Chapter 2

Ecological compensation of the impacts of a road; preliminary method for the A50 road link *(Eindhoven - Oss, the Netherlands)*

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Abstract

After years of efforts to avoid or reduce the impact of infrastructure projects on nature, the principle of ecological compensation has been incorporated in Dutch governmental policy. Ecological compensation aims to recover those ecological functions and natural values that still remain affected after maximum effort has been made to reduce the impact of the intervention (mitigation). The accepted aim of current policy is thus no-net-loss of area and quality by means of mitigative and compensatory measures.

As part of the planning process for construction of a stretch of road in the Netherlands, viz. the A50 road link in the province of Noord-Brabant, an Ecological Compensation Plan (CP) was required to be drawn up. This work has recently been completed by the Regional Directorate of Public Works and Water Management, the initiator of the intervention. The CP, initially presented as a Draft Plan, was drawn up by the Regional Directorate using a preliminary method designed by the Centre of Environmental Science of Leiden University for deriving compensatory measures. After an opportunity for public comment, the Draft Plan was revised to form a Final CP.

This article describes, firstly, the preliminary method for deriving ecological compensatory measures. The method starts by quantifying the effects of habitat loss, habitat disturbance (by changes in noise emissions, in the water table and in outdoor recreational patterns), barrier action and fauna casualties. Following mitigation of impacts on nature, compensation for non-mitigable effects focuses successively on area size, derived from the impacts on breeding birds, and on area quality, derived from the habitat requirements of the vegetation and fauna groups affected by the road. Guidelines for identifying appropriate locations for compensation are also formulated. Secondly, the compensation method is applied to calculate the mitigative and compensatory measures for the A50 trajectory between Eindhoven and Oss. Thirdly, two comparisons are made: the Draft CP is compared with the results of the preliminary method, and the Draft and the Final

CP are compared with one another in order to identify the role of the interest groups that played a major role in commenting on the Draft Plan. Finally, realization of the compensatory measures and development of the preliminary method itself are discussed. On the basis of the experience with the A50 case study, a more robust compensation method for road projects is to be developed.

Keywords: road infrastructure, habitat loss, habitat disturbance, barrier action, fauna casualties, no-net-loss of area and quality.

1. Introduction

Roads can cause considerable damage to nature. Their physical presence hampers the exchange of plants and animals between dissected habitat areas. In addition, traffic noise decreases the quality of fauna habitats adjacent to the road, leading to lower densities of breeding birds over considerable distances (cf. Van der Zande *et al.* 1980, Reijnen & Foppen 1991). Over the last two decades, much progress has been made in preventing and diminishing the negative impact of roads on nature.
Today, the avoidance of damage to nature is generally given serious attention in Environmental Impact Assessments, in which alternative engineering designs and routing plans are evaluated and compared with one another. Increasingly today, once the design and route have been finalized, road construction is accompanied by mitigative measures such as fauna underpasses and wire fences to reduce barrier action and fauna casualties (Anonymous 1993). It is also becoming increasingly common for expensive engineering structures to be built for nature conservation purposes, such as ‘ecoducts’ (also known as ‘cerviducts’). Such structures have been introduced for example in Switzerland, France, Germany (cf. De Vries 1994) and the Netherlands (Verkaar & Bekker 1991) in order to connect the populations of large mammals, i.e. of Red deer *Cervus elaphus*, Roe deer *Capreolus capreolus* and Wild boar *Sus scrofa*, that were to be dissected by construction of roads.

While major efforts can be made to prevent and mitigate the negative impacts of infrastructure projects on nature, it is obvious that such impacts can never be fully avoided. Over the last few years there has been a growing call by interest groups to compensate for the effects remaining after mitigation. As a result, the

Dutch national government has introduced an obligation to act in compliance with the so-called compensation principle. The 'Structure Plan for the Rural Areas in the Netherlands' states that '.. when nature, forestry and/or recreational functions are to suffer demonstrable damage as a result of another important societal function, effects should be mitigated and (if such is not sufficiently possible) compensated ..' (MANF & MHPE 1993). From the compensation principle it follows that losses of area and quality caused by interventions should be balanced out elsewhere, which is called 'no-net-loss' (INN 1991, Lynch-Stewart 1992). As yet, there are no underpinned and quantified guidelines available for establishing such a no-net-loss, except for wetlands (cf. Lynch-Stewart 1992).

In this article we focus - in anticipation of forthcoming guidelines from the Dutch national government - on ecological compensation. This type of compensation implies the development of habitat area that is, in terms of extent and nature quality, comparable to the lost or affected area. As no method was yet available for deriving ecological compensation, one was developed with reference to the construction of the A50 road link between Eindhoven and Oss, in the Netherlands. This article starts by describing the preliminary method, and the mitigative and compensatory measures for the A50 derived according to this method (cf. Cuperus & Canters 1994). Next, the Draft Ecological Compensation Plan (MTPW 1995a) subsequently drawn up by the North Brabant Regional Directorate of Public Works and Water Management is compared with the results of the developed method. This was necessary as the measures proposed in the Draft Plan differ on several points from those of the preliminary method. Finally, the consequences of the opportunity for public comment for the Definitive Ecological Compensation Plan (MTPW 1995b/c/d) are discussed, as well as the possibilities for implementing the compensatory measures.

2. A method to determine ecological compensation

The ecological compensation method is a step-by-step process whereby first the impacts of an infrastructure project on nature are identified (Section 2a), and then appropriate mitigative and compensatory measures are drawn up (Sections 2b and 2c, respectively). Guidelines for identifying appropriate locations for compensation are outlined in Section 2d.

2.1 General effects of road infrastructure on nature

We distinguish the following impacts of roads on nature (see also Fig. 1):

(a) *Habitat loss*: destruction of habitat area through the physical presence of the road and associated infrastructure elements;

(b) *Habitat disturbance*: deterioration of habitat quality due to traffic noise (noise effects), depressed water tables (hydrological effects) and road-induced changes in outdoor recreation patterns, resulting in sub-optimal or even marginal vegetation and fauna habitats;

(c) *Barrier action*: separation of functional areas, leading to decreases in species mobility and/or inaccessibility of functional areas;

(d) *Fauna casualties*: injury or death of fauna due to collisions with motorized traffic.

Single or combined effects on individuals can cause population effects (Fig. 1), leading in the short term to a decrease in population densities. In the long term, ecosystem characteristics may be influenced by the extinction of local or regional populations.

2.2 Mitigative and compensatory measures

For each type of effect distinguished, we describe the (range of) mitigative and compensatory measures that can be taken (see also Fig. 2). The basic point of departure is a no-net-loss of functions, implying that non-mitigable effects qualify for compensation.

2.2.1 Habitat loss

Road construction results in the loss of habitats for vegetation and fauna, and is an irreversible process. Therefore, mitigation of these effects is not possible. The area of lost habitats should be compensated by developing natural areas of equivalent size which, in the long term, will have the same qualities as the intersected area prior to intervention.

2.2.2 Habitat disturbance

Noise effects. Field research has proven the existence of a ‘disturbance zone’, i.e. the zone from the road axis to the point at which no effects on breeding bird densities can be demonstrated (cf. Van der Zande *et al.* 1980, Reijnen & Foppen

Intervention	Effects on species	Higher-level effects
highway construction and use	habitat loss habitat disturbance - noise effects - hydrological effects - changes in recreational patterns barrier action fauna casualties	isolation of habitat area and changes in population densities ▼ disappearance and extinction of species ▼ changes in structure of eco-systems

Fig. 1: Distinguished effects on nature of the A50 highway.

Effect	Mitigative measures (1st step)	Compensatory measures (2nd step)
Habitat loss		Obtaining land for habitat functions
Habitat disturbance		
- Noise	Sunken road, acoustic walls/baffle boards	
- Hydrological effects	Offset lowered ground-water table (bentonite screen, road geoliner)	Rising ground level (development of moist / wet vegetations)
- Changes in recreational patterns	Two-level crossing (underpass)	Creation of recreational zones elsewhere
Barrier action	Extended bridge sections, fauna tunnels, ecoducts	Closing road to motorized traffic
Fauna casualties	Wire fencing, 'hidden hedges'	In case of 'leak'

Fig 2. Effects distinguished and relationship between mitigation and compensation.

1991). Reijnen & Foppen (1991) have provided strong evidence that noise effects predominate over the other effects of motorized traffic such as air pollution and decreased visibility for fauna. According to their results the width of the disturbance zones can be derived from the combination of traffic intensity, speed limit and timber fraction in the surroundings of a road; the field research data also indicate an approximately 50% loss of the breeding bird population within the disturbance zones of the road.

The contribution to the overall noise impact of raising or sinking parts of the road can be taken into account, although underpinned relationships are not available. In the case of fine scale landscapes, grassland and marshland, elevations above grade are assumed to increase the disturbance zone (width) by 20% compared with at-grade position. In the case of woodland, no correction of the disturbance zone is necessary because of its high sound-insulating properties (adapted from Reijnen *et al.* 1992). A sunken construction is also not subjected to correction, as there appears to be only a negligible reduction of effects.

With sound-suppressing asphaltic concrete (SSAC), the width of the disturbance zone is assumed to be reduced to 80% of that without SSAC.
The effects of traffic noise disturbance on especially breeding birds can be mitigated by means of sound-suppressing structures, since these decrease the width of the disturbance zone. Noise screens 1-3 m and 3-7 m high reduce the disturbance zone width by, respectively, 50% and 80%, compared to the situation without such screens (adapted from Reijnen *et al.* 1992). To achieve the same efficiency, an acoustic wall must be 0.5 m higher than a noise screen. A correction is not applied for sound-suppressing structures when they are combined with sunken road construction and a slight verge gradient (1 in >4), as the large distance between the structure and the road means that there is little reduction of the disturbance zone. It should be noted that sunken construction makes for effective sound-proofing directly behind the acoustic walls (< 100 m) for residential quarters, while the width of the disturbance zone for breeding birds (>200 m) is left unchanged with such measures.
Any effects that still remain after mitigative measures have been taken can only be compensated for by aiming to increase the number of breeding bird territories through nature development (increasing area) and/or enhanced nature management (increasing quality).

Hydrological effects. Depressed water tables can cause disruption of moist and wet vegetation habitats. As a result these sites may disappear completely (e.g. through drying up of pools) or change in species composition (e.g. through diminished quantities of seepage water).
Effects on the water table can be reduced by hydrological isolation. If the road is sunk below grade, use of a road geoliner will in principle leave groundwater flows unchanged. In cases where geological faults are intersected, bentonite screens can be used to offset seepage water losses. Bentonite screens consist of a natural clay material and imitate the impermeability of the undisturbed clay soil prior to intersection. Elevated road construction is another way - although a rather drastic one - of avoiding hydrological effects, since roadside ditches can then be omitted and there is no drainage of surface or seepage water.
Compensation for non-mitigable hydrological effects may take the form of raising the water table elsewhere, allowing development of new moist and wet vegetations.

Road-induced changes in outdoor recreational patterns. Road construction may affect the location of recreational zones, thus disrupting vegetation habitats and reducing fauna densities (cf. Van der Zande & Verstrael 1985). In such cases mitigation should focus on adaptation of the zoning principle, for example by improving recreational facilities near the less vulnerable natural areas.
If it is anticipated that these measures will not sufficiently mitigate the negative impact, roads in the most vulnerable natural areas may be closed to motorized traffic temporarily or permanently. Closing roads locally will compensate for increased disturbance elsewhere in the planning area.

2.2.3 Barrier action
Areas that are ecologically dissected by a road can be connected by structures that diminish the barrier action. Several experiments have shown that structures such as underpasses (culverts, tunnels), overpasses (ecoducts) and extended bridge sections are used by fauna (cf. Hunt *et al.* 1987, Yanes *et al.* 1995). Although little is known about the efficiency of these structures on the scale of animal populations (cf. Nieuwenhuizen & Van Apeldoorn 1995), we assume that these structures are effective for mammals.
For amphibians and reptiles an effective way of reducing the barrier action is to oversize bridge sections so that the bank zones are not interrupted by the road

structure. Effective mitigating measures for insects such as butterflies are not well known; besides the physically absolute barrier action of the road itself, the air displacement of the traffic is also likely to make functional areas on both sides of the road inaccessible for butterflies.

A possible approach to compensating for non-mitigable barrier effects is to close (some of) the roads of the underlying road grid to motorized traffic (as already mentioned above for recreational effects). The aim of closing secondary roads is to improve the quality of nature in the vicinity of a planned road. Compensation must be applied if there is evidence that mitigating measures will be inadequate.

2.2.4 Fauna casualties

Intersection of core areas of fauna may result in casualties. Landscape transitions such as the edges of woods, hedgerows and brook basins, in particular, are often used by animals as routes to foraging or dispersal grounds that may lie on the other side of the road.

In such cases wire fences can reduce the number of fauna casualties, especially for mammals. 'Hidden hedges' (a dry ditch along the road with a very steep bank at the roadside, so that the road itself forms the 'hedge') are visually compatible in open landscapes.

Non-mitigable effects, resulting mainly from 'leaks' in fences and 'hidden hedges' in complex situations such as cloverleaves, qualify for compensation.

2.3 Compensation of the non-mitigative effects based on selected breeding bird species (area size) and the requirements of the vegetation and other fauna groups

Compensation for balancing non-mitigable effects focuses first on area effects (following from the effects of habitat loss and habitat disturbance by noise) and second on quality effects (following from the other types of effects).

2.3.1 Compensation for area effects

For each type of effect of roads on nature, species groups should be selected for use as indicators in the compensation method (see Table 1). Selection is to be based, firstly, on the availability of spatially comprehensive information about the distribution and abundance of plant and animal species and, secondly, on the

Table 1: Types of effects of roads related to types of compensation and species groups that are used as indicators of impacts on nature.

Type of effect	Compensation for area or quality effects	Species groups
Habitat loss	area	breeding birds
Habitat disturbance		
Noise	area	breeding birds
Changes in recreational patterns	quality	vegetation
Hydrological effects	quality	vegetation, fauna
Barrier action	quality	mammals, amphibians and reptiles, butterflies
Fauna casualties	quality	mammals

available knowledge of dose-effect relationships. As both criteria often apply to breeding birds, these can be taken to represent the (overall) effects of habitat loss and disturbance by noise. An additional argument for this choice is that breeding birds of different landscape types are, to a large extent, mutually exclusive in their distribution (cf. Kwak *et al.* 1988).

After mitigation of the effects of habitat disturbance, the compensation area is calculated by multiplying the number of lost and non-mitigated disturbed territories of the selected species by their (estimated) territory size. The territory sizes are specified in terms of a minimum and maximum area, leading to a compensation area range. The minimum territory size is used if the nature quality in the compensation area is expected to be high to very high, i.e. little or no disturbance by human activities, high abiotic potential for nature quality and/or linkage with large natural areas. The maximum territory size is used if the nature quality in the compensation area is expected to be moderate (also in the long term), i.e. moderate disturbance by human activities through urbanization or intensive farming, moderate abiotic potential for nature quality and/or a more or less isolated location.

2.3.2 Compensation for quality effects

Quality compensation is used as an additional tool in cases where particular effects on groups of organisms cannot be quantified. This means that compensation for effects on vegetation and on faunal groups other than breeding birds can be established by appropriate rearrangement measures and nature management in the compensation areas for breeding birds or by closing roads in the vicinity of a planned road. In principle, therefore, qualitatively described impacts do not contribute to area compensation.

2.4 Guidelines for identifying appropriate locations for compensation

The areas that come into consideration for implementing compensatory measures ('search areas') should preferably link up spatially with larger existing natural areas, for two reasons. First, large natural areas contain more species in higher densities than small areas (cf. Spellerberg 1991); and second, management of large natural areas will be more cost-effective than management of small, isolated compensation areas. Furthermore, compensation areas ensuing from deterioration of the habitat quality should be located near the intervention area but outside the disturbance zones of the road, so that natural values can develop undisturbed by the intervention.
From the strategic point of view compensation areas should not to be located in nature areas for which a development strategy is laid down by the government. This accounts at the least for the Dutch National Ecological Network, a coherent configuration of areas in which natural and landscape values are to be conserved, recovered or developed in a sustainable manner (MANF 1990).

3. Application of the method to the A50 road link

3.1 Road plan, planning area and acceptance of the A50

For many years the regional road grid between Eindhoven and Oss (in the centre of the province of Noord-Brabant, S. Netherlands) has been overloaded and has now reached its maximum capacity. The traffic congestion in the rural areas and the city centres has led to a plan for adapting the existing road grid. An Environmental Impact Assessment was drawn up for the new A50 road link scheduled for the region (MTPW 1991, see also Fig. 3 and 4). In 1993 the Minister of Transport and Public Works decreed that the link should be constructed as a dual carriageway (2x2 traffic lanes, divided by a central band). Much of the link is to be constructed by widening the present main road between

Fig 3. Location of the new A50 road link in the province of North Brabant, The Netherlands.

Eindhoven and Oss, although several re-routings are to be established. As planned, the road includes twenty-five overpass junctions. Traffic intensity on the A50 is estimated to be 40-50,000 vehicles per 24 hours (MTPW 1993). From south to north, the following four stretches are distinguished: Son-Nijnsel (S2/N2), Koevering (K), Veghel (V1) and Uden-Oss (U1).

The road is planned in an area of sandy soil. The higher -mainly dry- soils are afforested, with vegetation dominated by more or less aggregated pine, deciduous and mixed woodland. The lower sandy soils and brook basins are surrounded by marshes and mainly wet grassland. In between, there is a variegated, dispersed landscape in which small copses, hedgerows, areas of grassland and arable farmland alternate. The road will intersect these landscapes over a distance of more than 30 kilometres. Moreover, the road is to cross two canals (Wilhelminakanaal and Zuid-Willemsvaart), four brooks (Leijgraaf, Aa, Dommel and Venloop) including their basins, a disused goods railway line and two

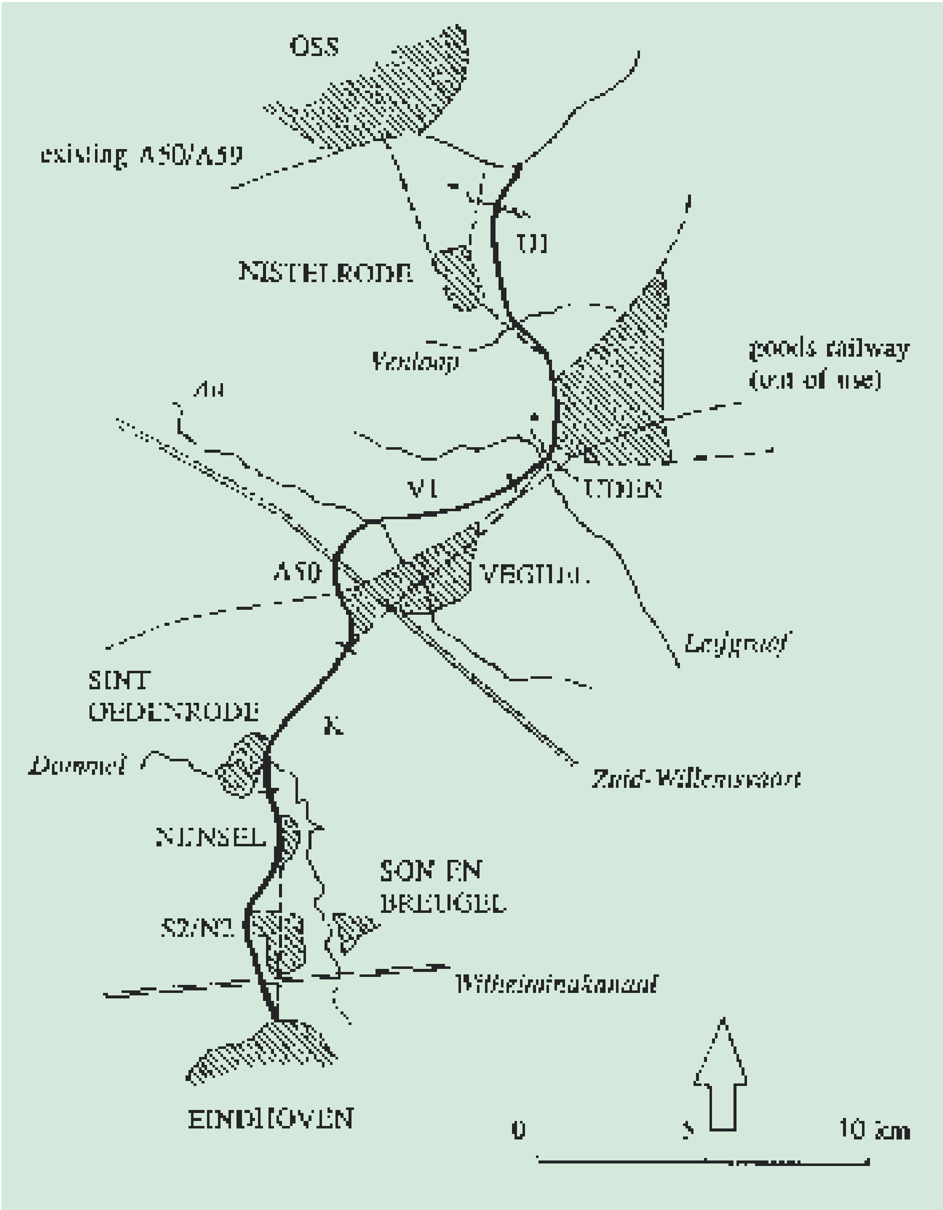

*Fig. 4: Route of the A50 road link. Stretches: S2/N2 Son-Nijnsel, K Koevering, V1 Veghel, U1 Uden-Oss (acronyms correspond with the alternatives in the EIA (MTPW 1991)). * : geological fault; --- : links in present situations.*

geological faults (see Fig. 4). These linear elements are assumed to have (landscape) ecological corridor functions for vegetation and fauna. In the rural areas habitation is scattered and consists of mainly farm-houses.

The road is to be constructed mainly with a standard profile, viz. a width of approx. 45 m, including verges, although in some situations slightly different profiles have been chosen for safety and landscape reasons. To reduce the visibility and noise nuisance of the A50 for a residential quarter of the town of Son en Breugel, over a length of approx. 2,000 m the road is to be semi-sunken, i.e. sunk less than three metres below grade, and shielded with acoustic walls. Between Veghel and Uden 3,300 m of road is to be raised six to seven metres above grade, to overpass the Zuid-Willemsvaart canal and the disused railway line. One side-effect of this elevated construction is to minimize the hydrological effects resulting from dissection of the geological faults.

The road construction plan was received with mixed feelings by the various municipal authorities. On the one hand, re-routing of the A50 relieves two town centres (Veghel and Son en Breugel) of high traffic intensities and the road is therefore strongly supported by these two local authorities. In addition, lateral re-routing will open up industrial zones, thus giving a new impulse to local economic activities. On the other hand, as re-routing is not possible near two other towns (Nijnsel and Sint-Oedenrode), the A50 is expected to have a substantial negative impact on the human environment there. The authorities of these two towns have requested radical measures to offset noise nuisance.
From the outset a number of environmental groups were seriously concerned about the traffic congestion in their region. In the Environmental Impact Assessment they agreed to a ‘zero-plus alternative’ in which the major bottlenecks affecting the quality of life along the road were to be solved by optimizing the existing infrastructure. In this alternative two local re-routings were inevitable, however: near Son en Breugel and between Veghel and Uden. More so than the other options, the zero-plus alternative focused on restricting the growth of motorized traffic in the planning area and strongly supported improvement of public transport facilities (MTPW 1991). The ultimate decision for the 4-lane alternative led to great disappointment among the environmental groups: serious damage to ecosystems and the landscape implies that the ‘quality of life’ objectives will not be achieved.

The government's 'Explanatory Statement' to the road construction decree contained a requirement to draw up an Ecological Compensation Plan (MTPW 1993). As a preliminary to this Plan, an exploratory study was undertaken to prepare a coherent programme of possible compensatory measures (Cuperus & Canters 1994). The preliminary method used in that study is described below. For the distribution of plant and animal species in the planning area of the A50 road link the data reported by Kleijberg & Klooker (1991) were used, with no additional field research being undertaken.

3.2 Quantification of the effects on nature

Information on the civil engineering aspects of the road link were obtained from the A50 Environmental Impact Assessment (MTPW 1991). Engineering aspects relevant to 'dose' parameters were: the geographic location of the road, including associated infrastructure elements (amenities, sliproads, roadsides and ditches), road height relative to grade level, road width, junctions with the existing road grid and expected traffic intensity.

Because of the limited knowledge of breeding bird distributions in the planning area, it was necessary to select some characteristic species for each of the four types of landscape distinguished (cf. Table 2). To avoid dependency on the occurrence of one single species, two species were chosen for each type of landscape. Of each species pair the one that eventually leads -later on in the method- to the highest degree of compensation, i.e. by territory area, is chosen to represent the most unfavourable impact (i.e. worst-case approach).
The impacts of changes in hydrological and recreational patterns, barrier action and fauna casualties are described qualitatively, due to the lack of detailed inventories in the planning area of the A50 (cf. Kleijberg & Klooker 1991).

The disturbance zone along the A50 road was estimated to be 500 m wide for woodland bird species and 1,500 m wide for species of fine scale landscapes, grassland and marshland. The effects of habitat loss and disturbance by noise are quantified in Table 3A. The data show that the effects of habitat loss are restricted to the selected species of fine scale landscapes. Along the S2/N2 and K stretches the selected species of the four landscapes are disturbed by noise to roughly the same extent, while along the V1 and U1 stretches effects on the

Table 2: Selected species and their territory size, based on data from the Netherlands and - if not available - from comparable habitat types in Europe (Cramp et al. 1983, Glutz von Blotzheim 1973-1993).

Type of landscape	Selected species	[a] Territory size (in hectares)
woodland	Golden oriole *Oriolus oriolus*	5-10
	Green woodpecker *Picus viridus*	5-10
fine scale landscape	Partridge *Perdix perdix*	[b] 10-20
	Whitethroat *Sylvia communis*	[b] 2-4
grass-land	Black-tailed godwit *Limosa limosa*	2-4
	Snipe *Gallinago gallinago*	2-4
marshland	Reed warbler *Acrocephalus scirpaceus*	2-4
	Water rail *Rallus aquaticus*	2-4

[a]: The territory sizes of 2-4, 5-10 and 10-20 hectares correspond with circular territories with a radius of 80-115, 125-180 and 180-250 metres, respectively.

[b]: Includes the area of linear elements (wooded belts, hedgerows).

species of woodland and fine scale landscapes predominate. The data show, furthermore, that along the K stretch the effects of habitat disturbance on the selected species of fine scale landscapes are minor; despite the presence of the Dommel brook there is only moderate disturbance of the grassland and marsh species.

The qualitatively described effects occur mainly on the S2/N2 and U1 stretches (cf. Table 3B). As no hydrological research has been undertaken in the planning area, it was not possible to estimate the extent of such effects. groundwater-dependent vegetations were considered to be affected within 500 m of the road (i.e. worst-case approach). The hydrological changes resulting from construction of the A50 link are expected to affect a pool in the woods of Sonse Heide (at a distance of 400 m from the S2/N2 stretch) and the immediate neighbourhood of the two dissected geological faults (U1). The road is furthermore expected to affect the recreational zoning as established in the Maashorst National Park (approx. 4,000 ha) along the U1 stretch. The National Park is visited by 8-900,000 people annually and the A50 intervention will lead to shifts in recreational activities towards areas which are now already extensively used.

Table 3. Quantitative (3A) and qualitative (3B) description of the effects of the A50 highway and the effectiveness of the proposed mitigative measures.

3A. Effects of the A50 highway: habitat loss ('loss') and disturbance by noise ('disturb'), expressed as number of territories of the selected species lost, summarized per habitat type and stretch (s). Remaining and/or non-mitigable effects (r) are indicated after application of sound-suppressing asphaltic concrete (SSAC) and acoustic walls according to the preliminary method (cf. Table 4).

Landscape/species	**Stretch**							
	Son-Nijnsel (*S2/N2*)		Koevering (*K*)		Veghel (*V1*)		Uden-Oss (*U1*)	
	loss s/r	disturb s/r	loss s/r	disturb s/r	loss s/r	disturb s/r	loss s/r	disturb s/r
- woodland								
Golden oriole	0/0	2/0	0/0	1/1	0/0	5/1	0/0	4/1
Green woodpecker	0/0	2/0	0/0	2/2	0/0	4/1	0/0	4/1
- fine scale landscape								
Partridge	0/0	6/5	0/0	3/2	2/2	14/11	2/2	11/9
Whitethroat	1/1	25/20	0/0	9/7	2/2	74/59	9/9	43/32
- grassland								
Black-tailed godwit	0/0	5/4	0/0	8/6	0/0	3/2	0/0	0/0
Snipe	0/0	2/2	0/0	0/0	0/0	1/1	0/0	1/1
- marshland								
Reed warbler	0/0	3/0	0/0	1/1	0/0	1/1	0/0	0/0
Water rail	0/0	0/0	0/0	1/1	0/0	1/1	0/0	0/0

3B. Assessment of the magnitude of effects per stretch (s). Remaining and/or non-mitigable effects (r) are assessed after application of the proposed fauna and/or recreation underpasses, 'hidden hedges'/wire fences, bentonite screens and extended bridge sections according to the preliminary method (cf. Table 4).

Effect	**Stretch**			
	Son-Nijnsel (*S2/N2*) s/r	Koevering (*K*) s/r	Veghel (*V1*) s/r	Uden-Oss (*U1*) s/r
hydrological effects	--/o	o/o	o/o	--/o
changes in recreational patterns	o/o	o/o	o/o	--/o
barrier action				
Badger	o/o	o/o	o/o	--/-
other mammals	--/-	o/o	--/o	--/o
amphibians & reptiles	--/-	--/o	--/o	--/o
butterflies	--/--	-/-	-/-	-/-
fauna casualties	-/o	o/o	o/o	-/-

Assessment of effects: o = absent to minor; - = moderate; -- = (very) serious.

3.3 Derivation of mitigative measures

The preliminary method proposes mitigative measures for specific species as well as for groups of organisms. The frequency of mitigative measures depends on the number of bottlenecks for the fauna along the road. Fauna underpasses (tunnels) with a cross-section of 2.5*1.75 m are proposed at locations where the dispersal or foraging routes of larger mammals, in particular Roe deer for the A50 planning area, are intersected. Smaller mammals, e.g. the Mustelidae: Stoat *Mustela ermina*, Weasel *Mustela nevalis* and Polecat *Mustela putorius*, will also benefit from these underpasses. In cases where the habitat of medium-sized mammals such as the Red fox *Vulpes vulpes* and Badger *Meles meles* is intersected, fauna tunnels with an entrance diameter of 0.50 m are proposed. In Badger habitats these tunnels should be spaced 250 m apart on average, and 125 m apart if setts are located less than 200 m from the road. For species other than the Badger the suggested average spacing of the tunnels (of the same diameter) is 200 m (cf. Van Nierop 1988). Fauna tunnels should be shielded from high groundwater levels so that animal passage is guaranteed.

The use of acoustic walls combined with planted elements and wire fences is restricted to woods and fine scale landscapes. Application of acoustic walls in open landscapes would mean a deterioration in the appearance of the landscape for characteristic species; meadow bird species, for example, profit from the openness of grassland and arable land habitats. 'Hidden hedge' constructions can be applied in all types of landscape, however, as they are not anticipated to have any negative impact on the fauna.

The mitigative measures derived from the effects (cf. Tables 3A,B) are presented in Table 4A. Wire fences are proposed behind the acoustic walls in woodland (total length 25 km) to facilitate combined application with fauna underpasses. Two larger underpasses (2.5*1.75 m), in the U1 stretch, are designed to improve the permeability of the road to Roe deer, Badger and Red fox in the Maashorst National Park. The twenty smaller underpasses (∅ 0.50 m) are concentrated in the V1 and U1 stretches, where the road intersects Wijboschbroek and Maashorst, respectively, two core areas for Mustelidae. Since underpasses cannot be built along the sunken S2/N2 stretch, a viaduct is proposed, combined with a fauna

Table 4: Summary of mitigative and compensatory measures in the A50 highway planning area according to the preliminary method. Sound-suppressing asphaltic concrete (SSAC) is used over the full length of the road link.

4A. Mitigative measures	**length/number**
Acoustic walls (height >3.5 m)	[a] 25 km
Wire fencing (height >1 m)	[a] 25 km
'Hidden hedge' (height >1 m)	[a] 6.5 km
Road foliation	2 km
Bentonite screen	2 x
Fauna underpass (tunnel ∅ 0.50 m)	20 x
Fauna underpass (tunnel 2.5*1.75 m)	2 x
Recreation underpass (width 8 m) [b]	1 x
Extended bridge sections; brooks (2xΔ10 m)	4 x
Extended bridge sections; canals (2xΔ10 m)	2 x
Extended viaduct over sunken A50; fauna overpass	1 x
4B. Compensatory measures	**number/area**
Acquisition, design and management of [c]:	
- woodland	30-60 ha
- fine scale landscape	[d] 345-665 ha
- grassland	26-52 ha
- marshland	4-8 ha
Closing roads to motorized traffic (1-2.5 km)	3 x

[a] Total length of double-sided application.

[b] Also designed for use by fauna.

[c] Total area of 405-785 ha, dependent on the location and expected nature quality of the compensation area, should be obtained by acquisition, design and management.

[d] I.e. 320-640 ha compensation for effects on breeding birds and 25 ha compensation for loss of Badger habitat.

overpass, i.e. a strip of vegetation 2 m wide providing an ecological link between the two halves of the dissected woodland.

Bridges are proposed at six locations, to be extended by 10 m on both sides to avoid interruption of bank zones. Use of road geoliners over a distance of approx. 2,000 m (S2/N2) and two bentonite screens (V1, U1) is proposed, to offset depression of the water table. A recreation underpass is proposed to restore the recreational zoning of the National Park. The underpass can be designed for use by fauna at the same time.

Due to the qualitative descriptions, impacts on water table, recreational patterns and fauna casualties, are not considered further in deriving compensatory measures.

3.4 Derivation of compensatory measures

3.4.1 Compensation for area effects

Those territories of the selected species lost as a result of the new road and those still disturbed by noise (after mitigation) qualify for compensation. The non-mitigable disturbance effects are indicated in Table 3A, in terms of territory numbers. The table shows that, although the use of acoustic walls is restricted to woods, fine scale landscapes also benefit from soundproofing as they alternate with or are adjacent to wooded areas. This is also the case for the marsh species Reed warbler *Acrocephalus scirpaceus* along the S2/N2 stretch. Use of sound-suppressing asphaltic concrete (SSAC) appears to mitigate disturbance of the grassland species Black-tailed godwit *Limosa limosa* and Snipe *Gallinago gallinago* to a limited extent only. In addition, also twenty-five hectares of Badger habitat, not covered by territories of the bird species, will become unsuitable for habitation because of the extensive cloverleaf situation connecting the A50 with the existing road near Oss. In spite of 'hidden hedges' and wire fences, leaks will remain. This lost Badger habitat should be compensated for.

3.4.2 Compensation for quality effects

The contribution of quality compensation is relatively limited (cf. Table 3B). All the effects are assumed to be mitigated except for the barrier effects on the Badger (along U1), on 'other mammals' (along S2/N2, mainly Mustelidae), on amphibians and reptiles (along S2/N2; eight species, i.e. Pool Frog *Rana lessonae*, Viviparous Lizard *Lacerta vivipara* and Alpine Newt *Triturus alpestris*) and on butterflies (along all stretches; approx. 40 species of various habitat types). Barrier effects on these species must be compensated for in the compensation area for breeding birds.

3.4.3 Summary of compensatory measures

Application of the described method to the A50 road link yields the measures summarized in Table 4B. The range in the size of the compensation area, 405-785 ha, follows from uncertainties about the anticipated long-term quality of habitats. The net compensation area includes 25 ha of lost Badger habitat (cf. Table 4B: 'fine scale landscape'). Twelve search areas for compensation are indicated along the stretches S2/N2 (4x), K (2x), V1 (3x) and U1 (3x). The net search area is highly oversized (i.e. two to three times the required area), thus giving ample scope for determining the exact locations of the compensation areas through negotiations with municipal authorities and other interested parties. The compensation areas should be designed and managed making due allowance for the barrier effects of the road, as indicated above.

3.5 Location of the compensation areas

The search area locations for compensation follow directly from three provincial spatial plans relevant to the A50 planning area (Province of Noord-Brabant 1993). Under the terms of the Green Network provincial planning policy excludes further establishment or expansion of industry, and aims to improve extensive agriculture. The Provincial Ecological Network provides the backbone of natural functions in North Brabant. By means of this network, nature quality and diversity are to be improved according to well-defined 'target types for nature'. Under the terms of the Agricultural Structure zoning policy, intensive farming operations are to be optimized within the existing environmental context. There is a considerable overlap between the (Provincial) Ecological Network and the Green Network, while the Agricultural Structure is spatially distinct from these two networks.
Search areas for compensation must be situated outside the Agricultural Structure area, since present farming management may not be affected. The compensatory

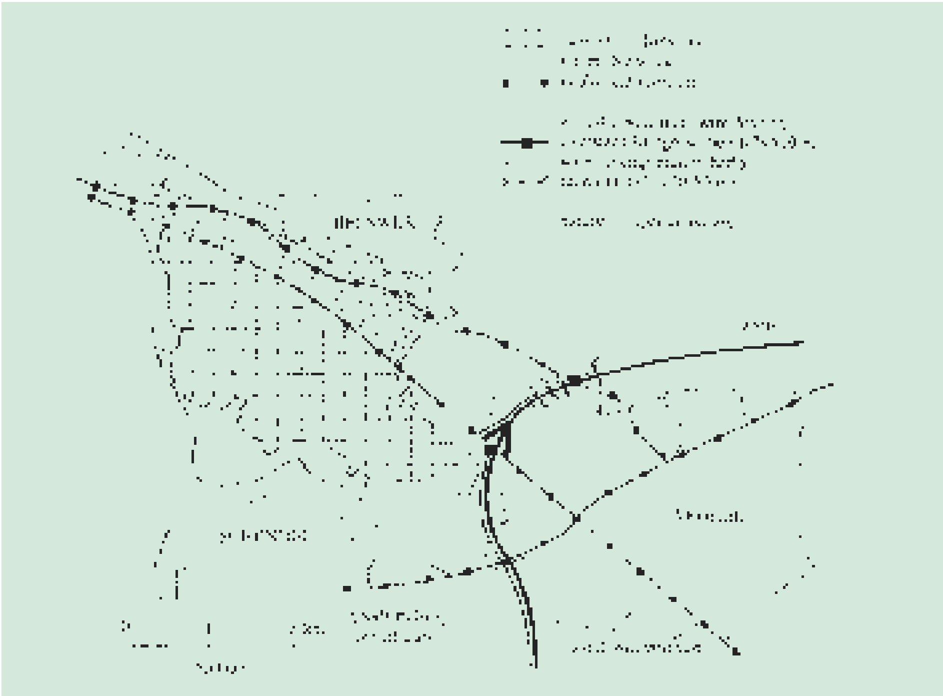

Fig. 5: Survey of mitigative measures and the search area for ecological compensation along the Veghel stretch (V1). The search area is oversized in comparison with the calculated compensation area (150-300 ha).

measures should also preferably not been implemented in the Ecological Network, as current provincial policy aims to protect or develop this Network and land is available for compensation purposes outside the Network. Thus, the potential area for compensatory measures, i.e. for establishing ecological functions and/or improving nature quality, is that part of the Green Network not overlapping the Ecological Network.

Although in conflict with one of the basis points of departure, it proved impossible to avoid location of some of the search areas in Agricultural Structure zones. This was true of the K stretch, in particular, where one of the compensation options is to connect the two divided Dommel brook basin areas through extension of the natural values adjacent to the A50 bridge span, an area in use as farmland. Three other search areas have also been located in Agricultural Structure zones, as implementation there would enhance the natural values in nature development areas. These areas are: an agricultural area adjacent to woods (S2/N2), an extensive part of the Aa brook basin adjacent to Wijboschbroek (V1, see Fig. 5) and an agricultural enclave in Maashorst (U1).

The minor effect of barrier-weakening measures along the S2/N2 stretch (i.e. an extended viaduct over the sunken part of the road) makes compensation necessary in the form of closing one road (length approx. 1.2 km) of the underlying road grid to motorized traffic. Two other roads (lengths approx. 2 and 2.5 km) near the U1 stretch are also eligible for closing, to overcome uncertainties in assessing the barrier action of the A50. These roads would become alternative, ‘short-cut’ routes after realization of the A50; their closure will relieve the badger population along the U1 stretch, in particular.

4. Towards the Final Ecological Compensation Plan

4.1 The Draft Compensation Plan

The Draft CP, drawn up by the Regional Directorate of Public Works and Water Management of the province of Noord-Brabant (MTPW 1995a), follows from the results of Cuperus & Canters (1994). Compared with the preliminary version, the Draft CP was modified in the following respects (compare Table 5A with Table 4A):

(a) In the Draft Plan acoustic walls are no longer applied. Their efficiency, i.e. the reduction of the number of disturbed territories of species of woodland and fine scale landscapes (cf. Table 3A) in relation to the costs, is considered to be too small. Noise effects are compensated directly.

(b) Wire fencing to prevent fauna casualties are assumed to be just as effective as ‘hidden hedges’. ‘Hidden hedges’ are therefore not included in the Draft CP, but replaced by fences.

(c) As the compensation areas will be realized by developing optimal natural areas, the Regional Directorate has made use of the minimum territory sizes of the selected species of woodland, grassland and marshland (cf. Table 1). For the species of fine scale landscapes a different approach was followed, as these are now considered - contrary to the preliminary method - to be compatible with agricultural management. ‘Condensing’ of agricultural land, by increasing the figure of 4,000 m of wooded belts, hedgerows and/or wildflower margins per 100 ha in the basic design (existing situation) to 8,000 m in the optimal design, is expected to lead to increased densities of Partridge *Perdix perdix* and Whitethroat *Sylvia communis*. This step is assumed to have no deleterious impact on farm management. Mitigative and compensatory measures for impacts on fine scale landscapes are derived as follows. Each lost Partridge or Whitethroat territory is compensated for by the development of 4 and 2 ha shrubland, respectively. For each disturbed Partridge and Whitethroat territory, the compensatory measures take the form of creating 160 m (i.e. 0.16 ha) of wildflower margins or 80 m (i.e. 0.08 ha) of wooded belts and hedgerows, respectively, within the 1,500 m disturbance zone (mitigation) as well as outside the disturbance zone (compensation).

(d) The fauna overpass combined with a viaduct (S2/N2) was considered to be pointless.

(e) Planting linear landscape elements within the disturbance zone over 298 ha of grassland and arable land is applied as a mitigative measure for the impact of traffic noise, which implies the planting of 12 ha of linear elements in the Agricultural Structure zone.

(f) As a final step, the Draft CP adds a surplus to the calculated compensation area for some landscape categories because of the interim period during which the lost quality standard will not be achieved in the compensation area. This quality surplus is determined as a function of the replaceability of the lost qualities and amounts to 1/3 of the compensation area for grassland and fine scale landscapes and 2/3 of the compensation area for woodland and marshland. This means that lost and disturbed territories of the selected species of grassland/fine scale landscapes and woodland/marshland are compensated for area and quality losses by applying factors of, respectively, $1^{1/3}$ and $1^{2/3}$.

The resultant compensation area according to the Draft CP is summarized in Table 5B. The area to be used for compensation purposes is seen to be 25-50% the size of that according to the preliminary method (cf. Table 4B), despite omission of the acoustic walls and introduction of the quality surplus in the Draft Plan. This reduction in size is due to use of the minimum size of the selected species' territories and particularly to the 'condensation' of agricultural land

Table 5: Summary of mitigative and compensatory measures in A50 highway planning area according to the Draft Ecological Compensation Plan (MTPW 1995a). SSAC is used over the full length of the A50.

(5A) Mitigative measures	**Length / number / area**
Wire fencing (height >1 m)	31,5 km
Road geoliners	[a]2 km
Bentonite screen	2x
Fauna underpass (tunnel ∅ 0.50 m)	20x
Fauna underpass (tunnel 2.5*1.75 m)	2x
Recreation/fauna underpass (width 8 m)	1x
Extended bridge sections; brooks (2xΔ10 m)	4x
Extended bridge sections; canals (2xΔ10 m)	2x
Optimal design fine scale landscape [b]	12 ha
(5B) Compensatory measures	**Area (ha)**
Acquisition, design and management of [c]:	
- woodland	109
- fine scale landscape [d]	12
- shrubland	25
- grassland/marshland	56

[a] Total length of double-sided application.
[b] Mitigative measures, i.e. plantation of 12 ha linear elements, applied to 298 ha of agricultural land *within* the disturbance zone.
[c] Total area: 202 ha.
[d] Compensatory measures, i.e. plantation of 12 ha linear elements, applied to 298 ha of agricultural land *outside* the disturbance zone.

through the planting of linear elements in the Agricultural Structure zone outside the disturbance zone. These ‘condensation’ activities imply prior agreement being reached with the agricultural interest groups. In comparison with the results of the preliminary method the Draft CP yields a greater amount of woodland, owing to the quality surplus for this type of habitat.

In interim negotiations with the parties concerned, five search areas identified in the preliminary method proved to be unsuitable, for administrative reasons. At the same time, new search areas revealed more convenient locations for compensation (five areas were added). In the Draft Plan six search areas proposed in the preliminary method have been enlarged by adjusting and/or moving their boundaries. One search area was adopted without modification (cf. MTPW 1995a).

4.2 The Final Compensation Plan

Although not laid down by law, the Draft CP was sent to interested parties in the region to give the public an opportunity to give their comments. In the four-week period provided - the month of March 1995 - 41 comments were received by the Regional Directorate of Public Works and Water Management (cf. MTPW 1995b). The principal areas of comment on the Draft Plan were as follows:

(a) The environmental groups emphasized the uncertainties in the compensation methodology, e.g. indications of territory size, and the risk of underestimating the impacts on other groups of organisms besides breeding birds. Furthermore, the underpinning of the choice of species representing habitat loss and disturbance effects was considered disputable. Although the Regional Directorate considered the species to be representative of the landscape types in question and sensitive to infrastructural interventions, the Directorate expected a certain amount of overlap of the habitats of the various groups of organisms. However, the Directorate did not consider it necessary to adapt the size of the compensation areas for reasons of representativeness or sensitivity.

(b) The impact of habitat loss on birds and amphibians was considered to be under-estimated. It was brought forward that a large area of woodland that will be lost to the road was not covered by territories of the selected species nor by amphibian habitat. To offset the underestimation of the impact of habitat loss on birds, in the Draft Plan 36 ha of woodland and 6 ha of grassland/arable land have now been added to the compensation area. For amphibians additional measures, such as the creation of toad pools, will be realized in the compensation areas (viz. in the 'condensed' agricultural landscapes).

(c) The fauna underpasses are held to be insufficiently linked, ecologically, with the landscape in the Draft Plan. To overcome this problem, the fine scale landscapes that are to be developed will be located, where possible, around these underpasses in order to intensify ecological connections.

(d) Several new search areas were suggested during participation by the public. As a result, in the Definitive Plan four new areas have been added to the list of search areas.
(e) The agricultural interest groups agree, in principle, with the plantation of linear elements along farm lots. In their view, though, there is too much emphasis on the voluntary willingness of farmers to cope with the ‘condensing’ objectives.

In June 1995 the Definitive Plan (MTPW 1995d) was approved by the Minister of Transport, Public Works and Water Management. Besides the proposed measures along the A50 (Table 5A) the Definitive Plan consists of the development of 145 ha of woodland, 24 ha of shrubland, 62 ha of grassland/marshland and the ‘condensation’ of approx. 600 ha of agricultural land (50% inside and 50% outside the A50 disturbance zone; cf. Table 5B). The precise nature of the compensation plan is to be established before the year 2003. The Regional Directorate has already started acquiring land for compensation purposes.

4.3 Implementation and realization of ecological compensation

The Regional Directorate has practical experience with the envisaged mitigative measures. However, realization of the compensatory measures will be hampered by the current lack of a legal basis for the compensation principle. Policy-making is in progress for scheduled areas of special governmental interest, such as the Ecological Network. Until this process has been completed, the present policy instruments must be used, particularly those applicable to land use and land consolidation activities. Compensation areas can still be designated by the exchange and purchase of land in the ‘Sint Oedenrode’ reallotment scheme which has recently been set in progress in the centre of the A50 planning area. Another possibility is to make use of the scope for so-called ‘land adaptation’, within the framework of the Land Use Act. This act enables the negative impact of infrastructural works on their surroundings to be mitigated or compensated (MANF 1993). A potential area for a ‘land adaptation’ approach can be found west of the line of towns Veghel-Uden-Nistelrode.

As the Definitive Ecological Compensation Plan has recently been approved, agreements on the extent and location of the compensation areas should be forthcoming in negotiations between the parties involved (i.e. municipal authorities, nature conservation organizations and environmental groups). After agreement has been reached, the compensation locations must be incorporated in the zoning plans by the local authorities with properties along the road. A promising perspective in the negotiation process is the increasing contribution of agricultural interest groups to possible realization of nature conservation objectives. This is a lucky circumstance in a country where every hectare of land is usually claimed by more than one societal function.

An important aspect of realizing the compensation objectives is the announcement that progress is to be monitored in the form of annual reports. Such monitoring may result in adjustment of the measures in cases where the compensation objectives are not fully achieved.

5. Conclusions and discussion

5.1 Comments on the preliminary method

As there was no method available for determining the extent and type of ecological compensation, a preliminary method was developed for the A50 road link. Breeding birds play an important role in the method and are used to quantify the impacts of habitat loss and habitat disturbance by traffic noise. The dominant role of breeding birds is based on the following facts:

(a) compared to other species groups, spatially comprehensive information on breeding birds was, although limited, the best available (cf. Kleijberg & Klooker 1991);
(b) breeding birds are assumed to be useful indicators for the presence of different types of landscape (Kwak *et al.* 1988);
(c) the dose-effect relations for disturbance by noise are relatively well-underpinned for breeding birds (Reijnen & Foppen 1991, Reijnen *et al.* 1992);
(d) breeding birds are disturbed by traffic noise over a relatively long distance (Van der Zande *et al.* 1980).

Nevertheless, several critical remarks should be made. Firstly, by assessing the territories of the selected characteristic breeding birds that are to be dissected by

the A50, lost habitat sites not covered by any of these territories are neglected. This follows from the implicit focus of the method on actual habitat sites, with potential ecological values not being taken into consideration. Although 'no selected species territory present' may suggest 'the absence of corresponding habitat quality', we assume that this problem is of relatively minor importance. Argument for this is that a lost territory is bigger than the area strictly destroyed by the road and, consequently, that the totalized surplus will balance the total extent of habitat not covered by any territory.
Secondly, the lack of detailed information, leading to qualitative descriptions, has resulted in underestimating the extent of compensatory measures. Effects on hydrology, recreational patterns and fauna casualties were not considered in determining the size of the compensation area. So, a no-net-loss situation will not be reached completely when significant knowledge is lacking. This can be used as an argument to compensate more for quantitative effects than the compensation that follows from the corresponding dose-effect relations (i.e. by so-called overcompensation).

5.2 The Ecological Compensation Plan versus the results of the preliminary method

As initiator of the A50 road construction project, the North Brabant Regional Directorate of Public Works and Water Management has drawn up an Ecological Compensation Plan for the road link, using the results of the preliminary method and the opportunity for public comment. In the process of formulating the CP, the Regional Directorate has demonstrated its serious intention to compensate for impacts on nature. Still, several uncertainties in the compensation methodology have to be solved.
Two major new aspects of the Final CP proved to result in considerable differences in measures compared with the preliminary method: introduction of the 'condensing' objective in the Agricultural Structure and omission of acoustic walls. It is clear that both of these will have to be critically discussed during further development of the compensation method.
The role of interest groups appeared to be of great importance for the Final CP. On the one hand interest groups can bring forward extensive knowledge of natural values in the planning area (i.e. the introduction of alternative search areas for compensation in the Plan). On the other hand, the implementation of

their comments in the Final CP will promote the public support for the intervention, which will work out positively especially when interest groups participate in designing and managing the future compensation areas (i.e. individual farmers and nature trust organisations).

5.3 Further developments

The Final CP is rooted in the preliminary method. Experience with the A50 road link and other case studies will lead to elaboration of a more robust compensation method for road projects. As mentioned above, the method will be adjusted for the aspects of landscape 'condensing' and direct compensation through omission of mitigative measures such as acoustic walls.
Furthermore, consideration might be given to incorporating losses of bird communities rather than specific bird species in the method. The choice of characteristic species for the various types of landscape and the estimation of their territory sizes are two aspects that are open to question, being subject to regional differences. Working at the community level makes the method less dependent on maximum and minimum territory sizes, so that a more robust method can be obtained. It should be noted that new dose-effect relations for the different aspects of communities are to be established. At the same time, efforts should be made to offset the underestimation of qualitatively described impacts on vegetation and groups of organisms other than birds in the preliminary method. This offset must enable us to reach a no-net-loss situation for area and quality.
The implications of the lack of certain relevant information will also be evaluated, to adjust the method and thus make it a useful tool for future road projects. An important aspect in this context will be the search for compatibility with the government's Structure Plan for the Rural Areas in the Netherlands (MANF & MHPE 1993), which sets out legislation and other regulations relating to ecological compensation programmes.

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