG) that can provide support in setting up, monitoring and assessing nature-friendly canal banks.

7.4 Compensation measures

National trunk roads

The consequence of the compensation principle (see § 4.5) is that the Directorate-General for Public Works and Water Management initiates – on an increasing scale – nature development outside its traditional scope of road management. The paragraph below indicates how the compensation principle has taken shape in the planning and construction of motorways and main roads.

Since the compensation principle took effect, about 25 planning/EIA reports for national trunk roads have been published or are being prepared in which nature compensation plays a role. The finalised planning decision for a small number of road sections is being prepared and for several other projects the decision has recently been published. These projects will be carried out using the procedure described in the Infrastructure (Planning Procedures) Act (Government Gazette, 1994; see § 4.5).

The following conclusions can be drawn with respect to compensation during the planning phase and the decision-making process:

- In practice, compensation measures are worked out in greater detail as the procedure progresses. The planning/ EIA report gives a global outline of the consequences of the compensation principle for the various feasible alternatives; the compensation measures are worked in detail when making the planning decisions;
- With several projects, the compensation principle has led to alternatives that could cause a relatively large amount of damage to nature being withdrawn.
- In the planning/EIA reports, in which the effects of several alternatives are described, the amount of compensation varies from 1 to 300 ha (see table 25A for examples). A decision has now been made for two road sections. Although the costs of the compensation measures related to the decision on each section are within the margins set in the respective planning reports (table 25B), the amount of compensation may be increased depending on the results of further research (A2-RsH).
- In the planning/EIA reports, the costs of compensation vary from approx. 1% to a maximum of 8.2% of the total projects costs (table 25A); in the two available finalised decisions, these costs are a maximum of 2.3% (table 25B).

Table 25A. Compensation aspects of six representative Routing EIAs associated with construction and reconstruction alternatives (source: Cuperus et al. *submitted*).

	A4-DB	A2-RsH	A4-DS	A2-VsH	A2-TE	A15
developing new habitat (ha)	0-300	1		8-24	56-81	2-7
upgrading existing habitat (ha)			22-190			2-104
mitigation costs (US$ mln.)	ns	ns	ns	4.6	ns	ns
compensation costs (US$ mln.)	0-16.0	1.0	0.2-1.2	6.2	ns	0.3-6.9
relative compensation costs	0-8.2%	0.5-1.0%	0-0.7%	0.8-1.3%	ns	0.3-2.0%

projects: A4 DB (Dinteloord-Bergen op Zoom), A2-RsH (Ring road 's-Hertogenbosch), A4 DS (Delft-Schiedam), A2 VsH (Vianen-'s-Hertogenbosch), A2 TE (Tangents Eindhoven), A15 (Varsseveld-Enschede)

ns: not specified

Table 25B. Compensation aspects in two Routing Decisions (source: Cuperus et al. *submitted*).

	A4-DB	A2-RsH
compensation area (ha)	53	27
upgrading existing habitat (ha)		
mitigation costs (US$ mln.)	1.0	0.5
compensation costs US$ mln.)	3.7	2.2
relative compensation costs	2.3%	0.7%

projects: A4 DB (Dinteloord-Bergen op Zoom), A2-RsH (Rondweg 's-Hertogenbosch)

There is, however, in this respect no compensation plan available or being carried out in any of the plan study projects. This is because of the large amount of time involved in infrastructure planning.

For seven road construction projects, for which compensation measures will be implemented, the planning decision was taken in the period before the compensation principle took effect. With each of these decisions, it was announced that a compensation plan would be drawn up for the alternative that was selected. This has now been done for all these projects. Because in these cases, the compensation plan ‘was drawn up in arrears’, compensation did not play a role in working out the alternatives or therefore in the decision-making process.

Three of these compensation projects are currently being carried out (see table 26A). The compensation plan for the A50 Eindhoven-Oss (VenW 1995b) has already achieved half of its acquisition target only three years after it was drawn up; the first section of land has now been transferred to the responsible authority. For the N34/37 Hoogeveen-Emmen (DLG 1998), 15% of the target has been achieved after only one year. The first section of the compensation area for the N57 Veersedam-Middelburg have now also been purchased. The other compensation plans are not yet operational. This is partly due to the postponement of road construction and partly because of people’s unfamiliarity with the procedures involved (see table 26B).

With regard to drawing up and implementing compensation plans the following conclusions can also be drawn:

- The size of the compensation areas varies from 14 to 281 ha (tables 26A and 26B); the compensation for one project will be financial instead of physical.
- The compensation costs for the seven projects vary from 0.1 to 3.6%.

Table 26A. Compensation aspects of the two compensation plans that are currently operative (source: Cuperus et al. *In prep.*).

projects	A50	N37/34	N57
developing new habitat (ha)	281	47-94	4
upgrading existing habitat (ha)	—	0-47	17
total (ha)	281	94	21
mitigation costs (US$ mln.)	4.9	1.2	0.2
compensation costs (US$ mln.)	11.4	2.3-3.1[a]	0.1[b]
relative compensation costs	3.6%	2.0-2.7%	0.1%

projects: A50 (Eindhoven-Oss), N37/34 (Hoogeveen-Emmen-German border), N57 (Veersedam-Middelburg)
[a]dependent on the ratio developing new and upgrading existing habitat, [b]costs for upgrading 17 ha grassland not included

Table 26B. Compensation aspects of the four compensation plans not yet operative (source: Cuperus et al. *In prep.*). Because the compensation plans have not been drawn up yet and are not operational, the names of the projects have not been given.

Directorate	L	ZH	U	ON
developing new habitat (ha)	188	7-15	(8)[a]	9-11
upgrading existing habitat (ha)	59	0-8	—	5
total (ha)	247	15	(8)[a]	14-16
mitigation costs (US$ mln.)	13.7	1.2	68.4	0.3
compensation costs (US$ mln.)	12.3	2.4	—	0.9
financial compensation	—	—	0.4[b]	—
relative compensation costs	2.1%	0.8%	0.1%	0.5%

Responsible Directorate: Limburg (L), South Holland (ZH), Utrecht (U) and Eastern Netherlands (ON) [a]based on theoretical in-kind compensation of grassland, [b]in the plan an equal amount is reserved on behalf of a railway development project which is associated with the highway

Secondary roads

The provinces also apply the compensation ruling set out in the Structure Plan for the Rural Areas. In continuation of this, a number of provinces, for example North Brabant, North Holland and South Holland have worked out their own compensation principles. Compensation is therefore a fixed part of the (re)construction of provincial roads. The compensation ruling has, however, not been included in the regional plans of all the provinces. There is no systematic registration of the compensation projects that are carried out in the (re)construction of roads in any of the provinces. In some provinces, a number of definite road (re)construction projects are known in which compensation is being applied or is being prepared. In other provinces, however, there is virtually no road (re)construction taking place. In these provinces, compensation is, in practice, only being applied on a small scale, for example Friesland, North Brabant, Limburg and Flevoland. In principle, the compensation ruling also applies to local authorities. However, there are hardly any roads being built in rural areas, which means that compensation in this case is in effect not a topical issue.

South Holland – Compensation plan for the northern ring-road around The Hague

The province of South Holland has devised a policy for implementing the compensation ruling, in which it adheres to the principle that damage to nature and landscape should be compensated by the party that caused it. This policy is followed in the construction of new provincial roads. In all road building projects, the fragmentation, destruction and disturbance of nature reserves is compensated. Because compensation is an integrated part of road building projects, there is no information available at present about the total quantity of compensation made available during the building of provincial roads. A registration system is being set up. Concrete examples can, however, be given of situations in which compensation takes place. One of these is the compensation plan for the northern ring-road around The Hague that is the joint responsibility of the national government, the province of South Holland and the city council of The Hague.

In the compensation plan, the effects of building the road are mapped out – destruction of biotopes as a result of building (new sections of) the road, disturbance of fauna, acidification/slurry from road traffic and the spreading of environmentally harmful substances through the soil and groundwater. Advice is given on possible compensation measures for each section of the road. For the provincial section, the effects include the loss of vulnerable plants because the road leads up the slope of a sand dune; disturbance caused by an increase in noise and vehicle movements as a result of the rise in traffic density; disturbance caused by traffic lights; the barrier effect of the road and the acidification of the neighbouring sand dune region. For the section that is the responsibility of the city council, the negative effect will be the loss of a small biotope measuring 0.1 ha in an area where protected plant and animal species are found (e.g. the striped back toad *Bufo calamita* and the common toad *Bufo bufo*).

Compensation measures have been proposed for each road section. For the city council and provincial sections, these include modifying the building specifications, choosing work methods that minimise damage during construction, building a small fauna tunnel and the purchase of land to make a new haven for avifauna.
(DHV Environment and Infrastructure, 1997).

Railways

Compensation can be included in decision-making processes to prevent an existing or future undesirable situation from occurring. With a number of large-scale new and reconstruction rail infrastructure projects, only future scenarios has been relevant until now. The compensation principle has been applicable to all major rail infrastructure projects that fall under the Infrastructure (Planning Procedures) Act since 1998 (1993?). It means that compensation measures for specific sections of track are recorded in the planning decision and that additional compensation measures are described in detail. In principle, compensation is physical (i.e. in hectares), unless this is impossible because of the circumstances in a particular situation. Compensation does not involve compulsory land purchases. The Dutch Railways Infrastructure Management Board has developed a number of specific tools for translating this policy into practice (Guidelines for Nature Compensation and the Methodology of Nature Compensation, literature?). The policy of the Dutch Railways Infrastructure

Management Board is to assume responsibility and remain involved in the preparation and realisation of nature compensation until planned new nature is actually “complete”.

There are various bottlenecks in developing plans for rail infrastructure with respect to nature compensation:

- the experiences with implementing nature compensation are extremely limited;
- the existing instruments for implementing policy are inadequate, which means they have to be used ‘creatively’ (especially in the case of land acquisition);
- Different interpretations of the compensation ruling are applied to projects in different stages at a provincial level. This can cause problems with the progress of a project.

Table 27 gives an overview of the characteristics and scale of nature compensation with new construction projects.

Table 27. Achieved and planned nature compensation with rail infrastructure projects.

project	**planned ha**	**achieved ha**	**form of compensation**	**problems**
Betuwe Route	PM	PM	physical	compensation measures concentrated in tunnel
HSRL South	approx. 200	0	physical	discussion about the areas that have to be compensated
Boxtel-Eindhoven	approx. 4	0	physical	in addition to the land acquisition, the construction of windbreaks and walls. Compensation only included after the process had started
Amsterdam-Utrecht	PM	0	PM	compensation only included after the process had started
HSTL East Hanze Line VERA	These projects are still being studied. The characteristics of and the size of nature compensation are as yet unknown.			

Waterways

Compensation for waterways rarely takes place. The only known example comes from North Brabant where the Directorate-General for Public Works and Water Management purchased land to construct a pool for amphibians as compensatory measure for the loss of breeding habitat for amphibians.

Chapter 8 Management and evaluation

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8.1 Introduction

Competent management is vital for the effective implementation of defragmentation measures. Regular inspections are necessary in order to ascertain whether fences are still intact and fauna passages are still usable and accessible. This also requires attention to the design of provisions. Central questions for designers are can the provision be managed (enough room, equipment, required materials), and can management be simplified? This chapter discusses the management and maintenance of the various provisions: i.e. corridors (roadsides, roadside ditches and nature-friendly banks), fauna passages, fencing and compensation areas.

For any study of the effectiveness of fauna passages, it must first be clear that these passages are used by the species for which they were intended. Only then can the question be asked whether they are effective in linking subpopulations to form one viable network population (metapopulation) or in adequately connecting various sub-habitats separated by infrastructure (for instance, feeding and resting grounds) so that the area can also accommodate a viable population. Past and present studies mainly refer to the use of fauna passages. In addition, models are used to compare the effectiveness of the various types of measures (mitigation and compensation) in a given situation with each other or to compare the effectiveness of the same measures in different locations. This chapter provides a summary of the current state of affairs of researching the effectiveness of measures and lists some of the results that have been produced to date.

8.2 Management and maintenance of mitigation and compensation measures

National trunk roads

The network of main roads, with a length of more than 3,000 km (and including all motorways) is managed by the Directorate-General for Public Works and Water Management. The Directorate-General bases its management of the nature along these roads on ecological principles. Nowadays, taking plants and animals into account is an important starting point in road building, design and management. Efforts are made to reduce the damage caused by roads as much as possible by adapting them to the landscape, taking into account existing nature and landscape values as well as developing new values. In actually carrying out the management, measures are preferably selected that have a beneficial effect on the flora and fauna. The main example of this modus operandi is the management of grassy vegetation on roadsides. The usual practice until the 1970s was to mow roadsides five or six times a year and leave the mowed plants behind. This form of management led to highly uniform grasslands with a poor structure and little biodiversity. In addition, the costs incurred were high. Management focused on mowing and removing plants prevents the accumulation of many nutrients on roadside roadsides, which leads to rough vegetation poor in species. Not only does this lead to much higher nature values (see § 5.3.6), but in many cases it also costs less; in any case, it is no more expensive. Furthermore, it is possible to make even better use of the possibilities for planning nature development, during the design and subsequent construction. It is precisely because ecological management has been successful (see fig. 50) that an effort is now being made to allow ecological principles to play an even more important role in the management of brush vegetation on roadsides and in roadside ditches.

[figuur 50: foto berm]

Figure 50:

For each road in the national main road network, a landscape plan that meets set quality criteria is made once every ten years. The plan shows how the road must be fitted into the landscape on a scale of 1:2,500 and where grassy and brush vegetation, and areas of water are located. After the landscape plan has been compiled, a green management plan is drawn up with a term of 5 years that indicates the management activities that will be carried out on each road section in order to achieve the desired landscape image. Green plans also contain set requirements. It forms the basis of the specifications for roadside maintenance work, which is put out to tender for one or several years. The objective of the Directorate-General is to draw up up-to-date landscape and green management plans that meet the quality requirements for all roads by 2010.

The ecological management of green amenities in the Directorate-General is part of a strategy for dealing with nature and landscape around infrastructure. This strategy can be briefly summarised as 'Care for public works and hydraulic engineering is also care for the environment'. In practice, this means, amongst other things, the reduction of litter on roadsides, stopping the use of chemical pesticides in management and maintenance, and optimising adaptation to a particular landscape. To be effective at the landscape level, an attempt is being made to align roadside management and defragmentation measures. For instance, the effectiveness of a fauna passage under or over a road can be remarkably increased by using layout and management to optimise the route on the roadside from and to the passage for those animals for which the passage is planned or realised (see § 7.3.1). Furthermore, there is an alert response to opportunities that are found in the execution of activities concerning the infrastructure, such as reconstruction or the execution of traffic measures. For instance, the creation and layout of nature-friendly roadside ditches can easily be included in the reconstruction of a road, since much soil excavation activity must be carried out anyway. Then, the re-profiling of banks and beds is a relatively small part of the activities to be carried out and produces a potentially large landscape and nature gain.

By now, an increased degree of taking into account the landscape, flora and fauna around the infrastructure has become better embedded in policy. Already in 1981, the Board of the Directorate-General of Public Works and Water Management recognised that care of the environment was part of its tasks. The Second Transport Structure Plan (1990) also speaks in general terms about this subject (see § 4.4). The execution of the policy intentions from this structural schedule has all sorts of consequences for the regional layout of the Netherlands and therefore plays a background role in the realisation of the Structure Plan for the Rural Areas (1993). This clearly states that the management of roadsides must do justice to the main nature function of said sides. As an extra support, the Fourth Memorandum on Water Management states that the layout and management of ditches must include not only the water management, but also the ecological functions of ditches.

For national trunk roads, inspection of the technical state and the operation of facilities for fauna are part of the inspection of the state of the road and related objects, under the responsibility of the service districts of the Directorate-General.

The management of the four ecoducts in the Netherlands has been divided. The management of the civil-technical construction is the responsibility of the road manager, being the Directorate-General of Public Works and Water Management, whereas as the management of green space has been given to the nature-conservation organisation which also manages the immediate environment. The agencies referred to also monitor the use. The experiences with this construction (i.e. divided management) have been positive. The management of the various adapted tunnels, viaducts and bridges usually resides with the road manager. It is however desirable to make additional agreements with a municipality or water district board with an eye to the original function of these constructions. The many smaller fauna facilities are managed by the road manager itself. Where the roadside plays a part in the use of the fauna facility, the management has been included in the management plan of the roadside and the management takes place via roadside management.

Special attention is required, both as to creation and management, in situations where the operation of the facility also depends on the fences being intact. Many causes can lead to the malfunctioning of fences (cars leaving the road, vandalism, insufficient harmonisation between two road managers, careless mowing management, opposed interests of the road manager and the owner of the adjacent land). This therefore requires regular inspection with consecutive repairs. This also applies to the prevention of clogged badger tunnels. Erratic waste and high groundwater levels can temporarily make a tunnel inoperative. Erratic waste must be regularly cleared. Solving the problem of water nuisance is often more difficult in view of the low position of the road system compared to the groundwater level. The inclusion of inspections adjusted to these relatively new problems does not go all that smoothly. The reason for this is that these are additional and new activities for the road inspectors—who already have a full set of tasks—of sizeable scope, especially in the last decade. As a solution, in some service districts it has been proposed to deploy some road inspectors exclusively in this area. Also the start of the next round of maintenance and repair activities appears to incur undesirable delays.

The Directorate-General transfers the management of compensation areas to nature-conservation organisations. The Directorate-General makes a one-time payment to the managing organisation, so that the interest on the funds allow perpetual management.

Secondary roads
In principle, the ecological layout of roadsides must be applied independently of the road category (Van der Weijden & Schippers, 1996). It can however be noted that the possibilities increase as the roadside is wider (see fig. 51). In actual practice, this means that the possibilities along rural roads, with their usually narrow roadsides, are more limited than along national and provincial roads.

[figuur 51: foto bermbeheer langs provinciale weg]

Figure 51:

In most provinces, the main road managers look after the fauna facilities along main roads. The maintenance of these facilities includes checking planks, keeping tunnels unobstructed, etc., and in many cases is linked to road maintenance. Provinces in which the maintenance of fauna facilities is a regular task of road managers are Limburg, Friesland, Flevoland, North Brabant and Groningen.

In some provinces, work is in progress on the establishment of a further specified plan for maintaining the fauna facilities near main roads. In 1999, in the Province of Utrecht a beginning was made with the creation of mitigating measures to be implemented during the next 5 years, in which the costs and responsibilities for maintenance have been established. In recent years, Drenthe saw the installation of some fauna facilities, especially tunnels for badgers and small game. The Product Group Roads and Canals is working on a fauna facility management plan, which is to map the existing facilities and pay attention to the desired method of managing each facility. The Product Group Roads and Canals also handles the execution of such management. Also in the Province of Overijssel, work is in progress on a maintenance plan for the created fauna facilities, in which the maintenance method will be indicated for each fauna facility. The Province of Gelderland has adopted a badger facility policy plan, in which inspection forms are used to evaluate the repair activities that are needed in the created facilities, for instance, for keeping tunnels free of obstructions and repairing damage to fences.

National trunks roads and secondary roads
Fauna passages can only function well if they satisfy the requirements formulated for them by the species concerned. Also the fences or other guidance facilities must be in order. It appears that these two aspects are not always satisfied (Janssen *et al*., 1997).

Railroads
Sections of railroad that are covered with vegetation are maintained for various reasons. In principle, this maintenance is focused on primary functions (safety, functionality). The nature of the growth on the railroad and its management is governed by a series of laws and arrangements, i.e. the Railroad Act, Forest Act, Municipal cutting regulations, Thistle Decree, Pesticides Act, Water District Certificates, and the Flora and Fauna Act. Within the general conditions imposed by the primary

functions, laws and regulations and financial scopes, the ecological values are maintained and reinforced as much as possible. In this, Dutch Railways Infrastructure Management Board wishes to contribute to the execution of government policy in the field of nature and landscape. Locations with or with potential for legally protected, rare and/or endangered species are given priority. In view of its extensive character, ecological management can also form a means to carry out cost-efficient roadside management.

The Dutch Railways Infrastructure Management Boards efficiently manages track-sides and green areas in a form of roadside management, in which the desired management is planned, executed and evaluated in five steps:

1. Working out *general conditions* determining the sphere in which a certain type of management is possible.
2. *Surveying* the existing situation of a line section, in which the vegetation, flora, fauna and growing conditions for various zones along the railway are determined.
3. Carrying out an *analysis* of ecological potentials and operationally and financially feasible management. On this basis, choices are made and strategies are determined, in the form of management objectives, target species and any special objectives.
4. Working out the *package of measures.*
5. *Evaluating* the management carried out, during which it is ascertained to what degree the desired situation has been realised.

The responsibility for the management and maintenance of green sections of the railroad resides with the four regions of Dutch Railways Infrastructure Management Board (Randstad North, South, Northeast and South). In all regions, if possible nature organisations are involved in the maintenance. These organisations are used to clean and check fauna facilities. The financing of special projects with regard to management and maintenance is established each year, in year plans in cooperation with interest organisations. The financing of general maintenance is paid from a separate roadside management item on the regional budget.

The Dutch Railways Infrastructure Management Board has a seat in provincial committees where the use of adjacent land is harmonised. With regard to fragmentation problems, so-called defragmentation platforms have been drawn up at provincial level. In addition, landscape plans are drawn up in cooperation with interested parties in order to harmonise the land use as well as possible. In order to increase the support, Dutch Railways Infrastructure Management Board provides public information about projects, such as the change of the roadside management to a more ecological management. Information is distributed by such means as newspaper articles, field visits for interested parties and public information evenings.

There are no financial bottlenecks in maintenance and management. However, the conversion to more ecological management and the realisation of fauna facilities do produce problems. Especially the requirements for an ecological layout of waterways regularly appears to conflict with the hydrological requirements that water managers formulate for waterways.

Waterways

In order to maintain fauna exits, it must be prevented that the relevant spots become overgrown with trees, shrubs or brushwood. The management of nature-friendly banks depends on the target situation for the bank. Three forms of management are of special importance: cleaning, dredging and mowing.

For the macrofauna it is important that the open water does not silt up or become clogged with water plants, especially uniform weed growths are poor in species. Cleaning is preferably done after September, and then preferably in phases, so that the macrofauna can survive and reoccupy the cleaned parts. Phased cleaning also is the best method for producing or keeping water vegetation that is rich in structure. Cleaning occurs preferably in the months of October, November and December, since then fish are hardly active, but still active enough to escape. It is recommendable to dispose of the material in order to stop rough growth from forming on the bank. The material can for instance be composted. If the silt layer is too thick (more than 10 cm), water plants no longer can take root and micro-contaminants will attach themselves to the silt particles, polluting the silt layer. It is then necessary to dredge wet strips. This is preferably done in the period September-October. It is best to remove and reuse the dredge spoils, but often this will not be possible due to its pollution. In that case, it is preferable to concentrate the dredge spoils on one spot of the bank, rather than spreading them over the entire bank.

The land vegetation can be managed in various ways. On tree-grown banks, the method of management will be to do nothing, while grassy vegetation and rough growths must be mowed. The mowing management depends on the richness in food and the percentage of moisture in the soil. It is important that mowing is not done all that frequently; in many cases, the canal banks will need mowing only once, in Autumn. It is important that mowing occurs after seed setting of the desired plant species, that mowing is done in phases, and that the mowed material is disposed of. To the butterfly fauna it is important that some sections of rough growth are left to remain. For instance, the >>zwartsprietdikkopje>> hibernates as an egg in the rough growths. Rough growths are preferably mowed every three years.

The regional boards of the Directorate-General for Public Works and Water Management usually contract out the management to specialised contractors. The contractor carrying out the work is crucial. Contractors prefer to carry out mowing activities in a uniform way and at high speed, whereas effective insect management requires customised action. Bottlenecks are the costs of removing the mowed product and the problems of polluted dredged material. Where possible and necessary, management follows the management of for instance adjacent nature areas. (Relationship with water-district boards?)

8.3 Evaluating and monitoring mitigating and compensating measures

National trunk roads

Studies have been made of the use of the ecoducts Woeste Hoeve and/or Terlet by large mammals (Litjens, 1991, Worm, 1995) and of a wall of tree-stumps underneath a viaduct by small mammals (Van der Linden, 1997). In 1993, a field survey was carried out into the use by mammals of fauna passages near a new motorway. These were an ecoduct, two culverts with dry walkways and six small fauna tunnels (Nieuwenhuizen & Van Apeldoorn, 1994).

In 1996, a summary was made of the fauna facilities existing near national trunk roads in the Netherlands, with a short literature study carried out into the use of domestic and foreign fauna passages of relevance to the Netherlands by relevant species or groups of species (Smit, 1996; Brandjes & Veenbaas, 1998; Veenbaas & Brandjes, 1998). By then, there appeared to have been many facilities of this type created, but—contrary to other types of fauna passages—practically nothing was known about their use. In 1998, an experimental study was set up to ascertain the optimal width for gangways underneath bridges or in culverts, and whether the installation of such covering materials as tree -stumps on continued banks provides a clear contribution to the correct operation of this type of fauna passages. For this, the use of these passages in their current form by mammals and amphibians was studied (Veenbaas & Brandjes, 1999) and later their use, in the same period of the year, will be studied once the passages have been widened or provided with covering materials.

Also in 1998, North Holland saw an orienting study carried out by Landscape Management North Holland into various types of fauna passages near motorways, i.e. three bicycle tunnels with walls of tree-stumps, two large lower passages provided with walls of tree-stumps and next to a waterway, six gangways in large culverts, one rectangular dry culvert of 1.2 x 0.6 m, one metal duct in a culvert and one fauna tube with a diameter of 60 cm (anonymous, same year). In addition, employees of the Directorate-General in North Holland for one year investigated fourteen small fauna tunnels (small-game tunnels or badger tunnels with a diameter of 30 to 40 cm) concerning their use by mammals; this was reported by Oord (Oord, 1998). Also some different types of facilities in the Flevopolders were studied concerning their use (Smit & Brandjes, 1998; ibid., 1999).

Various methods are used for monitoring the use of fauna passages. For a first impression of such use, an infrared detector may be useful: it records the motions of animals that are not all that slow (Brandjes et al., 1999). It is still uncertain whether slow-moving (and also cold-blooded) animals such as toads, newts and possibly also frogs are observed. For more accurate data about the numbers of passages and the groups of species and often even the species that the passing animals belong to, use is made of sand beds or a type of ink pad with paper sheets (see Fig. 51). Sand beds are the least disruptive and the use of very fine sand (white sand) can also record good footprints of small mammal species (Brandjes et al., 1999). A disadvantage is that they are fairly sensitive to the weather (for instance, if the sand dries, it will be blown away). The prints obtained on paper using the ink method have some advantages: often they are even slightly better than the sand prints, they can be kept for later identification and they do not dry (Brandjes et al., 1999). Although the ink is made of a fairly neutral substance (liquid paraffin mixed with carbon powder), invertebrate animals can be fatally affected and it is not quite certain that other animals (such as amphibians) are not injured by it.

[Figure 51: photograph of ink beds]

Figure 51: An ink bed with on both sides a paper sheet can obtain footprints of passing animals.

These methods often cannot determine small mammals down to species level. If such is desirable, use is made of the capture-mark-return method (Van der Linden, 1997; Hollander, 1992). Also hair tubes are good for identifying small mammals: near the openings of a small plastic tube, a two-sided piece of adhesive tape is installed. The animals leave loose hairs behind on these, and the species can subsequently be identified by specialists (Brandjes & Smit, 1996a, 1996b). The ink method (paper saturated with oil and carbon powder, in combination with a white sheet of paper on each of two sides) provides more information about the number of passages (Brandjes & Smit, 1996a).

Combination of a registration method of footprints with an infrared detector can supply additional information, especially if the detector also records the date and time of passage. The Road and Hydraulic Engineering Division is now developing a monitoring method using an infrared video camera, controlled by an infrared detector (motion detector). Furthermore, a study method is being developed to, if possible, establish the effectiveness of some fauna passages at population level for some species by means of field study.

The evaluation of compensation measures concerns the evaluation whether they have been carried out according to plan regarding size, location and design. Monitoring whether the intended plant and animal species settle themselves in the compensation areas only takes place marginally.

Secondary roads
In the Provinces of Groningen, North Brabant, Overijssel, Zealand, Flevoland and Gelderland, there is as yet no monitoring of the created fauna provisions. In the Provinces of Friesland, Utrecht, Drenthe, North Holland, South Holland and Limburg, the fauna facilities are monitored on an ad-hoc basis. In Friesland and North Holland, this is done by local organisations and not by the provinces themselves. In Limburg, monitoring is carried out by the provinces and by third parties. The information thus obtained in Limburg produces a positive image of the use of the facilities, but supplies no clarity about the effectiveness of the facilities. Also in the Province of Utrecht, monitoring is carried out on an ad-hoc basis. It studies only the question which species make use of the measures. It is therefore impossible to make a statement about their effectiveness at population level. For instance: in the northern part of Utrecht, there are some badger populations for which in recent years many passages were created. The populations are growing, but it is not clear to what degree this is because of fauna

passages having been created, since simultaneous measures were taken for habitat enlargement and enhancement.

In the Province of South Holland, there are monitoring activities for a small number of fauna passages created underneath main roads. These are some five sites in Haaglanden (near Voorschoten and Zoetermeerse Meerpolder). A track study was set up in order to establish which animal species make use of the walkways and to what degree. In the walkways, aluminium plates have been installed with an ink bed halfway. These plates are as wide as the walkways. Animals using the walkways leave footprints on one of the cardboard strips left on either side. The cardboard strips are installed and renewed once a week. In 1998, cardboard sheets were installed in various fauna passages and checked at various times. The general results could be interpreted very well. A large number of the tracks could be effectively identified. On the cardboard strips in the walkways, traces were found of the following animal species: hedgehog *Erinaceus europaeus*, continental vole *Microtus arvalis*, wood mouse *Apodemus sylvaticus*, snails, housecat *Felis catus*, weasel *Mustela nivalis*, stoat *Mustela erminea* and possibly polecat *Mustela putorius*. The track study made it clear that the created fauna passages are used by many different animal species. As yet, not much can be said about the degree to which these can be used. This limited study has already realised an important objective, i.e. the establishment of the actual use of these walkways by the various animal species for which they are intended (Province of South Holland, 1998).

National trunk roads and secondary roads

Studies have been made of the use of badger tunnels by the badger (e.g. Derckx, 1986, Maaskamp, 1983), and by badger and other animals (Dinther, 1994). Furthermore, in 1993 a large literature study was made of the effects of roads on amphibians and reptiles, with a summary being produced of the existing knowledge about the effectiveness of measures for these animal groups (Vos & Chardon, 1994; Chardon & Vos, 1996). It appeared that at the time the Netherlands only incidentally studied the use of amphibian facilities by amphibians.

Table 30 provides an overview of the results of the Dutch study (see also under national trunk roads and under secondary roads). This table allows only conclusions about actual use by the indicated species, as opposed to non-use. Where the table reports no use, this still says very little about the question whether the species concerned uses the facility type concerned: the study possibly was not focused on that species/group of species and/or the survey method was carried out in a period in which the group is not active. In addition, it is possible that there is no habitat of the species concerned near the studied passages, which markedly reduces the possibility of the species being present or using the passages. Concerning the walking strip studied on the viaduct, it must be noted that this viaduct was not yet ready for fauna. The study is to be repeated now that the footpaths on both sides of the road on the viaduct have formed spontaneous growth.

Table 30: Use of fauna passages

♦ ♦ ♦	= tracks on > 3 passages, of which many on > 1 passage
♦ ♦	= tracks on > 3 passages, of which fairly many on > 1 passage
♦	= few tracks on > 3 passages
o o o	= many tracks on 1 or 2 passages
o o	= fairly many tracks on 1 or 2 passages
o	= few tracks on 1 or 2 passages
#	= walked, number of tracks unknown
( )	= number of studied passages

	ecoduct (3)	large wildlife under pass (1)	Rect. small game tunnel 1.2x 0.6 (wh) (1)	Round small game tunnel. 0.6-0.85 m (3)	Badger tunnel round, diam. 0.3-0.4m (58)	Eco culvert (culvert with dry ridge (2)	Bank strip under bridge, unpaved, (approx. 10)	Bank strip under bridge, unpaved, w/ tree-stumps (2)	Bank strip under bridge, paved, (approx. 17)	Gangway under bridge/in culvert (30)	Floating planking in culvert (1)	Stub bank under viaduct (1)	Bicycle tunnel w/ stub bank (3)	Bicycle tunnel with basalt-block strip (1)	[cy e tun el wit cor rete wal way (1)]
red deer *(Cervus elaphus)*	ooo														
roe deer *(Capreolus capreolus)*	♦♦♦	oo										o			
fallow deer *(Cervus dama)*	o														
Scottish Highland cattle	#														
wild boar *(Sus scrofa)*	ooo														
red fox *(Vulpes vulpes)*	♦♦_	oo		oo	♦♦	o	♦_						o		
badger *(Meles meles)*	oo			oo	♦♦										
beech marten *(Martes foina)*					♦♦		o		♦_	♦_					
marten *(Martes spec.)*	oo	o			♦♦	oo									
polecat *(Mustela putorius)*	o	oo		oo	♦♦		♦♦		♦♦	♦_		oo			
stoat *(Mustela erminea)*	o	oo			♦♦		♦♦		o	♦♦					
weasel *(Mustela nivalis)*		oo		o	♦_		o		o	♦_				o	
stoat/weasel *(Mustela spec.)*					♦_	o						oo			
hedgehog *(Erinaceus europaeus)*	oo	oo			♦♦	oo	o			o					o
hare *(Lepus europaeus)*	ooo	ooo			o			o	♦_						
rabbit *(Oryctolagus cuniculus)*	ooo	ooo		o	♦♦	oo							oo		
rabbit /hare *(Oryctolagus /Lepus)*					♦_		o		♦♦			o			
red squirrel *(Sciurus vulgaris)*	oo						o			o		o			
mole *(Talpa europaea)*							♦_	o	o			oo	o		
muskrat *(Ondatra zibethicus)*							♦♦		oo						
rat *(Ondatra/Rattus)*		o													
brown rat *(Rattus norvegicus)*			o		oo		♦♦		♦♦	♦♦	oo				oo
water vole *(Arvicola terrestris)*							o		♦_	o					o
wood mouse *(Apodemus sylvaticus)*							♦♦		♦_	♦_		ooo			o
mice, voles		oo	o		o	oo	♦♦ ♦	oo	♦♦	♦♦ ♦		ooo	oo	oo	o
water shrew *(Neomys fodiens)*										oo					
shrews							♦_		♦_			oo			
domestic cat *(Felis catus)*		oo	oo	o	♦♦		♦♦	o	♦♦ ♦	♦♦		o			
dog *(Canis canis)*		oo	o		o		♦♦	oo	♦♦	o					o
toad					o					♦_					o
frog										o					o
newt/salamander					o					♦_					
partridge *(Perdix perdix)*		oo													

pheasant *(Phasianus colchicus)*		oo

Computer simulation of the effectiveness of measures
In 1996, for three species of amphibians (toad *Bufo bufo*, treefrog *Hyla arborea* and newt *Triturus vulgaris*) computer computations were made to establish to what degree the survival potential of a population network is influenced by the barrier effect of roads. Furthermore, for these three species the effectiveness of mitigating and compensating measures against such barrier effect were reconnoitred (Bugter & Vos, 1997). Network populations of species with a large action radius (toad) in a sub-area surrounded by roads appeared to become extinct sooner than species with a small action radius (newt). Mutually isolated sub-areas for a species with a large range tend to be too small for a viable network, as compared to a species with a small range. For the treefrog, the fragmentation by roads in combination with the current relatively poor quality of habitat, usually leads to local populations becoming extinct. This effect can be insufficiently compensated for by mitigating measures. Only compensation by the creation of a new habitat, if possible in combination with fauna passages, can improve the survival potential of the species. At sites where the barrier effect of roads becomes too large for adequate exchange, there are always mitigating measures needed to make sure that a sub-area can be recolonised after the local extinction of the species (Bugter & Vos, 1997).

Railroads
Currently, there is no systematic evaluation of the defragmentation measures to be applied to rail infrastructure. The Defragmentation Study of the Rail Infrastructure does however provide for a monitoring study of fauna passages. This study will be made in the next years.

As yet, there has been hardly any evaluation of the large new-construction projects, since these are not yet in progress. Only for the Betuwe route has an evaluation programme been established, of which the zero situation by now has been included.

Waterways
The effectiveness of fauna-exits has been studied by Hoek (1988). This showed that fauna-exits are used by roe deer *Capreolus capreolus*, mustelines and rabbit *Oryctolagus cuniculus*. The effectiveness is also shown by the virtual absence of drowning victims in North Brabant since the fauna-exits were created, whereas before their creation regular drowning victims were reported. Fauna-exits are an effective means to prevent animals from drowning (Bekker et al. 1995).

The effectiveness of culverts as connections between brook parts in Brabant was studied for the upward migration of fish (Kemper, 1998). For perch, roach, bream, white bream, river gudgeon, rudd, pike and tench it could be proved that the culverts could be passed. For bleak, >>bermpje>>, carp and bindwind this could not be proved. In any case, for some species the culverts are a means to maintain an upward/partially upward connection under a canal between brook sections. The creation of new culverts must take into account the flow speeds (overdimensioning) and structures as resting spots for fish during their long journey through the tubes.

Specific studies of the effect of nature-friendly banks as defragmentation measures were carried out in North Brabant. These were a pilot study to show whether the selected method (suitability of the habitat for some guide species) were suitable to be able to ascertain whether the canals are satisfactory as parallel connections (Soesbergen, 2000), meaning:
- between brook valleys intersected by the canals,
- as connections between large moist areas (Biesbosch and Peel),
- between nature-core areas mutually,
- between nature-core areas and nature-friendly banks, and
- between nature-friendly banks mutually.

The monitoring of habitat-suitability based on the percentage of realised suitable banks as compared to the policy-established target percentage in North Brabant appeared to be suitable for evaluating the policy formulated. It also came to the fore that lack of management can reduce habitat or corridor quality, but that this was not directly expressed in the evaluation. For this, also the ambition level (for which species the bank has to be suitable) must be laid down and monitored in the field. Continuity in management and quality is a must since monitoring would otherwise not be useful. It is desirable to monitor defragmentation and this can contribute to the adjustment of management.

Chapter 9 Fragmentation and future development of the infrastructure

Contributions from: R. Cuperus, L. Fliervoet, Y.R. Hoogeveen (?), C.F. Jaarsma, D. Kamphorst, A.A.G. Piepers

9.1 Introduction

A number of new policy papers are being drawn up, both in the field of nature conservation, and in the field of the questions surrounding mobility. The problem of fragmentation is being emphatically involved in these papers. In view of the fact that most policy papers are not yet ready, paragraph 9.2 provides a short description of the direction policy is expected to take. Indicators and models are necessary in order to be able to make statements about the present and future consequences of the fragmentation of nature that results from constructing and using infrastructure. The indicators and models available at the moment or under development are described in paragraphs 9.3 and 9.4. Future infrastructure developments and what these mean for the fragmentation of the Dutch countryside are described in paragraph 9.5. Investigation into fragmentation continues to be necessary in order to fill the gaps in our knowledge and for empirical validation of the indicators and models. Studies in progress and studies that will soon be initiated are described in the last paragraph of this chapter.

9.2 New policy, strategy and trends

The National Traffic and Transport Plan (NVVP) is the follow-up to the Second Transport Structure Plan (SVVII). At the moment, it seems that the line laid down by the Second Transport Structure Plan will be adhered to as far as fragmentation is concerned. This means that new dissections through the National Ecological Network will be avoided and, where this is not possible, they will be mitigated and the results compensated. A broad reconnoitring phase (the phase prior to a making the environmental impact assessment, see fig. 15) will form the basis to new infrastructure projects. Traffic and transport problems will, as far as possible, be placed within the context of the area. As far as the existing infrastructure is concerned, further attempts will be made to solve known bottlenecks in the network of main roads. Prioritisation will be given to the development of the National Ecological Network. Until 2010, a budget will be available of a total of NLG 100-130 million. It is also important to reduce fragmentation that results from the secondary road network. The idea is to set up provincial and local authority defragmentation programmes. The quality of the countryside can be improved by reducing the amount of motorised traffic, especially in the National Ecological Network, in favour of slow-moving traffic. Motorised traffic will as a result become concentrated in access roads to specific areas and through roads in accordance with the “Sustainable Safety” concept (cf. also Jaarsma 1997). The National Traffic and Transport Plan (NVVP) will also contain innovative ideas. Lack of room is currently an important bottleneck for countryside compensation. The following ideas are intended to solve this problem: the creation of a nation-wide land-bank for compensation of main roads, providing good alternatives for raising the quality of nature and improving co-operation with and between the regions.

In setting up the National Ecological Network, as suggested in 1990 in the Nature Conservation Policy Plan, attention has during the last few years been given to defining key areas and nature development sites. A network of ecological connection zones is transforming these areas into an entirety that will make up the National Ecological Network. The paper “Nature, Forestry and Landscape in the 21st Century” (in preparation, completion planned for autumn 2000), in which key policy points are defined, refers to ecological connection zones as being an inextricable part of the National Ecological Network, and one deserving additional attention since the key areas and nature development areas have largely been defined and determined by the provincial authorities. The National Ecological Network needs to start functioning as an entity. The way in which areas are connected to one another is closely related to the question regarding the plants, animals and/or ecosystems for which the connection zones are intended. Realising a network of qualitatively efficient connections, however, does require a degree of elaboration. The book “Quality by connection” (Pelk and Van Ettinger, 2000) goes into this in greater detail and contains examples. Three types of connection are described – main arteries that join large ecological units to one another, such as the Utrecht Hill Ridge with the Veluwe and subsequently with the water meadows of the Gelderland river region. A system of smaller (secondary) connections can be used for migration between parts of key areas and nature development areas and is specifically aimed at certain parts of different ecosystems. Finally, a fine network (capillaries) of all sorts of small natural elements can be included, such as the edges of fields and brooks, pools, wooded banks and small woods that join up the areas within and outside the National Ecological Network with one another. In setting up all these ecological connections on a national level, the arteries have been given first priority, because of the significant impact of town and country planning.

Fifth Paper on Spatial Planning.

The Fourth Paper on Water Management (NW 4) is important for the defragmentation of waterways. This policy paper aims at resilient ecosystems that stay intact over a long time. As far as the North Sea Canal is concerned, the NW4 states that there is room for healthy salt/freshwater biocommunities and that the saltwater has been allowed to exceed its boundaries. In line with this policy, much wider nature-friendly banks are now being constructed than previously (Spaarnwoude). Two large areas have also been planned alongside the Amsterdam-Rhine canal for ecologically connecting the Venen lakes and the Vecht lakes (Directorate-General of Public Works and Water Management, Utrecht Directorate, 1997).

9.3 Indicators

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 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 be able to make statements about the fragmentation effects caused by the construction and use of infrastructure, use is made of indicators and computer models. There are relatively simple indicators and indicators that are based upon computer models. The first category can be regarded as a rough measure of the effects on biodiversity, while computer models can involve complex calculations and are capable of making statements about the continued existence of (local) populations. A distinction can be drawn between various scale levels: local, regional and national. 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). This paragraph discusses the simple indicators, and paragraph 9.4 discusses the mathematical models.

What is important on a local level is describing the fragmentation effects caused by the (re)construction of finalised infrastructure projects. Predictions about these effects can be made with the aid of studies on environmental impact. The following indicators have usually been used until now (De Haas, Notebaart and Zeilstra, 1998):

- the length (usually in km) of the transection of the habitat of fauna;
- the number of transections of migratory and dispersion routes;
- the surface area of the largest remaining part of a habitat that remains after the transection, divided by the original surface area of the habitat.

The length over which a road, a railway or a canal transects the habitat of a species or population is a rough measure for all fragmentation aspects: destruction, barrier effects, disturbance and the risk of fauna fatalities. The choice of the species can be based on the model ecosystem types in nature conservation policy and/or fragmentation-sensitive species. Instead of species, attention can also be paid to the transection of complete ecosystems. This indicator does not take other factors into account that affect fragmentation, such as the location of the transection, traffic density and speed, and the width of the infrastructure.

The number of transections of migration routes is an indication of the barrier effects of a section of infrastructure and the risk of animals being killed while crossing between different functional areas (feeding grounds, resting area, breeding grounds, hibernation area). The number of transections is important because of the effects on individuals colonising new habitats. The chance of survival of a species becomes smaller in proportion to new habitats becoming less accessible.

The last indicator is an index varying between 0.5 and 1, which also takes the surface of the average area into account. The lower the index, the smaller the remaining area, and thus the greater the chance that it is no longer large enough to house a viable population. The disadvantage of this indicator is that it pays no attention to the requirements per species in relation to the actual surface area. A recent study carried out by students (Haubrich, 1999) provides a method that does take this into account by looking into the size of the habitat (the home range) of a species. The following assumptions are made – if the surface of the remaining area is smaller than the smallest home range found, then this area is no longer viable as habitat for a given individual. If the area is larger than the largest home range found, then the area is suitable as a habitat for all individuals in a population. In between these two extremes, the values range from 0 to 100%. No attention is paid to whether the home ranges overlap or not. The following formula provides an indication of the inaccessibility of a habitat – score = $(area_{tot} * viability_{tot}) – ((area_{part1} * viability_{part1}) + (area_{part2} * viability_{part2}))$.

The LARCH-SNIP/MAAT computer model (lit…) was developed to work away the objections to the aforementioned indicators, and to improve substantially the reproduction of the actual effects of infrastructure. This computer model is an add-on to the expert system LARCH and is based on the concept of metapopulations (see §9.4).

On a regional level, it is not so much the effects of a single infrastructure project that count, but the effects of a whole network. This also involves predicting the effects of mobility scenarios. What the effects will be of various infrastructure plans and policy measures on the ecosystem in a region. Various road categories have different fragmentation effects. Within this context, the following characteristics of roads are important – the total length of the road, the density of the road network, the density of the traffic and the composition of the traffic.

The degree of fragmentation of the landscape by (rail)roads can be quantified by calculating the length of the linear infrastructure per unit of surface area. This provides a standard for rail(road) density (km per km^2). In field studies, the occurrence of certain species can be related to rail(road) density (see §5.3.5). The average mesh-width - the average distance between two infrastructure lines when the infrastructure network is visualised in grid-form - can also be illustrative. Paragraph 5.2 show the mesh-widths for motorways, provincial roads, rural roads with hardened surfaces and railroads respectively throughout the Netherlands.

The busier a road becomes, the greater the fragmentation effect. Traffic density can be quantified by relating road density to traffic density. Traffic density is the degree of fragmentation due to roads, expressed in vehicle kilometres per 24 hours per km^2. It is worked out by calculating the length and the intensity of the road together per unit of surface area. Traffic density can be calculated for the various categories of roads.

Fragmentation can also be quantified by looking at the number of habitats within a region that have a specific continuous surface area. The larger the number of sites with a large surface area, the smaller the amount of fragmentation (Jaarsma and Van der Knaap, 1998). From the index in figure 12 (see §4.3), apart from the average size of the units, the average distance between the units is also calculated: index = $(area_{ave} / area_{max}) / (distance_{ave} / distance_{max})$. To avoid allowing one of the two factors to weigh too heavily in the final results, the values are related to the respective maximums. This means that the percentage of the maximum score will be used each time in the calculations. The final index value will be higher as the average surface area increases and/or the distance between them is reduced. A low value is equivalent to a large degree of fragmentation.

Computer models are usually used for making detailed statements. The Traffic and Transport Evaluation instrument (EVV) (Cuperus and Canters, 1997) is a computer model that was especially developed for questions related to infrastructure on a regional level (see §9.4. above).

On a national level, indicators and models are necessary for evaluating the effects of national plans for the construction of infrastructure (strategic environmental impact assessment) and for evaluating national policy regarding reducing and preventing fragmentation. In order to evaluate national policy in the so-called policy impact report, attention is paid to the bottlenecks between the national trunk road network and the National Ecological Network (Ministry of Transport and Communications, 1999) (see §5.3.8). The length of unsolved bottlenecks is reproduced as the percentage of the total length of bottlenecks. The degree to which a bottleneck has been solved is divided into categories:

0 = unsolved;
0.4 = solved to certain extent;
0.8 = solved (all measures have been carried out);
0.9 = solved and used (the measures are being used by the target species);
1 = solved (the measures are effective on a population level).
Dividing bottlenecks into categories is taken into account in the calculation. Until now, 0.9 has been the maximum value due to an almost complete lack of insight into effectiveness on population level. At the end of 1998, the value of the indicator was 64%. The aim is to reach 60% by the year 2000 and 10% by 2010 (see figure 52). This kind of data is not yet available for railroads, waterways and the secondary road network. The indicator is particularly informative about progress made in policy but less about the ecological effects. A pragmatic approach has been chosen, however, for the benefit of the policy impact report.

[figure 52: grafiek uit Beleidseffectrapportage]

Until now, we have had no experience in evaluating fragmentation in strategic environmental impact assessments.

Computer models can also be used on a national level (see §9.4).

The indicators described above can prove their worth in comparisons between the effects of alternatives and scenarios and as a gauge in policy assessment where these can be compared with target figures. A fragmentation indicator is needed that can be used to gauge the situation against a reference model – to what extent can the Netherlands be fragmented so that the survival of populations of certain species is not endangered. Or, translated into infrastructure terms – what degree of impassability is acceptable, i.e., what is the minimum acceptable degree of passability? The question is whether this requires the implementation of even more – and new – defragmentation measures than would be required by simply meeting the policy goals – solving 90% of the bottlenecks between motorways and the National Ecological Network by 2010.

9.4 Models for predicting fragmentation by new infrastructure

Alterra (the former Institute for Forestry and Nature research and the Winand Staring Centre) has developed a whole new set of models and expert systems with which the effects of fragmentation and infrastructure can be analysed. The models can be divided into the following categories:

1. **dispersion models**: simulation models of movement of individuals through the landscape (GRIDWALK, POLYWALK, SmallSteps)

2. **metapopulation models**: simulation models with births, deaths and dispersion in a landscape with physically separated habitat sites (METAPHOR)
3. **expert systems for biodiversity**: models that make statements about the expected or possible existence of ecosystems and viable network populations on the basis of a standard database (GREINS, LEDESS, LARCH).

The following are more detailed summaries of a few of the models and expert systems, with comments on the way in which effects of infrastructure are (or can be) implemented.

GRIDWALK and **POLYWALK** describe the dispersion of individual animals through a heterogeneous landscape. They are based upon grids and vectors respectively. The path for walking is initially determined at random, so that the chance of walking to a neighbouring grid cell or polygon depends upon the quality of the habitat in the present and in the neighbouring grid cell or polygon. The time an animal remains in a grid cell or polygon is determined by the attractiveness of the type of landscape and its dispersion resistance. The models distinguish between absolute and relative barriers and corridors. The most important aim of these models is to determine the accessibility of neighbouring habitats and to show how the dispersion streams take place and where “bottlenecks” occur. GRIDWALK is based on a grid and is intended for larger animal species. It is particularly suitable for large-scale analyses. POLYWALK was developed to make use of the advantages of a vector-based geographic information system (GIS), i.e., ArcInfo. It can take account of many more spatial elements and it is possible to define linear elements as corridors or barriers. POLYWALK comes in three models for different groups of animals: random movement (small mammals), directional preference (including Mustelidae) and random movement with ‘homing’: the ability to find breeding grounds again (amphibians). Both models are particularly used for scenario analysis on a regional and a national level (see §5.3 and §5.4).

SmallSteps describes the movements of individuals through heterogeneous landscapes with flat-shaped and linear elements. Important species-related parameters are preference, speed and mortality in the various landscape types. An example of the output of the model is the dispersion stream between various areas. SmallSteps can take aspects of the infrastructure into account, in detail, such as accompanying plants, fences, tunnels and barrier effects. It was developed in particular for use on a local scale, for example, for the tree frog (*Hyla arborea*).

[figure 54: foto boomkikker]

Figure 54: The tree frog *Hyla arborea*

METAPHOR is a population-dynamic simulation model in which populations with a certain sex- and age-structure can be followed through space and time. Among other results, this model shows the risk of extinction of populations (durability of networks). The model takes into account habitat quality, fluctuations as a result of small numbers (demographic stochasticity), environmental fluctuations, social structure (polygamous/monogamous), density-dependent processes and, explicitly, spatial structure. Infrastructure is introduced into the model on the one hand via the quality of the local site (this can depend upon the distance to a road or, for example, the length of the road that transects the patch), and on the other hand via the opportunities for dispersion between sites (opportunities for exchange). There are three algorithms for determining these, one of which is SmallSteps. There is not as yet an automated procedure for coping with infrastructure, although parameter values can be individually adjusted in order to alter the opportunities for exchange (dispersion opportunities between, for example, sites A and B) as a result of, for example, road construction. This has been done for various projects, including the badger *Meles meles*, by generating exchange possibilities for the model on the basis of experts’ opinions and determining the effects on durability by means of dynamic simulation.

GREINS has been developed for the evaluation of scenarios for nature development based on habitat factors (soil, hydrology) and management and layout. It predicts vegetation structure and composition and can therefore be of importance for charting habitats in fragmentation studies of animal species. This has, however, not yet been done. Where fragmentation has an effect on soil hydrology, GREINS can be used to calculate the effects on habitat quality.

LEDESS is a decision-supporting system based on GIS that tests spatial plans for ecological feasibility and their effects on nature. It has a ground-suitability model, a vegetation development model and a fauna model. Its output takes the form of vegetation structure maps and habitat-suitability maps for a large number of fauna groups. These can then in turn be used as input for dispersion models. It is capable of showing expected developments in time for both the vegetation and habitat-suitability for the fauna, under various forms of management. The fauna model calculates the total surface area of a suitable habitat and the degree of fragmentation, whether or not as a result of infrastructure. LEDESS has been used in scenario studies in the field of nature development and city expansion (see §5.4).

LARCH (Landscape ecological Analysis and Rules for the Configuration of Habitat) was developed in order to be able to make statements about the effects of spatial cohesion between landscapes and biodiversity. This entails dissecting a landscape "through the eyes of an animal species" into species-specific habitat networks (see fig. 5 in §2.2). One then determines whether these networks are durable for the species by making use of spatial norms. The species-specific results are aggregated to biodiversity indices. The spatial norms are largely determined with the help of the dynamic model METAPHOR. LARCH has been used for a large number of birds, and a number of mammals, reptiles, amphibians and butterflies. LARCH is used for national, regional and local studies. Infrastructure-related effects are evaluated via habitat quality or via spatial cohesion. It implements the possibility of allowing roads, canals and other linear barriers to 'split out' habitat sites and/or habitat networks, so that linear barriers lead to more fragmentation. Work is being done on a more subtle form in which the barrier effects of various types of infrastructure can vary between 0 and 100%.

LARCH-SNIP/MAAT analyses the viability of metapopulations (see §2.1). It involves the following characteristics:

- indicator species that are sensitive to fragmentation of habitats;
- the potential ability of habitats to support viable (meta-)populations of these indicator species
- the spatial classification of habitats and the presence of barriers;
- norms for the capacity of habitats per indicator species, weighing up the fragmentation aspects of destruction and disturbance;
- spatial norms per indicator species, such as dispersion distances;
- habitats that are wholly or partially within areas liable to compensation or which indirectly affect these areas.

The level of detail in which analyses are carried out and the scale level on which the results are presented are linked to the subsequent phases of the Planning/EIA procedure' (§ 4.5). The starting point is that, for every species, the durability must be the same after an intervention as it was before the intervention. When this is not the case, then a decision-tree can be used to look for a set of suitable mitigating and/or compensatory measures. This method is not yet operational.

The Traffic and Transport Evaluation instrument (EVV) was developed by the Environmental Science Centre in Leiden (Cuperus and Canters, 1997). This computer model is especially aimed at regional infrastructure problems. The model has not been applied in practice, but its basic concept is still usable. With the aid of a file from the LKN (landscape-ecology map of the Netherlands), seven landscape types have been defined: arable land, grassland, heathland, open water, fenland, half-open landscape and forest. Typical species have been linked to these landscape types for a number of types of effects. Typical species, based on their spread and other characteristics, are supposed to be a model for a group of species that are sensitive to specific intervention. No typical species have been linked to the effect ‘destruction’, because this is an absolute effect that can be expressed, per stretch of road, in the loss of surface area of a landscape type. A typical species has been determined per landscape type for disturbance. Assuming a disturbance zone based upon traffic density (Reijnen en Foppen, 1991), the surface area of a landscape type that has been disturbed is measured on each side of a stretch of road. Although three likely approaches for quantifying barrier effect have been developed, until now it has not turned out to be possible to work these out. This has to do with the fact that the exact position of a stretch of road relative to the landscape type has not been determined. A typical species has been determined for the number of collisions per landscape type. The number of annual (expected) collisions of a typical species alongside a stretch of road is calculated according to the risk of the typical species having a collision and the size of the landscape type relevant to the typical species in the surroundings of the stretch of road.

There are no models available for predicting the fragmentation effects of newly planned waterways. Study has been carried out, however, into the possibility of using models for predicting the suitability of the banks of rivers and canals as a corridor for fauna (Duel, 1992).

9.5 The future development of the infrastructure network

National trunk roads
Since the Second World War, a great deal has been invested in extending the Dutch network of main roads (motorways, railways, national waterways). This extension programme involved motorways in particular. The total length of motorways was less than 1,000 km in 1950, but it had increased to 2,200 km in 1996. There was a turning point in this development at the end of 1998, because it became clear that the available budget was inadequate for fulfilling every requirement regarding mobility and transport. This restriction resulted in considerable curtailment of a number of plan-studies, the various alternative solutions of which were screened, in accordance with EIA legislation, for their environmental impact. Initially, a number of projects for which decisions had already been taken, but which had not yet been carried out, were also scrapped. These projects will, however, finally all be carried out, due to substantial financial contributions provided by the provinces involved. In total, approximately another 100 km of motorways will be constructed over the next five years.

Another development that had previously already been set in motion involves the choice of the government for structural widening existing connections with the surrounding countryside. The connections of the four large cities in the west of the Netherlands with the Belgian and German borders are projects that will be carried out within the framework of ‘Cooperating on Accessibility’ (SWAB). The network of main roads will be widened over many hundreds of kilometres.

Measures aimed at 'better, cleverer, quicker' are in line with the ideas of the SWAB. Throughout the Netherlands - more than previously - measures will be taken to optimise transport capacity within the boundaries of the existing infrastructure, i.e., without new road construction or widening, by improving road utilisation. Examples of this are measures such as controlled access, traffic signals, rush-hour lanes, DRIPs (dynamic route information panels) and HGV-lanes

Coming years a great number of fauna passages is planned to be built. An overview is shown in table 31.

Table 31: The number of fauna passages that will be built under and over national trunk roads in the Netherlands coming years.

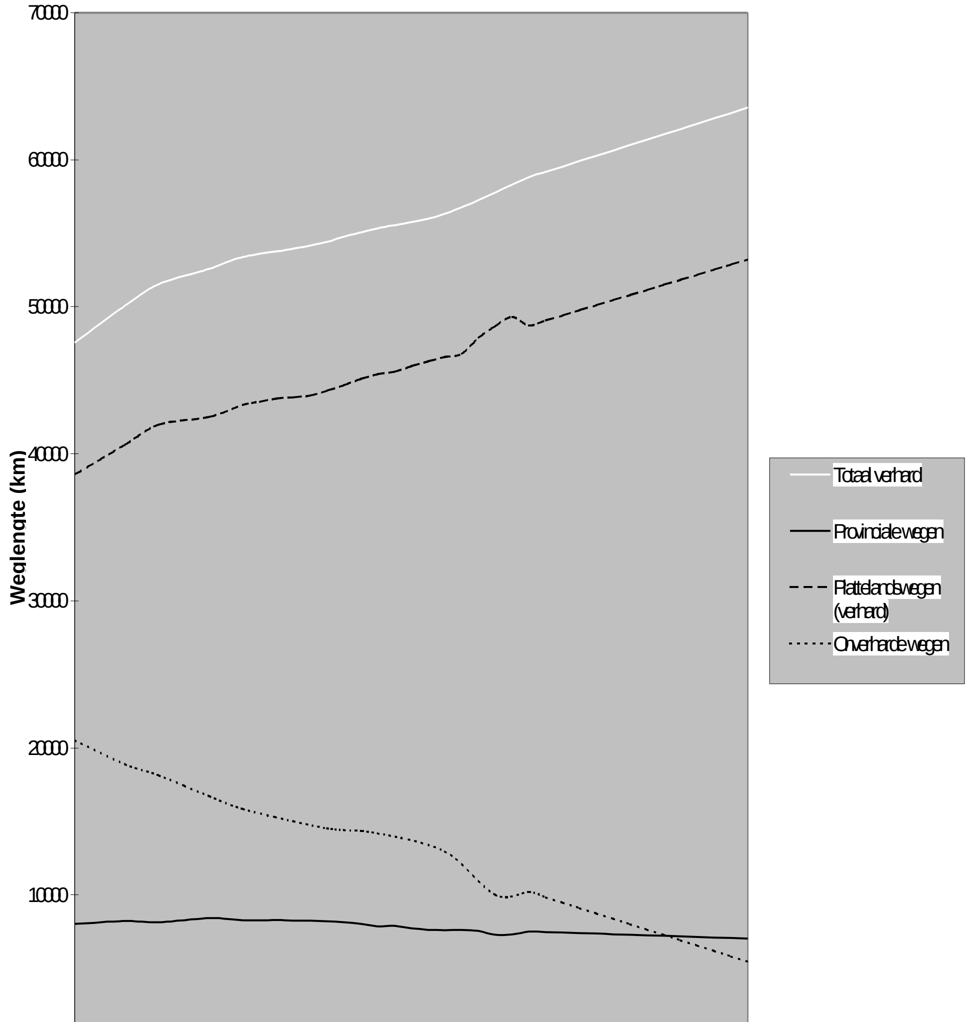
Type of fauna passage	**number (approx.)**
small fauna tunnels	261
large fauna tunnels	3

ecoducts	31
tunnels for amphibians	4
eco-culverts	56
modified engineering structures	98

Secondary roads

There are no national papers for the expected network developments of secondary roads similar to the plans for the national trunk roads. However, in order to be able to estimate the lengths of provincial and rural roads in the (near) future, use has been made of statistical data from the (recent) past: the CBS (Central Bureau for Statistics) road figures. These are available for 1970, 1973, 1975, 1978 and from 1980 to 1996 annually. There is, however, one complication. In January 1993, a complicated large-scale reform of road management took place. As a result of this operation, on balance, the provinces now have 1,300 km less roads to manage because these roads have been transferred to local authorities. As a result, the length of asphalted rural roads was extended – on paper at least – by the same amount. (National trunk roads were also transferred to the provinces at the same time though). To facilitate comparison with the present situation, the road lengths of provincial roads for 1993 have been reduced by 1,300 km (referred to in the 1993 statistics as secondary and tertiary roads). The same length of roads has been added to the asphalted rural roads in 1993 (referred to in the 1993 statistics as quaternary and miscellaneous rural roads).

Based upon the (corrected) lengths of provincial roads and asphalted rural roads and lengths of non-asphalted roads, using the reference years from the Road Statistics, an extrapolation was carried out for the years 1997-2010. The results are given in figure 53. We would like to emphasise that the results of such an extrapolation should be interpreted with care! An extrapolation assumes that developments in the past will continue to develop to more or less the same degree in the future. Effects of alterations in policy, which are actually aimed at altering the trends of the past, are usually not visible in extrapolations.



road length (km)	Total asphalted Provincial roads Rural roads (asphalted) Non-asphalted roads

Figure 53. Length of roads outside town centres per category of road during the period 1970-2010; the data from 1997 on were obtained by extrapolation.

The network length of the provincial roads between 1970 and 1986 stayed more or less the same. After 1986, there was even a small continual reduction. The length of provincial roads in 1996 (7,299 km) is 90% of the figure for 1986. If this trend were to continue, the length in 2010 will have been reduced to 7,033 km, or 86% of the 1986 figure. Note: this reduction does not mean that roads are "disappearing". What is happening in particular is that the provincial roads are being transferred to councils.
The extent of the network of asphalted rural roads is affected by the following four processes:
(1) reduction due to the growth of built-up areas, so that roads are being transferred to the category "within the built-up area", which is not relevant to this report;
(2) increase due to asphalting of non-asphalted roads in rural areas;
(3) increase due to the construction of new roads in rural areas;
(4) reduction due to conversion to provincial roads.

However, these processes cannot be separated based upon the statistics available. On balance, there has been a steady increase in the number of asphalted rural roads. If 1986 is set at 100 (with 44,661 km), then the length in 1970 was still 86 (with 38,450 km). On 01-01-1996 this had increased to 109 (48,700 km). Extrapolation for 2010 leads to a result of 119 (53,212 km).

In contrast with the increase in asphalted rural roads, there has been a large reduction in non-asphalted roads outside the town centres. Again, taking 1986 to be 100 (14,413 km), the length of non-asphalted roads in 1970 was still 142 (20,530 km). On 01-01-1996 this had been reduced to 69 (10,012 km). Extrapolation leads to a further reduction, i.e., to 38 (5,461 km) in 2010.

It is noticeable that the total length of asphalted rural roads and non-asphalted roads outside the town centres between 1970 and 1996 remained pretty much the same. One is tempted to assume, therefore, that the increase in asphalted roads has been caused in particular by asphalting roads that were previously non-asphalted. This would then retain globally the same map of roads. New rural roads have, nevertheless, been constructed. This is particularly the case in places that traditionally had a small number of roads per unit of surface area, such as the peat meadows in the middle of our country. Scale magnification of the landscape is the reason why the total length of rural roads has not grown. There has also been some (local) clearing up of non-asphalted roads that have become superfluous. Modern town and country design projects, however, pay a great deal of attention to retaining non-asphalted roads (Keizer and Bauhuis, 1995).

Based upon the extrapolated data in figure 53, the prognosis for mesh-width of all asphalted roads in 2010 is approximately 1,13 km.

Railways
The Long-term Programme for Infrastructure and Transport (MIT) provides a overview of routes that will be constructed and altered in the next few years, in various categories:

- plan-study programme passenger transport railways: 5 projects that are still in progress, including a partly new railroad between Lelystad and Zwolle (*Hanze line*);

- realisation programme passenger transport railways: a large number, generally small projects for altering existing infrastructure, generally situated in the urban conurbation of Western Holland. Alterations include widening existing rails (see also table 31);
- realisation programme Light Rail: 6 projects for Light Rail, mainly in city areas;
- realisation programme High-speed tracks: 2 superior connections between the urban conurbation of Western Holland and the European network of high-speed tracks (*HSL East and HSL South*);
- plan-study programme goods transport railways: goods railways being studied (5 projects);
- realisation programme goods transport railways: goods railways in progress (5 projects).

De rail infra-projects that transect country areas over large distances are included in table 31. These are new routes and railways being constructed. The table suggests what global fragmentation effects might be expected.

Table 31 Large new rail infra-projects and their global effects on nature

new / reconstruction	rail infra-project	position	stage	global effects
reconstruction	rail widening Boxtel-Eindhoven	Boxtel-Eindhoven	in progress	Doubling of the track along existing tracks in order to (both goods and passenger transport) along the route intersection of the Ekkersrijt and the Wilhelmina cana the EHS and provincial GHS and disturbance due to s passages will mitigate these effects. Nature compens
new	HSL-South	Amsterdam-Antwerp	route decision	Construction of a new high-speed track, bundled as fa transections and to concentrate the disturbance zone due to space usage and sound. There will be mitigati drill tunnels) for the barrier effects The HSL will attem as far as possible. Destructive effects and disturbanc currently being studied.
new	Betuwe route (goods)	Rotterdam-German border (Zevenaar)	route decision	New goods line that will be bundled with an existing m potential fragmentation effects are the intersection wi adjoining nature reserves. These effects will be mitiga whole route due to sound and dehydration.
reconstruction	rail widening Amsterdam-Utrecht	Amsterdam-Utrecht	route decision	PM
reconstruction	HSL-East	Utrecht-German border (Zevenaar)	study phase	Altering the existing railroad to make it into a high-spe forest reserves of the Veluwe and the Heuvelrug in Ut design and use. These will be mitigated and compens
new	Hanze line	Lelystad-Zwolle	study phase	New railroad, that will traverse nature and forest reser the polder land and could lead to fragmentation effect design and the mitigating measures to be taken.
Reconstruction / new	VERA (goods)	Roosendaal-Antwerp	study phase	Any new routes of this goods line will lead to an increa the area in between the sand grounds of Brabant and
New	Sloe line (goods)	opening up Sloehaven Flushing	study phase	Due to the limited length and the limited natural value
reconstruction	rail widening Groningen-Leeuwarden	Groningen-Leeuwarden	carried out in1998	Rail broadening from single to double tracks between fragmentation of small nature reserves that are alread lanes).
reconstruction	rail widening Vleuten-Geldermalsen	Vleuten-Geldermalsen	study phase	PM [HR]

Another 250 km of railroads will be constructed during the coming five years.

The new rail infra-projects in the Netherlands will affect nature reserves. The use of space in these areas can be as much as several hundred hectares. The negative effects will be limited as much as possible by fitting in and by compensation of the remaining effects.

Table 32 is a review of the nature and the extent of mitigating measures that have been determined or suggested in various new construction projects.

Table 32. Mitigating measures in new construction projects.

project	nature and extent of mitigation
HSRL-South	The effects of dehydration and disturbance by light and visual hindrance

	can be entirely avoided (100%) by suitable measures. A large number of eco-culverts, tunnels and walking strips have been included in the design for mitigation of the barrier effect
Betuwe Route	mitigation of effects will be done by: • bank development along intersecting waterways (24 ha) • wet eco-culverts (63 locations) • fauna tunnels (37 locations) • nature development: 13 ha species-rich grassland and 53 ha woods/thickets
Boxtel-Eindhoven	mitigation of effects will be done by: • deer tunnels (2) • dry culverts (6) • eco-culverts (1) • amphibian tunnels (2) • eco-u-vessels and eco-elements (19) • eco-pipe (1) • parallel passages (7) • fauna provisions in combination with fauna-exits • guiding provisions in combination with nature • nature development: circa 4 ha woods and additional windbreaks and banks, nature-friendly banks and pools.
Groningen-Leeuwarden	mitigation of effects will be done by: • constructing a sleeping bridge • dry fauna passages • walking ridges along waterways under the tracks.
HSRL-East	Various large-scale measures such as ecoducts and big game tunnels, flanked by smaller fauna passages are being studied. These measures are being studied in connection with defragmentation of the adjacent national trunk road (A12).
Hanze Line	Measures are being studied for removing the barrier effect along ecological connections and in nuclear areas of the EHS (eco-culverts, fauna tunnels).
VERA	Fauna passages where brooks dissect and in natural nuclear areas and forest areas are being studied.

Waterways

Developments for the national waterways are and always were limited: hardly any new waterways will be constructed, and widening and altering structural works such as bridges and locks are expected to involve less than a hundred kilometres. In North Brabant the 'Zuid-Willemsvaart' will be diverted around Den Bosch as well as being widened. The eastern parts of the Twenthe Canal will be widened and the Twente Canal might be extended to Germany. The locks on the North Sea Canal also need alterations. There is a plan to widen the Amsterdam-Rhine canal in Amsterdam and Maarssen and the Zeeburg passage is also going to be improved.

Various defragmentation measures are planned for waterways. In North Brabant, nature-friendly banks and fauna-exits will be created during the diversion and broadening. Almost 19 km of nature-friendly banks are planned along the Twenthe canal. A second broad nature-friendly bank is planned along the North Sea Canal. 60 ha of nature-friendly banks will be created along the Amsterdam-Rhine canal and a study will be carried out into making the canal more usable for migratory fish.

Future scenarios: the badger as an example

The badger *Meles meles* is a typical victim of fragmentation in the Netherlands. Badgers live in social groups in several burrows within a communal territory (Neal, 1986). Due to the intensification of agriculture, urbanisation and disturbance, the badger’s habitat and connecting elements in the landscape have disappeared or have been reduced in quality (Van der Zee *et al*., 1992). Local populations can therefore become extinct due to increased mortality rates, reduced growth in the population and reduced exchange with neighbouring populations.

A computer simulation calculated two scenarios for town and country development in the middle of the Netherlands and their effects on the badger. Use was made of a geographic information system (GIS), in which a population model and a dispersion model were combined. The population model describes the population dynamics of the badger population in terms of increase in numbers, deaths and emigration (Verboom *et al*., 1999). The dispersion model simulated the (partly indiscriminate) dispersion patterns of individual animals based upon landscape characteristics ('random walk' model, Schippers *et al*., 1994).

The starting point in the area concerned is reproduced in figure 58a. The 'Metropolis' scenario assumes maximum economic growth. This leads to further urbanisation, an increase in infrastructure and increased traffic density (see figure 58c). This scenario included no measures taken on behalf of the badger. The alternative scenario, 'Promeles', assumes a more or less stable use of space, in which the situation is optimised for the badger (see figure 58b). Badger habitats are protected and repaired and possibilities for dispersion are increased by the construction of badger tunnels, partial road closure and speed limits in the most important corridors.

Figure 59 (see frame) shows the results for the local incidence of badgers. In the present situation (figure 59a), only the central part of the total habitat is in permanent use. The low incidence in the periphery is partly the result of obstacles in dispersion (see black dots in the figure). In the 'Metropolis' scenario the situation for the badger deteriorates rapidly as a result of loss of habitat, disturbance by traffic and recreation and further dispersion obstacles. After 50 years the number of social groups has been reduced by 50% and the badger has withdrawn from a number of nuclear areas on the Veluwe. The Heuvelrug in Utrecht has been almost completely deserted and has become almost impossible to access (see figure 59c). In the 'Promeles' scenario, on the other hand, the accessibility and quality of the habitats is increased. This is translated into a higher incidence and more stable sub-populations, even in the periphery (see figure 59b). From figure 60 it is clear that reducing the mortality and increasing the spatial cohesion contribute more or less equally to this positive result. The incidence of suitable habitat (visible on the y-axis) increased with both types of measure (along the z-axis and the x-axis respectively). The effect of the types of measures is greatest when they are combined.

[figure 60: bar charts scenarios]

9.6 Current and future studies

Experimental studies are being carried out by the Road and Hydraulic Engineering Division into the optimum width of walkways in culverts or under bridges. To this end, 22 walkways were spread over the Netherlands to study their use by mammals and amphibians during four weeks in September/October 1998. Use was made of ink stamps with pieces of paper. In 1999 one-third of these walkways were widened to 70 cm and one-third to 100 cm. The rest retained their original width (usually 25 to 40 cm). Their use by animals will be studied again in September/October 2000, in order to determine the optimum width. This experimental study will also take a look at whether the use of protective material demonstrably contributes to improved use by fauna. To this end, the use mammals made of 18 man-made banks was determined during at least four weeks in October and November 1998, making use of silver sand-beds. Afterwards, tree trunks or stumps were introduced into half of these fauna passages. In 2000 the study of the use made of the man-made banks will be repeated in the same period of the year as in 1998 in order to be able to draw conclusions about the need to introduce protective material.

In the near future, an inventory will be made of the possibility of fauna being allowed to use existing engineering structures such as viaducts and traffic tunnels. If, after adjustment, existing structural works can be allowed to function as a fauna passage as well, this will save having to construct, real, more expensive, fauna provisions.

A project started some time ago to study whether the fauna passages created are effective for the target animal populations. The plan is to determine, for one or a number of species, by means of long-term field study, whether these species continue to exist and whether this is especially as a result of the fauna passages that have been created. As part of this, in the year 2000, the model LARCH (see §9.4) will be used to determine whether there are suitable locations in the Netherlands to undertake such a study for a number of species. If this turns out to be the case, then a decision will be taken as to the duration of such a study and the frequency with which it needs to be carried out.

The Road and Hydraulic Engineering Division will soon be starting a study into the effect of street lighting on the movement behaviour of earth-bound mammals. This study will be aimed at the possible (added) barrier effect of street lighting for one or a number of terrestrial species of mammals still to be chosen. As a follow-up, study will also be done into the possible effects of street lighting on bats. This refers to barrier effects both in the form of repulsion and in the form of attraction (due to the availability of food).

The Road and Hydraulic Engineering Division is studying the degree to which the general public appreciates de-fragmentation measures that have already been taken and ones that might be taken in the future. A questionnaire has been issued to holidaymakers and road users with questions about their opinion and their feelings about the construction of fences, the construction of ecoducts, lowering the maximum speed limit, digging tunnels and constructing sound-repelling provisions. The answers are being analysed at the moment.

Alterra (the former Institute for Forestry and Nature Research and Staring Centre) is studying the effects of infrastructure on the occurrence of species. They are doing this at the request of large infrastructure organisations (Directorate-General for Public Works and Water Management, the Dutch Railways Infrastructure Management Board) or within the framework of national policy (Nature, forest and Landscape-21 (NBL-21), Nature Balance 1999 (NB99) and the Fifth Paper on Town and Country Planning (VijNo).

Studies for infrastructure organisations focus on the question of which species are subject to fragmentation (Kalkhoven and Bergers, 1999), which locations are suitable for studying aspects of fragmentation, such as barrier effects and fatalities (Houweling et al, 1999) and the effect of traffic noise on the density of meadow bird populations. (Bergers et al, 1999).

Within the framework of national policy, a number of policy items have carried out studies into the effects of infrastructure on the durability of habitat networks of different animal species (VijNo, NBL21, NM99). For example, the present nature quality was compared with the quality that can be expected in 2020 for the Fifth Notice on Town and Country Planning. Within the framework of the effects of infrastructure, attention was paid to the durability and spatial cohesion for both situations for six barrier-sensitive species. Roads and rivers are said to be barriers (though not canals and railroads, etc.). The infrastructure for 2020 was also kept at the level of the present situation. The analyses took place making use of the expert systems LARCH, LARCH-SCAN AND LARCH-BEN (see §9.4).

Within Alterra, on the one hand, work is being carried out on decision-supporting systems in various fields. At the request of the Road and Hydraulic Engineering Division of the Directorate-General of Public Works and Water Management, a feasibility study is being carried out into the possibilities for developing an instrumentarium to strengthen the habitat and corridor function of roadside verges. To this end, they first found out for which animal species road verges could be of importance as a habitat or corridor and under which conditions. It was decided to develop a decision-making support system. The system attempts to support those constructing and maintaining roads with information about effects on fauna and possibilities for positive measures (Van Eupen and Knaapen, 1999). Actual development of the system has now begun. On the other hand, study is also being done into the broader landscape-ecological effects of alterations in the lack of space. This study is taking place in particular within the framework of the programmes Ecology and Green Space and Quality of Surroundings. Work is being done on the development of gauges (including landscape-ecological indices) and monitoring systems (Monitoring Quality of Green Space). Advanced GIS and Remote Sensing systems play an important role here.

Research is being started into the effects of fragmentation caused by infrastructure and the effectiveness of counter-measures that can be taken as a result of the government policy formulated in the Second Structure Scheme for Traffic and Transport. The Dutch Railways Infrastructure Management Board set up the Defragmentation Study of Rail Infrastructure in 1996 as a result. The aim of this study is to obtain specialised ecological knowledge for the benefit of the development of plans, bringing out advice, carrying out and evaluating defragmentation and compensation measures in railway projects. The study will carry on until the end of 2002.

The study is made up of the following elements:

1. preliminary investigation, in which study locations and species are selected for other sub-studies;
2. study into the dose-effect relationships between noise-pollution due to the use of rail infrastructure and the occurrence of meadow birds and mammals;
3. monitoring and quantifying mortality along rail infrastructure and analysis of death statistics of birds and mammals in relation to characteristics of the railway and the surroundings;
4. empirical study into the barrier effects of railways for amphibians, reptiles and small to medium-sized mammals, that should provide insight into the degree in which railroads hinder or limit dispersion movements and the effects of these on the size of the population;
5. investigating and quantifying the corridor function of railways;
6. developing a method for planning and carrying out mitigating measures;
7. monitoring and evaluating the use of fauna passages and the effects of mitigating measures on the survival chances of populations;
8. developing algorithms that can predict, in a simple way, the effects of disturbance, mortality and barrier effects;
9. developing an effect-predicting model. The model under consideration (NS-LARCH) predicts the effect of railway infrastructure on the durability of populations in the surroundings.

Numbers 1, 2 and 3 are being carried out at the moment. The other studies have been planned to take place over the next few years.

At the Nature Management Department of Wageningen Agricultural University, a study is in progress about the effect of isolation on spiders due to roads. The Planning Land Use Department of Wageningen Agricultural University and the Technical University of Delft are focusing specifically on 'Road Ecology' in connection with secondary roads. A research assistant's project is expected to start under the title of: "Optimising the network of roads in the light of ecology, nature and the environment."

A study is being carried out at the otter station into the wet ecological connection zone, South Laardermeer-Lekkstermeer. The description of this wet connection zone in relation to the otter *Lutra lutra* will also contain bottlenecks with roads. Study will also take place in relation to the re-introduction of the otter in De Wieden. Infrastructure will also be involved in this case. Studies of the effectiveness of fauna passages for the otter is expected to take place in the future.

Each year, The Tree and Badger Association nationally reviews fauna victims among badgers at the request of the Road and Hydraulic Engineering Division and the Ministry of Agriculture, Nature Management and Fisheries.

A study is being carried out by the Plant Ecology Department of the University of Utrecht – "Fragmentation and connectivity. Spatial and temporal characteristics of decolonisation process in plants." This is a study of habitat fragmentation and the obstacles that result for the spreading of plants, the effects of roads being an integral part of this. The Landscape Ecology Department is going to carry out a study into the distances from source populations to vegetation and the effects these distances have on repair management of vegetation. The effect of roads on the distances from source populations to vegetation is a part of the study (see figure 60).

[figure 60: vegetatie]

Figure 60: On the effects of the barrier action of roads on the dissemination of plants very little is known.

The Institute for Systematics and Population Biology of the University of Amsterdam is going to study the effects of fragmentation on the grass snake *Natrix natrix* in the vicinity of Amsterdam, an important part of which will be the effects of (rail)roads.

The Bird Sanctuary is currently carrying out a study in co-operation with the Directorate-General of Public Works and Water Management into the use of roadside verges as feeding grounds, related to the problem of victims, in particular those of mouse-eating bird species.

At the inter-facultative Study Centre, the Sustainable Built Environment (DIOC-DGO) in Delft, a study of the ecological connection zones between urban and rural areas problems/optimisation of the accessibility of green space near cities has just started. The role of roads and defragmentation are a part of this.

An important current study of waterways is the evaluation of policy regarding nature-friendly banks during the last ten years. One of the evaluation components in this case will be the degree of connectivity. At the same time an ecological outlook on the canals of Brabant has been drawn up in which management and design are central as connective routes for different organisms (models).

Chapter 10 Economic aspects

Contributed by: A.A.G. Piepers

10.1 Costs and financing measures

National trunk roads

The costs of creating fauna passages vary widely. The creation of such passages underneath and above existing roads is considerably more expensive than creating them during the construction of new roads. The cost of a badger tunnel underneath a new motorway is approximately 5,000 guilders, for instance, while the cost of inserting one underneath an existing motorway can be between 30,000 and 100,000 guilders. The most recent ecoduct—constructed over the already existing A1 motorway near Kootwijk—cost seven million guilders; the least expensive ecoduct—constructed when a new section of the A1 was being built—cost approximately two million guilders. One reason why the creation of fauna passages near existing roads can cost more is that traffic measures must be taken. Near Kootwijk, for example, approximately a million guilders was spent on building a temporary traffic lane on the central reservation. Other factors affecting the costs include the quantity of soil to be excavated, the required fence length and whether or not groundwater is a factor. For the construction of the ecoduct near Kootwijk, a lot of soil had to be excavated, which also increased the costs. Fences are relatively expensive but necessary items for the effective operation of fauna passages. The cost of adapting a lower passage along a waterway can vary from 2,000 to 10,000 guilders, depending on the applied construction and the access to the site (i.e. how easily the required activities can be carried out). The adaptation of an existing viaduct by means of walls of tree-stumps is an example of a measure that even generates money, since the tree-stumps no longer require storage.

[figuur 55: foto persen dassentunnel]

The defragmentation of national trunk roads is financed by the Ministry of Transport, Public Works and Water Management. A separate budget has been established for creating fauna passages above and below existing roads. Since 1993, an annual average of two to five million guilders has been spent on this. In the middle of 1998, the measures for existing roads were stopped, since it became clear that the 1999 budget for defragmentation measures would be limited (most of the money was earmarked for maintaining the infrastructure). Fortunately, as of the year 2000 there will be further funds available for defragmentation measures for existing roads. For 2000, this will be five million guilders, for 2001 through to 2005, ten million guilders a year, and for the years after 2005, as much as fifteen million guilders a year.

In the creation of new national trunk roads, the costs of defragmentation measures is part of the overall project costs. These are both mitigating and compensating measures. In many cases, it is not known exactly how much is spent on mitigating measures during each project. In environmental impact assessments, the costs are either not separately listed (the measures are regarded as an integral part of the design) or are not specified (the costs of the mitigating measures for all environmental impacts are totalled). For compensation projects currently in the planning phase, approximately 1% to a maximum of 8.2% of the total project costs are included in the project memoranda/EIA (see § 7.4). For projects currently under execution, this amounts to 0.1% to 3.6%.

Smaller roads

There are no data concerning the costs and/or financing of measures for smaller roads.

Railroads

There are no data concerning the costs and/or financing of measures for railroads, either.

Waterways

In many cases, bank projects are carried out during canal widening or enhancement projects, often making it difficult to obtain a clear picture of the funds spent on each specific measure. The funds for removing barriers come from a restoration and configuration programme, which is financed by the Ministry of Transport, Public Works and Water Management. This is currently under evaluation (RIZA, 2000). A cost-benefit analysis of the created, nature-friendly banks will be carried out in 2001. However, some figures can be provided. The total costs of 1,500 metres of nature-friendly bank along the Amsterdam-Rhine canal amounted to 130 million guilders. The creation of 10 fauna-exit cost 200,000 guilders. In North Brabant, 29 km of nature-friendly bank was created for ten million guilders. In the outlet-reservoir sluice complex in the North Sea canal near IJmuiden, a fish passage was realised at a total cost of almost 1.5 million guilders. In South Holland, 29 km of nature-friendly bank was created for ten million guilders. In the outlet-reservoir sluice complex in the North Sea canal near Ijmuiden a fish passage was realised at a total cost of almost 1.5 million guilders.

10.2 Cost-benefit analysis

Nationa trunk roads

Of course, the costs of defragmentation measures must eventually be related to their benefits for nature. However, this is not that simple. Research into such a relationship is still in its early days. There are two possible approaches. In a purely economic approach, efforts are made to translate the effect of fragmentation into money and to plot this against the costs of remedying the effects. The problem in this context is that the market mechanism does not apply to nature values or ecological functions, and thus the market price cannot be established.

There are, however, various methods that can provide an *estimate* of the market price (Rietveld et al., in press). Another approach is based on the preservation of biodiversity. The benefits can then be expressed as the contribution made by the measure to preserve biodiversity. Recently, a study was started by the Free University to find a methodology with which to evaluate in financial terms the lack of space in infrastructure and mobility (Rietveld et al., in press). The study will also deal with fragmentation. In 2001, the Road and Hydraulic Engineering Division will start looking into the cost-effectiveness of liveability measures for the system of national trunk roads. Eventually, this project will yield information on which to base management plans, and allow for weighting the selection of measures both by content (effects) and by operation (costs). In addition to sound-limiting measures, measures against the pollution of air and soil, ecological roadside management and other measures, as well as the cost-effectiveness of defragmentation measures are matters of concern.

Secondary roads, railroads and waterways

No data are available concerning the cost-benefit analysis of smaller roads, railroads or waterways.

Chapter 11 General conclusions and recommendations

Chapters 5 to 10 contain the known facts about fragmentation in the Netherlands caused by the construction and use of roads, railways and canals and what is known about defragmentation. This chapter lists the conclusions and recommendations – what do we know, where are the gaps in our knowledge, are we progressing in the right direction or should other solutions be sought. The conclusions and recommendations are given per chapter. They concern infrastructure in general or separate types of infrastructure.

11.1 Fragmentation caused by existing infrastructure

Fragmentation has potentially serious consequences for the biodiversity of ecosystems and the viability of (animal) populations. The construction of infrastructure plays an important role in this. The following characteristics of infrastructure networks are important with respect to the problem of fragmentation – the type of infrastructure and its width, the length and the density of infrastructure networks, the way they are used by traffic and the composition of the traffic.

In addition, the fragmentation effects of infrastructure are largely determined by a species' sensitivity to fragmentation. Animals that are sensitive to fragmentation can be divided into five groups (see Verkaar & Bekker, 1990; Van Apeldoorn & Kalkhoven, 1991):

1. Species for which infrastructure forms an absolute barrier (mice, beetles);
2. Species with a large habitat (that travel long distances on a daily basis as they move around their habitat), e.g. badger *Meles meles*, the pine marten *Martes martes*, stone marten *Martes foina*;
3. Species with a large dispersion or dissemination distance (reproduction, winter migration) compared with their movement speed, e.g. amphibians;
4. Species with a large habitat and a large dissemination distance, e.g. otter *Lutra lutra*, red deer *Cervus elaphus* and wild boar *Sus scrofa*;
5. Species that are sensitive to disturbance like summer birds.

All the ecosystems in the Netherlands – the coastal zone (the North Sea and tidal areas), the dunes (especially the area between the dunes and the bordering ecosystems), the grasslands, wetlands, heaths and forests are influenced by fragmentation as a result of the construction and use of infrastructure. In the past, the coastal ecosystems in particular have had to cope with several incursions, e.g. the construction of the IJsselmeer Dam, while at the present time, mainly the grasslands, wetlands, heaths and forests are threatened. In the future, the tendency to let wetlands and forests develop into more natural ecosystems will also play a more important role.

Not only are the direct effects important, but also the urbanisation patterns that are linked with infrastructure. It is advisable to take this into account in planning procedures. In general, compact forms of urbanisation are preferable to diffuse. Line urbanisation along infrastructure has a marked compartmentalising effect that can only be compensated through the conservation and strengthening of several important green corridors.

National trunk roads and secondary roads

With the exception of cutting through the Veluwe National Park, on a landscape scale, the additional fragmentation caused by infrastructure (national trunk roads, railways and most provincial roads) is small compared with other causes (such as intensive agriculture and urbanisation). The average surface area of the units of land in use is only slightly reduced when the relevant infrastructure is considered as a boundary. However, compared with e.g. agriculture, infrastructure produces several specific effects like disturbance and causing animal fatalities. Furthermore, the relationships between areas with a different land-use are also important from an ecological viewpoint, e.g. between the Veluwe with forests and the river wash and grasslands. The way in which these areas are cut through has not been studied.

Most studies have involved the effects of motorways on the natural environment. Because of this, relatively much more is known about the fragmentation effect of motorways compared with other forms of infrastructure. The effect of disturbance caused by traffic noise, the way in which accidents with animals affect population sizes and the numbers of different species have been researched particularly thoroughly.

Summer birds are apparently sensitive to disturbance caused by noise – 20.4% of the habitats of woodland birds and 15.3% of the habitats of meadow birds are situated within the zone disturbed by national trunk roads (and some provincial roads). In addition, the population density of the black-tailed godwit *Limosa limosa* is detrimentally affected by street lighting. Because the Netherlands has an important function internationally as a habitat for meadow birds like the godwit, this is a serious effect that requires more attention.

Secondary roads have a different fragmentation effect to motorways. Because of their length, they are more attributable for destruction of habitat and for causing more accidents with animals than motorways. Although more badgers *Meles meles* are killed per 100 km section of a motorway, in absolute terms, most fatalities occur on secondary roads. This does not however apply to birds. Half of all avifauna fatalities occur on motorways. Because they are not as wide, secondary roads are presumably less likely to form absolute barriers and because they are less busy, animals supposedly do not grow accustomed to disturbance as quickly as they would with other roads. Neither supposition has however been substantiated in the Netherlands with field research. It is therefore recommended that more field research is carried out on the fragmentation effect of secondary roads. Studies that have been carried out in other countries, where there are more roads of this type, could also be looked into.

For a number of species with a small population, the number of road accidents is relatively high. This is particularly applicable to the badger *Meles meles* and the barn owl *Tyto alba*. Roads therefore form for these species a serious threat. However, the number of accidents also seems to affect the population size of species that occur in large numbers. This applies e.g. to the hedgehog *Erinaceus europeus.*

The occurrence of amphibians is strongly influenced by the density of the road network. The denser the road network the lower the population density of both a number of common and rare species. Fatalities caused by traffic are a significant cause of this.

Roadside verges have an important habitat and corridor function. More than half of species of plant that are native to the Netherlands are found in roadside verges. This is also good e.g. for insects and one argument in favour of continuing with ecological roadside verge management. However, it also says something about the extremely poor quality of the surrounding natural environment.

The bottlenecks between the natural environment and the existing national trunk road and provincial road networks have been fairly extensively documented by respectively the regional directorates of the Directorate-General for Public Works and Water Management and the provincial authorities. It is more difficult to obtain a general impression of the situation with existing rural roads in rural areas. The bottlenecks are mainly associated with the places where these roads cross the National Ecological Network. Within this network, it would make sense to apply a different set of priorities based on future nature conservation policy giving preference to the construction of main connections (arteries). It is recommended that areas that have been recently designated as coming under the protection of the European Habitat and Bird Directive be checked to see whether any new bottlenecks are formed.

Railway lines

Not very much is known about the fragmentation effects caused by railway lines. The available literature does however show that the nature of the effects is similar to that of road infrastructure. The large-scale study of the actual fragmentation effects that was started in 1997 will help to provide essential knowledge about this. Within the framework of different studies for major new rail infrastructure projects, effects have been predicted, but because these projects are not yet under construction, the effects cannot be evaluated at the present time. Furthermore, predicting effects is mainly concerned with direct habitat destruction. Because of the lack of knowledge and because the instruments used to predict effects are based on what we actually know, the consequences of barrier effects, fatalities and disturbance cannot be reliably determined at the present time.

The smaller dimensions and the much lower intensity of use lead us to suppose that railway lines have in general a smaller fragmentation effect that motorways. In a desk-study of different groups of animals (insects, amphibians, reptiles, birds and mammals), there appeared to be differences in sensitivity to three specific fragmentation effects. For example, birds are particularly sensitive to disturbance, insects are mainly confronted with barrier effects and amphibians seem mainly to be affected by fatalities caused by crossing over rail infrastructure. When risk groups (a group of animals that react in a similar way to the presence or use of rail infrastructure) are analysed with respect to the spatial characteristics of the species in the groups, it appears that species, which have populations in smaller areas and species that form network populations (metapopulations) on a local scale are especially sensitive to fatalities and barrier effects. Small species are relatively more sensitive to the barrier effect of rail infrastructure, but larger species are relatively more frequently involved in fatal accidents. No relationship was found between the sensitivity to disturbance and spatial characteristics.

Track-sides have an even greater significance for nature than roadside verges. No less than 75% of the Dutch flora is found in track-sides. The fauna found in track-sides is also extremely diverse.

The bottlenecks between nature and the railway network have been mapped out. An inventory has been made of them and their seriousness has been assessed. In this case, priorities should also be set that are based on rigorous defragmentation. Bottlenecks should be completed from the European Bird and Habitat Directive.

Waterways

One of the most significant effects of the construction of waterways with steep banks is the drowning of animals that get into the water. This is particularly the case with common species such as the hare *Lepus europaeus*, rabbit *Oryctolagus cuniculus*, deer *Capreolus capreolus* and fox *Vulpes vulpes*, but also with more endangered species such as the badger *Meles meles* and Mustelidae. Nothing can be said about the effect on small mammals, because they usually vanish without trace.

Disturbance on waterways mainly involves waves from ships striking the banks, the supply of water that is foreign to a given area and dehydration. The dehydration effect of canals can be especially significant. When canals cross wet ecosystems, they can form a barrier for fish and species such as the warty newt *Triturus cristatus*.

Similarly to verges, banks have an important function as habitat and corridor. This especially applies to species such as the otter *Lutra lutra* (in places where this animal will have been released) and the water shrew *Neomys fodiens.*

11.2 Road safety with respect to collisions with animals

Through the years, collisions with animals have never been a significant in the total number of accidents resulting in injury. Data from several years during the period from 1991 to 1998 show that the percentage of accidents resulting in injury caused by collisions with animals varies from around 0.2 to 0.3%. This would seem to justify the assumption that collisions with animals do not play a significant role in road safety. It should however be remarked that various evasive manoeuvres to avoid animals on the road could lead to collisions with other objects such as guard rails, trees, etc.

Nearly all red deer *Cervus elaphus*, which form the greatest danger to motorists, are found in fenced off areas.

11.3 Approach: Prevention, mitigation and compensation

In the Netherlands, a great deal of time is spent on mitigation and compensation of the negative effects of infrastructure, but the most important factor – the prevention of fragmentation effects – receives relatively the least attention. This is in spite of the fact that the formulated objective of traffic and transport policy is that attention should be expressly devoted to 'the prevention of further fragmentation of the natural environment and landscape in the short term and the reduction of fragmentation in the long term'.

Mathematical models, such as shown for the central region of the Netherlands, indicate that a great deal can be achieved with compensation and mitigation measures. Both the quality of habitats and the possibilities of migrating between them can be improved. These measures have the largest effect when they are combined, which is an argument in favour of close cooperation between government agencies and the NGOs that are responsible for terrain management and infrastructure works.

National trunk roads

The following measures could be taken to facilitate meeting objectives with respect to preventing fragmentation:

- creating clarity about the consequences of the European Bird and Habitat Directive;
- extending the 'joint consultative/authority' tasks of the Minister of Agriculture, Nature Management and Fisheries;
- the development of a testable working method in the decision-making procedure for nature conservation by introducing clear-cut moments when decisions have to be taken with respect to the preventing of effects (whether or not infrastructure should cut through protected areas) and the type and scale of the compensation;
- putting forward alternatives to building and widening projects at an early stage in the planning procedure;
- integration of the problems regarding traffic/transport and nature/landscape;
- improved analysis of the effects of infrastructure destroying and cutting through nature reserves;
- the timely development of the Most Environment-Friendly Alternative – during the planning process.

As far as the mitigation measures for the existing national trunk road network are concerned, the emphasis has until now been on the construction of fauna passages and erecting fencing to reduce the barrier effect and the number of animals killed in accidents. Disturbance caused by noise is however also important and suitable measures should be sought to counter its effects. Reducing the maximum speed, the use of double-layer ZOAB (porous asphalt) and modifying street lighting are several possibilities. Raising the habitat quality of areas bordering infrastructure in compensation for the reduction in habitat quality caused by disturbance is also an option. An example is increasing the quality of the habitats of meadow birds by keeping grasslands wet, mowing them late in the spring, few free-ranging cattle during the breeding season and the use of farmyard manure.

At the moment, the lack of space is an important problem in nature compensation. The following ideas have been put forward to solve this – setting up a national 'land bank' for compensating the network of main roads, providing effective alternatives for raising the quality of the natural environment and improving the cooperation with and between the different regions in the country.

Secondary roads

The provincial authorities do not register the prevention of fragmentation. In order to obtain a better impression of the significance that is attached to the prevention of fragmentation in the Netherlands, registration of the cases in which fragmentation played a role in cancelling plans for road construction is important.

A practical problem in implementing effect-oriented measures along roads in rural areas are their great length, the usually narrow verges and the generally short distances between the entrances to farms and fields that have to be kept open. This reduces the possibilities for placing continuous fencing and screens.

Compensation is a fixed element in the (re)construction of roads in the provinces as part of the compensation regulation in the Structure Plan for the Rural Areas. A number of provinces (North Brabant and South Holland) have even worked out their own compensation principle. In other provinces, compensation is applied on a limited scale. There are differences in the provinces in the interpretation of the national compensation regulation. The reliable registration of compensation (when, how and how many hectares) could contribute to improving the overview of compensation for road building in the provinces of the Netherlands.

National trunk roads and secondary roads
Concentrating traffic flows on specially designed motorways and main roads in conjunction with diverting traffic from secondary roads in rural areas will, according to model calculations, have a positive effect on road safety and also benefit fauna.

In absolute terms, most badgers are killed on secondary roads but most badger tunnels (52%) have been built under national trunk roads. This means that the secondary roads have to catch up with building badger tunnels in order to reduce the number of fatalities – provided it is possible to erect continuous fencing. Diverting traffic from secondary roads in rural areas, as referred to above, is also an option.

Railway lines
The “no-unless principle” in the Structure Plan for the Rural Areas is hardly ever applied in the Netherlands as a support for and in the decision-making processes concerning the construction of rail infrastructure. The principle is however an implicit part of the public debate on the ‘Need and Necessity’ of new rail links. The EIA Committee recently started actively testing published environmental impact assessments for this. It is therefore recommended that the testing of this principle be taken into consideration with major projects in the future.

With rail infrastructure, the experience gained in implementing nature compensation is still extremely limited. It would seem that the existing instruments are inadequate for achieving the policy objectives. Because of this, they have to be used ‘creatively’ (especially land acquisition). Furthermore, carrying out projects is exasperated by the different interpretations of the compensation regulation at provincial level and during different stages of construction. This can cause problems in a project’s progress. Recommendations?

Waterways
There are a number of available options for solving the barriers caused by canals for wet and dry ecosystems (nature-friendly banks, fauna-exits, culverts and other passages for fish). Connection between different waters running along the length of canals can be solved by building nature-friendly banks (herpetofauna) or a different management system (butterflies). Bridges can be made passable by incorporating green strips. Fragmentation running perpendicular to canals can be solved with fauna-exits (mammals) or culverts (fish). For many species, it is still unclear what the effect of connection between different waters is. The undesired connection of different waters should however be prevented. Nature-friendly banks help compensate nature that is lost through canal building projects. There is a clear tendency towards building wider nature-friendly banks. In the beginning, the wet stretches were 1 m wide, then 5 to 10 m and now 50 m.

11.4 Management and evaluation

National trunk roads

Effective management and maintenance are crucial for the functioning of defragmentation measures. Because the control within the Directorate-General for Public Works and Water Management with respect to the state of repair of fauna passages and the actual maintenance work need to be improved, solutions have to be found. Further specialisation of road inspectors in this area, as suggested in some service districts, could also be taken into consideration at other service districts.

It is important to continue studying the use of faunapassages, because this is the first step in determining there effectiveness.

Monitoring the effectiveness of mitigation and compensation measures at a population level does not yet take place. Because the ultimate objective of defragmentation is aimed at the sustainable survival of populations, it is necessary to acquire insight into the effectiveness at this level. Monitoring studies should therefore receive priority in future research.

Secondary roads

The maintenance of fauna passages on main roads in most provinces is part of the normal tasks of the road managers (Limburg, Friesland, North Brabant and Groningen). In a number of provinces, a specific plan is used for the maintenance of fauna provisions in which the requirement management and maintenance is listed (Utrecht, Drenthe, Overijssel, Gelderland). Setting up similar maintenance systems should be continued.

The evaluation of fauna provisions on main roads does not take place structurally in the provinces. In some provinces, the use of passages is however looked into on an ad hoc basis. Research of the effectiveness of passages at a population level does not take place anywhere. It is recommended that not only the use of provisions (by which species) is looked into in the evaluation of defragmentation measures. Research of the effectiveness of measures at a population level has until now not been carried out, even though many parties (the provinces) are asking questions related to this aspect. In the future, this should become an important part of research.

Railways

The evaluation of defragmentation measures for rail infrastructure is not carried out systematically at the present time. Monitoring studies and evaluations have however been provided for. It is recommended that monitoring and evaluation be included in the planning of larger infrastructure projects.

11.5 Fragmentation and the future development of infrastructure

Over the next five years, planned developments will lead to the construction of approx. 100 kilometres of motorway and 250 kilometres of railways. In addition, the main road network will be widened over a length of many hundreds of kilometres and measures for improving the utilisation of roads, railways and waterways will be implemented over stretches of dozens of kilometres.

With respect to the fragmentation problem, it is positive to be able to report that the emphasis in the development of infrastructure has now shifted to widening and improving utilisation even though a number of decisions on construction projects will continue to work through into the near future. Widening projects will concentrate and strengthen destruction (additional asphalt), disturbance (increased traffic density) and barrier effects (increased density and wider roads) on existing transport arteries. Since the barrier effect will grow, the number of accidents will probably not rise, in spite of the fact that the traffic density and the width of the roads will increase. Improved utilisation will mainly lead to an increase in disturbance. The growth of the barrier effect and the number of fauna fatalities will presumably be relatively small and the increase in destruction of habitat will be virtually zero.

A fragmentation indicator is still needed that can be used to gauge the situation against a reference model – to what extent can the Netherlands be fragmented so that the survival of populations of certain species is not endangered. Or, in terms of infrastructure – what degree of impassability is acceptable or what degree of passability is desired? It should be asked whether this requires additional defragmentation measures, more and other than required for meeting the policy objective of solving 90% of the bottlenecks between the national road network and the National Ecological Network by 2010.

With respect to research, investments will have to be made in the validation of models; especially concerning the dispersion behaviour of species and studies of population dynamics. This will involve time-consuming fieldwork that is however essential for obtaining reliable prognoses. To move ahead in the (policy) discussions concerning fragmentation, more attention will have to be given to fragmentation effects at a population and landscape level. This means that the extent to which local populations are suffering from fragmentation and the location of bottlenecks (to supplement existing bottleneck analyses) will have to be researched in the field. A distinction should be made in this respect between different aspects of fragmentation – loss of habitat surface area, pollution and disturbance (light and noise) and barrier effects.

Research of the fragmentation effects and related traffic flows requires more attention. This is partly to study the effects of concentrating traffic flows on specially designed national trunk roads and provincial roads and diverting traffic from secondary roads in country areas as part of the Sustainable Safety concept.

If research of the use by fauna of existing engineering structures like viaducts and tunnels shows that there are realistic possibilities, more attention should be focused on this area. In this way, money could be saved and used in situations that require large-scale provisions for fauna.

It is advisable to research the effectiveness of building connections near waterways further. Innovative measures are required, because new methods for laying on provisions for fauna could prove to be more effective. For example, seepage ditches that are created as part of building a canal often house rare and protected species. The construction of pools instead of nature-friendly banks is also being considered, for example in situations where the surrounding countryside is important to amphibians. The tendency of making canal banks wider should certainly be continued.

11.6 Economic aspects

Virtually nothing is known about the cost-effectiveness of mitigation or compensation measures. Studies in this area are gradually being set up. Because policy is targeted on the optimum use of measures, it is important to obtain insight into the ratio between effectiveness and costs as quickly as possible. This is an argument in favour of giving more priority to this type of research and to take as many different types of measures as possible into consideration.

Chapter 12 References

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Annex I: Network of national trunk roads

Annex II Network of secondary roads

In deze bijlage wordt voor een drietal gebieden in Nederland uitgewerkt hoe het wegennet zich aldaar in de loop der jaren heeft ontwikkeld. Deze ontwikkelingen blijken enigszins te verschillen naar regio.

Tabel**1** Technische informatie kaartbladen.

Gebied	Tijdreeks	X-coördinaten	Y-coördinaten	Kaartblad
Doetinchem	1925 1966 1995	211.35-216.35	439.60-422.60	491 40F 40F
Oosterlittens	1925 1962 1988	171.30-176.30	471.10-473.10	109 10F 10F
Zegveld	1925 1957 1997	113.50-118.50	458.15-461.15	443 31D 31D

Doetinchem
In 1925 was er een groot aantal semi verharde en onverharde wegen. In de periode van 1925 tot 1966 is veel verharding opgetreden. Het wegenpatroon blijft van in tact, er worden weinig nieuwe wegen aangelegd. In de periode van 1966 tot 1995 zijn er grote veranderingen opgetreden. Niet alleen heeft er verharding plaats gevonden, maar er zijn nieuwe wegen aangelegd. De A18 is aangelegd en er daarbij verschillende wegtrajecten ter ontsluiting van de snelweg. Rondom Doetinchem zijn verschillende provinciale wegen aangelegd, deels lopend over bestaande wegtrajecten. Er zijn ook andere wegen aangelegd zoals de rondweg rond Wehl. Daarnaast heeft een grote uitbreiding van nieuwbouw plaatsgevonden. De regio rond Doetinchem wordt gekenmerkt door een dicht wegennet, waar vanuit het oogpunt van de versnippering dieren veel vaker dan vroeger een weg tegen zullen komen.

Oosterlittens
In de periode van 1925 tot begin van de jaren ’60 is er aan het wegennet weinig veranderd. Het merendeel van de wegen die in 1925 nog semi-verhard is, is dat begin jaren ’60 nog steeds. In de periode van 1962 tot 1988 zijn verschillende provinciale wegen aangelegd in de richtingen Franeker-Sneek en Bolsward-Marssum. Daarnaast zijn semi-verharde wegen verhard en zijn een aantallen stukken plattelandsweg aangelegd (o.a. het doortrekken van enkele doodlopende wegen naar elkaar toe). Uitbreiding van de dorpsbebouwing heeft op kleine schaal plaatsgevonden. De regio rond Oosterlittens wordt gekenmerkt door een ijl wegennet.

Zegveld.
In de periode van 1925 tot 1957 heeft veel semi-verharding plaatsgevonden van paden op de langgerekte landbouwkavels. In principe dienen deze alleen voord e individuele bedrijfsontsluiting. In de periode van 1957 tot 1995 is Zegveld uitgebreid en zijn wegen aangelegd. Tevens heeft verharding plaatsgevonden van de semi-verharde weg langs de Meije. Er is een “rondweg” aangelegd langs de boerderijen ten noorden van Zegveld rondom Lagebroek. Deze verharding heeft waarschijnlijk plaatsgevonden om redenen van ontwatering. Door deze nieuwe weg konden de semi verharde insteekwegen op de kavels vervallen. Aansluitend op deze nieuwe rondweg zijn enkele andere regionale en lokale wegen aangelegd en semi-verharde wegen verhard. In de regio rond Zegveld is sprake van een zeer ijl wegennet. Dit is te verklaren door de ondergrond van veen, die het aanleggen van wegen tot een zeer kostbare operatie maakt.

<u>**Opmerkingen voor Annette:</u>

- De bijgevoegde figuren zijn scans van de originele TOP-kaart. Wij (LUW) hebben hiervoor geen rechten. Hoe zit dat bij RWS?

- Het verdient aanbeveling om de kaartfragmenten in het nationale rapport in kleur op te nemen.

Annex III: Networks of railroads

Annex IV: Network of waterways

Annex V: Oversteekformule

Oversteekformule
Voor het berekenen van de kans op een geslaagde oversteek van een weg door een dier hebben Van Langevelde en Jaarsma (1997) een formule voorgesteld. Deze formule is gebaseerd op enerzijds de benodigde oversteektijd van de wegverharding door de diersoort en anderzijds de beschikbare tijdshiaten in de verkeersstroom. De oversteektijd is afhankelijk van de oversteeksnelheid en de lengte van het dier en van de verhardingsbreedte van de weg. De kans dat een tijdsinterval van minimaal deze lengte beschikbaar is, is afhankelijk van de verkeersintensiteit op de weg. In de verkeerskunde is namelijk via een zogenaamde Poisson-verdeling een verband bekend tussen de kans op tijdsintervallen van een bepaalde lengte (in secondes) tussen twee voertuigen en de verkeersintensiteit (in auto's per uur). De oversteekformule gaat uit van de veronderstelling dat een oversteek van een dier slaagt, wanneer een interval beschikbaar is met een lengte van tenminste de benodigde oversteektijd.
Een getallenvoorbeeld: een ree steekt een weg over met een loopsnelheid van 5,2 m/sec. De lengte van het dier is 1,35 m; bij een verhardingsbreedte van 7 m is de totale oversteektijd in dat geval (8,35 : 5,2 =) 1,61 seconden. De kans dat een interval van deze duur op deze weg beschikbaar is, is volgens de Poisson-benadering overdag (gegeven de gemeten intensiteit van 267 auto's per uur) 0,91. 's Nachts is de intensiteit veel lager, namelijk 67 auto's per uur. De kans op een interval van tenminste 1,61 seconden tussen twee auto's is dan aanzienlijk hoger, namelijk 0,98.
Van Langevelde en Jaarsma (1997) stellen dat het oversteekmodel vooral geschikt is om een (relatieve) vergelijking te maken tussen twee situaties, bijvoorbeeld voor en na verkeersmaatregelen. Elke verandering in verkeersintensiteit of in verhardingsbreedte leidt namelijk tot een verandering in de kans op een geslaagde oversteek. Voor het berekenen van het absolute aantal slachtoffers wordt het model minder geschikt geacht. Daarvoor zou onder meer ook het aantal oversteken per dag per diersoort voor elke weg bekend moeten zijn. Voor het berekenen van een relatieve vergelijking is dat niet nodig.

Annex VI Knelpunten van het provinciale (vaar)wegennet en de (provinciale) ecologische hoofdstructuur in de provincies.

Provincie	Knelpunten	Toelichting
Noord Brabant	205 knelpunten. Grootste aantallen in de regio Eindhoven/Helmond. Meest urgente knelpunten in het gebied rond Vught en Boxtel en langs de Maas bij Boxmeer en Cuijk (BTL Planbureau, 1998).	Inventarisatie van versnipperende effecten van het provinciale wegennet aan de hand van faunaslachtoffer gegevens, informatie van natuurbeschermingsorganisaties en veldbezoek.
Noord Holland	96 knelpunten tussen de provinciale ecologische hoofdstructuur en provinciale wegen en vaarwegen	Inventarisatie op basis van de ruimtelijke koppeling van de provinciale ecologische hoofdstructuur en het net van provinciale wegen en vaarwegen (Provincie Noord Holland, 1995).
Zuid Holland	10 belangrijkste ecologische verbindingszones worden op verschillende plekken doorsneden door elf provinciale wegen en op drie plaatsen door provinciale vaarwegen	Inventarisatie op grond van het areaal van de meest relevante soorten amfibieën, reptielen en zoogdieren en de belangrijkste ecologische verbindingszones (Provincie Zuid Holland, 1995).
Friesland	Knelpunten en barrières van natte en droge verbindingszones met vaar- en rijwegen zijn aangegeven op de plankaart ecologische verbindingszones (Provincie Friesland, 1991)	Knelpunten gebaseerd op gegevens over faunaslachtoffers. Met name in Z-O Friesland en Z-W Friesland worden duikers aangelegd voor dassen en otters (tevens voor gebruik door amfibieën en reptielen).
Limburg	26 zware knelpunten, waarvan er 14 in Zuid Limburg. 50 relatief minder belangrijke knelpunten, verspreid door heel Limburg, De minst zware knelpunten bevinden zich in Noord-Limburg.	Zwaar knelpunt: drukke doorgaande (snel)weg doorsnijdt ecologisch belangrijk gebied. Relatief minder belangrijk knelpunt: kleinere koppeling met EHS/knelpunt voor minder soorten. Minst zwaar knelpunt: lang, niet scherp afgebakend traject van doorgaande weg, knelpunt voor minder dan twee diersoorten/groepen (Bugter, R. 1993).
Groningen	Zware knelpunten binnen EHS: bij provinciale weg Winschoten-Ter Apel (N976) en de weg Sebaldeburen-Boerakker (N388). Zware knelpunten in verbindingszones tussen EHS gebieden en tussen EHS gebieden en waardevolle witte gebieden: Winschoterdiep en Van Starkenborghkanaal (Smit, 1995).	Inventarisatie door ruimtelijke overlap PEHS met de kaart van provinciale (water)wegen: 31 mogelijke knelpunten. Beoordeling knelpunten op basis van verspreidingsgebieden van aandachtsoorten (egel, hermelijn, wezel, bunzing, steenmarter, das, otter, ringslang en diverse soorten amfibieën), praktijk-gegevens over locatie van knelpunt landschappelijke waarden van EHS gebiedenen.
Zeeland	12 zeer belangrijke knelpunten, 25 belangrijke knelpunten en 69 overige knelpunten. Ongeveer twee derde van de zeer belangrijke en belangrijke knelpunten bevindt zich in Zeeuws-Vlaanderen. De meeste overige knelpunten bevinden zich op Zuid-Beveland en Schouwen-Duivenland (LB&P, 1995).	Inventarisatie door 15 gidssoorten (Otter, Bunzing, Ree, Ondergrondse woelmuis, Noordse woelmuis, Kerkuil, Roerdomp, Grutto, Rietgors, Kamsalamander, Boomkikker, Rugstreeppad, Heikikker, Levendbarende hagedis en Aal) (LB&P, 1995). Indeling knelpunten naar status en gevoeligheid van gidssoorten voor versnippering, aard van het knelpunt en wegtype, toekomstige problemen en reeds uitgevoerde maatregelen.
Drenthe	De twee grote kanalen in Drenthe vormen wellicht een groter knelpunt dan provinciale wegen. De kanalen vormen ten eerste een barrière in het leefgebied van o.a. reeën, dassen en marterachtigen. Ten tweede is er bij oversteek een zeer grote kans op de verdrinkingsdood.	Knelpunten gebaseerd op basis van slachtoffer registratie. Er is tevens een inventarisatie uitgevoerd naar knelpunten van provinciale (vaar)wegen met de ecologische hoofdstructuur, waarbij met name is gekeken naar natte ecologische verbindingzones.
Flevoland	Knelpunten niet expliciet benoemd	Knelpunten op basis van slachtoffer registratie
Overijssel	Knelpunten niet expliciet benoemd	Knelpunten op basis van slachtoffer registratie
Gelderland	Prioriteit overgangsgebied Veluwe – Achterhoek	Versnipperingsproblemen gebaseerd op onderzoek “Evaluatie ecologische verbindingszones provincie Gelderland” (Instituut voor Bos- en Natuuronderzoek).
Utrecht	13 knelpunten met provinciale wegen en 2 knelpunten met lokale wegen	Gebaseerd op verkeersintensiteit, typen barrièrewerking en typen fauna naar actieradius.

	(Bureau Waardenburg, 1993) (zie §5.3.8)	

Annex VII: Voorbeelden van compensatie in de provincies

Voorbeelden van compensatie in de provincies

Een aantal provincies is momenteel bezig met de voorbereiding van compensatie in een wegenaanleg of- reconstructie project. In de provincie Limburg is een aantal nieuwe provinciale wegen in voorbereiding, waaronder de N297 bij Sittard, waarbij compensatie plaats zal vinden. De aanleg van de N297 bij Sittard is een onderdeel van een groot ontwikkelingsproject (o.a. de uitbreiding van enkele bedrijven en wegen). Vanwege het reeds bestaande versnipperingsprobleem en de vergroting van het versnipperingsprobleem door de aanleg van de nieuwe weg, is er een plan in ontwikkeling om de (verplichte) compensatie bij de aanleg van de weg uit te breiden met natuur- en landschapsontwikkeling. De compensatie wordt gekoppeld aan het ontwikkelen van een nieuwe ecologische verbindingszone tussen het Duitse achterland en het waardevolle loofbosgebied Limbrigterbos en Grasbroek. Naast de aanleg van faunavoorzieningen zal het agrarische gebied aan de oostzijde van de verbindingszone ingericht worden met poelen, landschapselementen en bos. Het project bevindt zich in de planningsfase en aan de aantallen hectares wordt momenteel gerekend.
In de provincie Drenthe vindt compensatie plaats bij de aanleg van de provinciale weg N391 in de Veenkoloniën. Ten noorden van de weg wordt een kilometerslange ‘natuurstrook’ aangelegd, met een breedte van minimaal 15 meter. In deze strook worden door afgraving natte en drogere plekken gemaakt, waardoor verschillende soorten planten een kans krijgen. De strook zal vooral bestaan uit lagere beplanting en een enkele spontaan groeiende boom of struik. Het open karakter van de Veenkoloniën blijft daardoor zoveel mogelijk in stand. In de provincie Noord-Holland heeft compensatie plaats gevonden bij de N22 bij Uithoorn, d.m.v. het herstel van gras en moeras vegetaties. In de provincie Noord-Holland is een compensatieregeling opgenomen in het streekplan.

Compensatie bij plattelandwegen en stadsnatuur - enkele voorbeelden

Voor plattelandswegen zijn enkele waterschappen en gemeenten benaderd op aanraden van verschillende provincies. In het waterschap de Zeeuwse Eilanden vindt compensatie in de strikte zin van woord plaats bij landinrichtingen (b.v. bij Walcheren). Dit betreft met name bosaanbouw. Deze compensatie valt echter buiten de verantwoordelijkheid van het waterschap.
In de gemeente Apeldoorn verplicht de Boswet compensatie van bos. Daarnaast is een intern beleid in voorbereiding voor compensatie van natuur in de stad en dit beleid zal ook voor provinciale wegen gaan gelden.
In de gemeente Zoetermeer is een stadsnatuurplan opgesteld, waarin de natuur in drie niveaus wordt verdeeld, stad, wijk en regio. In het stadsnatuurplan worden knelpunten gesignaleerd, waarbij een aantekening wordt gemaakt dat versnippering bij reconstructies moet worden opgepakt. Er is een streven naar het zoveel mogelijk aaneensluiten van natuurgebieden. In het stadsnatuurplan is ook een compensatieregeling opgenomen die speelt op het niveau van de regio. Deze regeling sluit aan bij die van de provincie en gaat met name op voor provinciale wegen. In de gemeente Ede, een gemeente met veel buitengebied, wordt sinds 1984 aan (her)beplanting gedaan. Sinds 1989 wordt er veel nieuwe aanplanting gerealiseerd, onder andere ter compensatie van verloren gegane beplanting bij de aanleg of verbreding van wegen. Zo zal de provinciale weg N781 tussen Ede en Wageningen worden verbreed en daar zal 10 meter nieuwe beplanting plaats vinden ter compensatie. De N781 is gesitueerd in een kleinschalig dekzandlandschap. Er bestaat geen eenduidig beplantingsbeeld als geleiding van de weg. Verschillende landschappelijke eenheden die voorkomen langs de weg zijn boselementen en bomenrijen, verschillende soorten knotbomen, laanbomen zoals eik en populier, en houtwalstructuren. De nieuwe compenserende beplanting zal aansluiten bij deze gevarieerde structuur. In de gemeente Ede worden nauwelijks nieuwe plattelandswegen aangelegd, maar wel fietspaden, waarvoor dan ook nieuwe beplanting plaats vindt ter compensatie.