Ecological compensation of highway impacts; negotiated trade-off or no-net-loss?

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Chapter 3

Guidelines for ecological compensation associated with highways

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Guidelines for ecological compensation associated with highways

Abstract
Avoidance, mitigation and compensation are three planning concepts designed to counteract the adverse impacts of infrastructure on nature. To promote the compensation principle introduced in the Netherlands, this article proposes guidelines for its implementation in the context of highway development. To this end, a coherent framework has been developed comprising: (a) impacts on nature, (b) concepts for use in planning ecological compensation, and (c) ecological, spatial-planning and financial instruments for realizing such compensation. Finally, Dutch experience is discussed within the international context. Recommendations are made for improving the implementation of compensation. These stress the importance of creating 'win-win' situations to increase public support, of dealing with impacts that cannot be predicted, and of developing criteria for evaluating compensation plans. There are still several priority problems to be dealt with: the effects of habitat isolation caused by highway projects, the effectiveness of compensation measures and compensation ratios (viz. ratios of replaced to lost area) greater than one, the real costs associated with replacing habitats, the feasibility of compensation for ecological values that are difficult to replace, and the strategy to exchange impacted and substitute habitats.

Keywords: policy, planning, realization, legislation, instruments, costs.

1. Introduction

The construction and use of highways imply the loss, degradation and fragmentation of habitats (Andrews 1990, Bennett 1991, Atkin-son & Cairns 1992, Forman & Hersperger 1996, Canters 1997). Increased awareness of environmental problems caused by infrastructure has moved civil engineers, ecologists and policy-makers to develop planning concepts to deal with the impacts on nature and landscape, as embodied, for example, in the US National Environmental Policy Act (NEPA) regulations (1969). The first, and most fundamental approach is to avoid adverse impacts. Avoidance can be achieved by

simply not pursuing a certain development, by generating an alternative for the development or by limiting the intensity or magnitude of the development. If avoidance is not feasible, mitigation measures can be undertaken as a second planning concept. Such measures are designed to reduce or sometimes even eliminate the impacts of a given development on nature. Today, it is common practice worldwide to back up highway projects with mitigation measures, such as ecological management of roadside verges (Way 1977), fauna tunnels (Hunt *et al.* 1987, Bekker & Canters 1997), adapted culverts (Yanes *et al.* 1995) and ecoducts (Friedman 1995, Pfister & Keller 1995) for wildlife movements.

Recently, a third concept has been developed. Based on the experience that impacts may still persist after mitigation, several states and countries have adopted a compensation principle, envisaged as counterbalancing the adverse impacts of developments on nature. Examples of such a principle are: the German *Eingriffsregelung* (functioning since 1976, cf. Meier 1987), the US no-net-loss policy for wetlands (since 1986, cf. Section 404 of the Clean Water Act), and the Dutch compensation principle for spatial protected areas (since 1993, cf. MANF & MHPE 1993). This concept explicitly incorporates nature conservation interests in decision-making on spatial developments. The initial consequences of the compensation principle for Dutch highways have been discussed by Van Bohemen (1995). However, the principle has raised urgent questions about the basis for its implementation.

This article proposes guidelines for implementing the compensation principle in the context of highway development. After defining the setting of ecological compensation (section 2), the impacts of highways on nature (3) are briefly described. Subsequently, concepts for use in planning ecological compensation measures (4) and instruments for their practical realization (5) are presented. The article concludes with a discussion of evolving Dutch experience in the international context and identifies problems that are still to be solved (6).

2. The setting of ecological compensation

Ecological compensation is defined here as the substitution of ecological functions or qualities that are impaired by (highway) development (Cuperus *et al.* 1996). Such compensation aims either to improve damaged areas or to create new

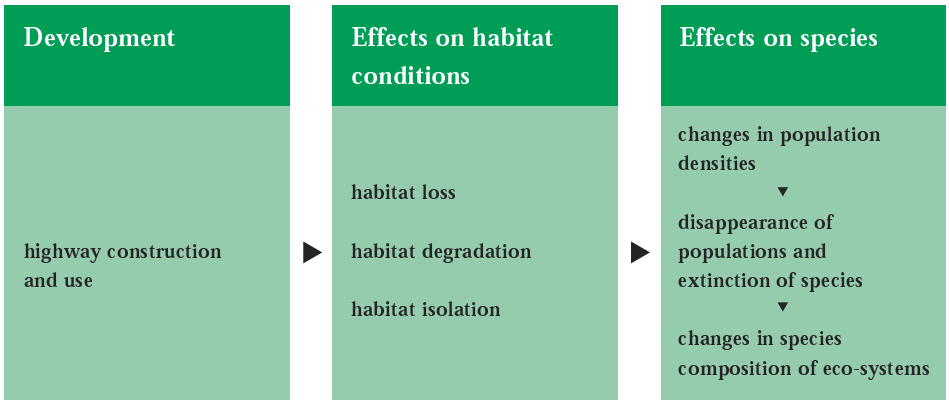

Fig. 1: Distinguished effects of highways on nature (adapted from: Cuperus et al. 1996).

habitat with ecological functions and quality attributes (Allen & Feddema 1996). Fundamentally, this does not differ from ecological restoration or habitat creation (Anderson 1995, Wyant *et al.* 1995), except that it is associated with adverse impacts on nature due to development. Moreover, in contrast to mitigation measures, ecological compensation is generally undertaken outside the highway management area.

The distinction made between the three planning concepts employed here — avoidance, mitigation, compensation — deviates from current international terminology. This describes 'mitigation' as any activity that avoids, minimizes, rectifies, reduces or compensates for the effects of environmental damage (NEPA 1970, National Research Council 1992). However, our concepts stress the three fundamen-tally different approaches to counteracting the impacts of a development. Within this framework, 'mitigation' contracts the NEPA interpreta-tion to 'minimizing, rectifying and reducing' effects. The terms 'avoidance' and 'compensation' are thus taken to refer to two specific issues, and to bypass the compound term 'compensatory mitigation' (cf. Bedford 1996). This article focuses on the problems and solutions associated with compensation measures in the stricter sense defined above.

3. Effects of highways on nature

Developments generally affect ecological values by modifying (abiotic) habitat conditions, which in turn influence the abundance and distribution of plant and animal species in the impacted areas. Ecological compensation may require no-net-loss of habitat conditions (cf. Adamus *et al.* 1987), of habitat types (U.S. Fish and Wildlife Service 1980), of species populations (Nilsson & Grelsson 1995), of populations of species groups (e.g. ecotopes for vegetation: Runhaar & Udo de Haes 1994), or of ecological functions (Brinson & Reinhardt 1996), all to the extent that they have ecological significance or characterize a specific ecological site. Before considering the planning and realization of compensation measures (see sections 4 and 5), we distinguish three primary effects of highways on nature in terms of changed habitat conditions, viz. the loss, degradation and isolation of habitat (Fig. 1).

3.1 Habitat loss

There is strong evidence that habitat loss is a problem for species in many habitats, implying serious threats to local and regional populations (cf. Reed 1995, Thomas 1995). Between the mid-1970s and mid-1980s annual wetland losses in the USA due to infrastructure amounted to about 1,050 km^2 (Mitchell 1992), i.e. 0.02% of rural land in the USA. Over the period 1980-1993 construction of Dutch rural metalled roads (including verges and road ditches) caused about 180 km^2 of habitat loss, an annual loss of 0.04% of rural land in the Netherlands (Central Statistical Office 1996).

3.2 Habitat degradation

Although habitat patches remain physically accessible to species, the construction and use of highways may lead to a decline in habitat quality in zones adjacent to the infrastructure. This decline may be due to noise, visual disturbance (e.g. illumination), changes in water table and microclimate, and the spread of toxic substances mainly by air and water pollution. These qualitative effects may result in decreased densities of species sensitive to the development, as is the case, for example, with woodland and meadow-bird populations exposed to the noise of car traffic (Reijnen *et al.* 1995, 1996).

3.3 Habitat isolation

Infrastructure may lead to a reduced exchange of species between populations, as a result of increased landscape resistance through barrier effects, and higher mortality rates through fauna casualties (cf. Andrews 1990, Saunders *et al.* 1991). Habitat isolation undermines the persistence of stable (meta)populations, in which local extinction and recolonization are well-balanced.

As metapopulation dynamics are complex, it is still scarcely feasible to make a quantitative assessment of the habitat isolation effects of infrastructure. Extinction thresholds and minimal viabilities of (meta)populations of single species have been demonstrated in theoretical models (Bascompte & Solé 1996, Hanski *et al.* 1996), but appear difficult to prove quantitatively in realistic situations (Opdam *et al.* 1994). This makes it all the more logical to adopt multiple-species approaches. Initial attempts at quantitative assessment are currently in progress in the context of introducing infrastructure-related compensation measures in single-species metapopulation models (cf. Van Apeldoorn 1997).

Secondary effects of highways, i.e. on species (cf. Fig. 1), are dependent on both species and landscape characteristics. The role of species characteristics is illustrated by (a) barrier effects decreasing and mortality effects increasing with increasing mammal size (Verboom 1996), and (b) specialist species being more vulnerable to development than generalists (Andrén 1994) or species with a restricted range (Simberloff 1994). On the other hand, landscape characteristics also determine the stability of populations: as more habitats are fragmented, the persistence of populations becomes increasingly dependent on the spatial arrangement and decreasingly dependent on the total number of suitable habitats (Andrén 1994).

4. Planning principles behind ecological compensation in the Netherlands

Recent experiences in Dutch highway projects provide opportunities for developing a new approach in which the different types of ecological compensation can be better combined with highway planning. The type of ecological compensation to be adopted depends on two aspects (e.g. Brinson &

Reinhardt 1996): (a) the degree of equivalency of habitats or species (in-kind versus out-of-kind compensation), and (b) the location of the compensation site relative to the development site (on-site vs. off-site compensation). In-kind compensation involves replacement with the same habitats, species or functions; out-of-kind compensation involves replacement with alternative habitats, species or functions. On-site and off-site compensation are defined here as being within and outside the effect zone of the highway, respectively. The width of this zone depends on the cause of habitat degradation (e.g. noise load, change of water table, etc.).

4.1 In-kind compensation measures

4.1.1 Habitat loss

The method used to reverse the effects of habitat loss is creation of habitat patches of the same size and quality via (on-site or off-site) in-kind compensation (Fig. 2). Upgrading existing habitat may also be effective as a secondary approach. Generally, the longer time required for the habitat to develop, the more difficult it will be to compensate for impacts. Long established and ancient habitats can scarcely be replaced, if at all (Anderson 1994).

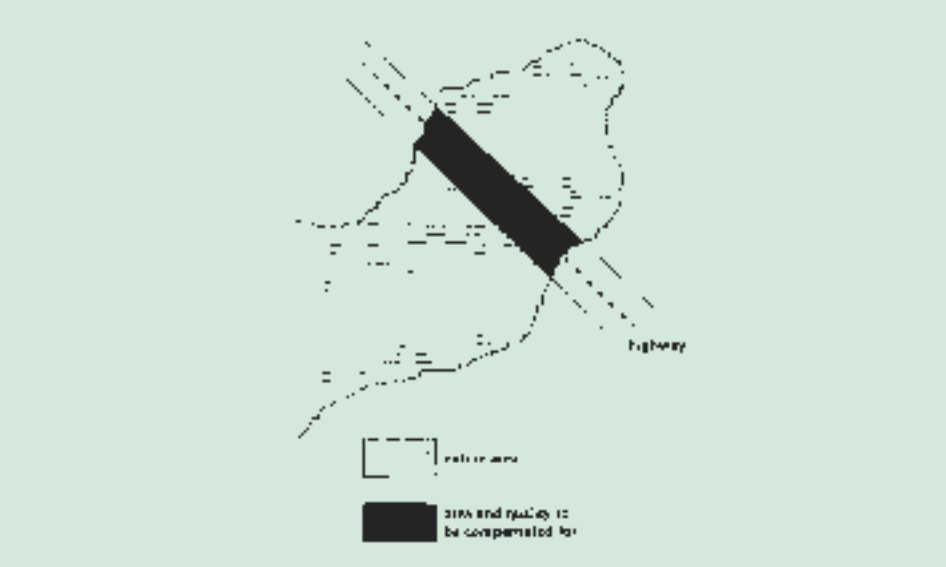

Fig. 2: Compensation for impacts of habitat loss.

4.1.2 Habitat degradation

No-net-loss of habitat degradation is preferably achieved by upgrading habitats. In-kind compensation measures should aim at restoring the ecosystem, expressed in terms of the densities of (selected) species prior to the development (Fig. 3A). Depressed water tables may be compensated for by raising groundwater levels off-site, providing suitable conditions for groundwater-dependent vegetation. On-site (in-kind) compensation for the impact of elevated noise loads can only be achieved by intervening in other habitat conditions, as habitat quality is determined by a multiple set of habitat conditions. Decreased meadow-bird densities in suboptimal habitat patches due to traffic noise may be compensated for basically within the effect zone either by raising the water table or by introducing a new management regime to render the affected habitat more attractive to meadow birds (cf. De Jong 1977, Fig. 3B). For highly sensitive species such measures are more effective off-site, as these species will probably persist in avoiding the impacted zones.

4.1.3 Habitat isolation

Compensation for isolation effects should aim to offset decreased dispersal rates and increased mortality rates. Appropriate measures are (a combination of) enlarging and upgrading habitats or increasing the connectivity of isolated habitat patches. An example of such a combination of measures associated with highway construction is concurrent closure of the 'lower-level' road network (e.g. trunk roads) to motorized traffic. This measure aims to achieve not only a decrease in the overall noise load of habitats and numbers of fauna casualties, but also continuity of suitable habitat patches. New patches may be developed and attached spatially to or located within existing nature areas, thus forming larger units with a potentially greater number of species and individuals. Alternatively, or in addition, new patches may be located so as to serve as links between the core areas of species, thus reinforcing or creating ecological corridor functions. This strategy does not appear particularly effective for old-growth forest plants, however (Grashof-Bokdam 1997). Generally, compensation is more effective in or close to the core areas of species than in areas at the edge of their distribution range.

If infrastructure is rendered more permeable for wildlife movements through mitigation measures (e.g. fauna tunnels and ecoducts), then compensation

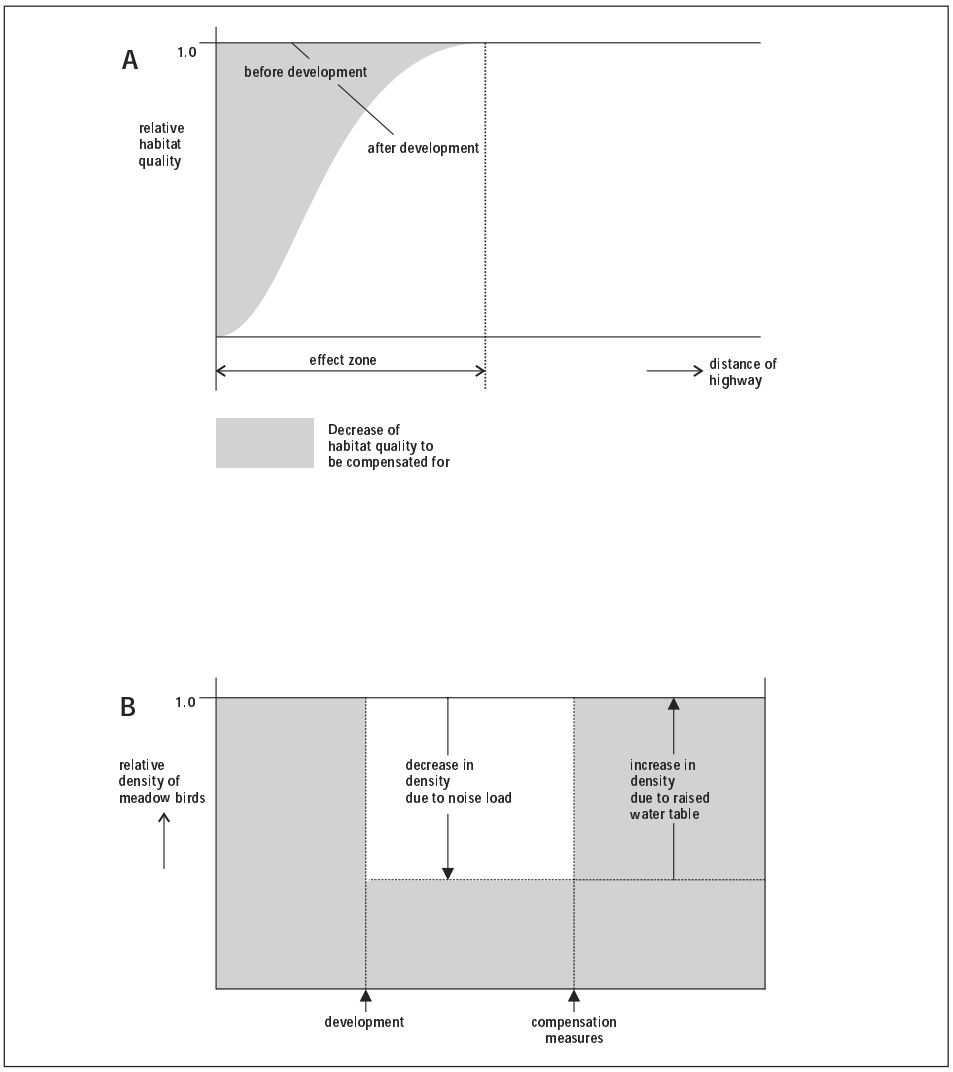

Fig. 3: Compensation for impacts of habitat degradation.

A. In-kind compensation derived from dose-effect responses (curve adapted from: Reijnen et al. 1995).

B. Close in-kind compensation in the effect zone of the highway for degradation of meadow bird habitat, by intervening on other habitat conditions. Realization of the infrastructure and the compensation measures are not successive in practice, but separated here for exemplification.

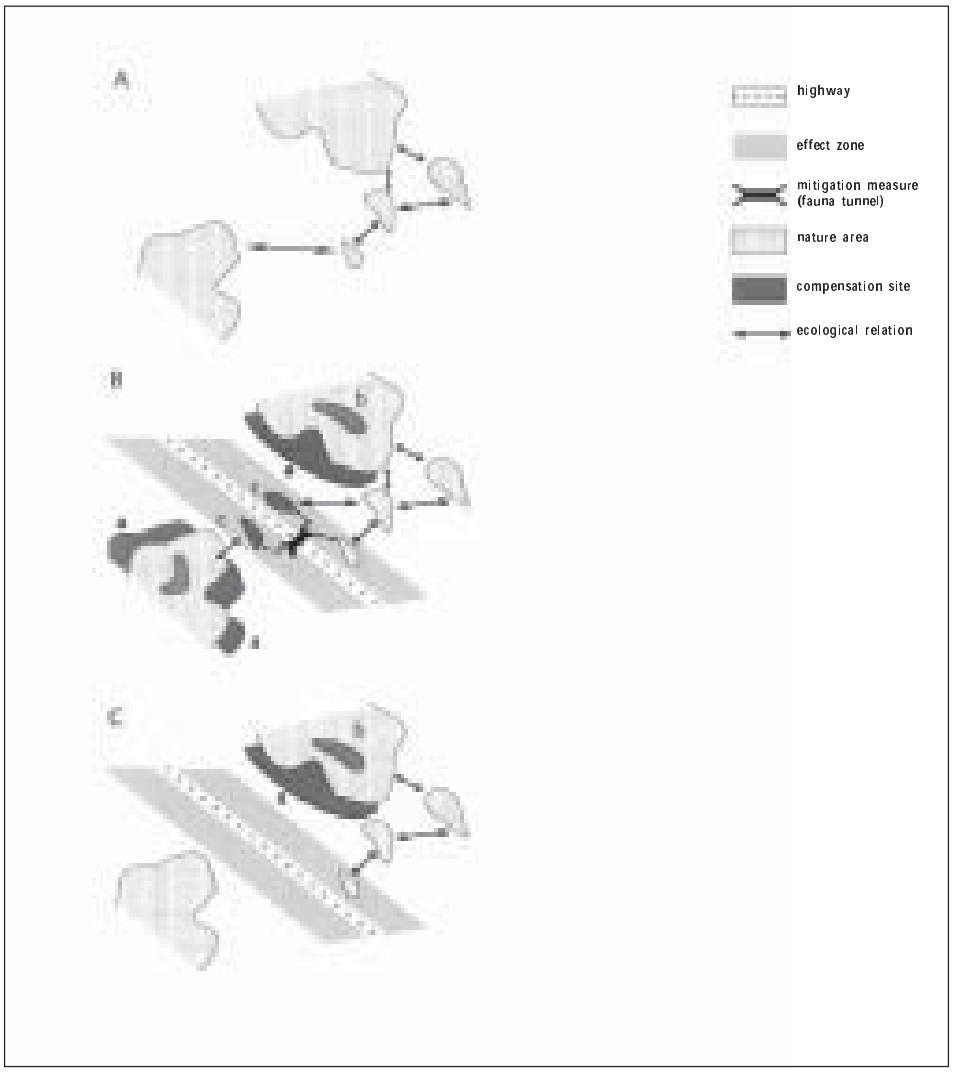

Fig. 4: Compensation for effects on habitat isolation.

A. Reference situation (without highway).

B. Combination of on-site and on-site compensation through enlarging (a), upgrading (b), and connecting (c) habitats, requiring an effective mitigation.

C. Off-site compensation through enlarging and upgrading habitats, the compensation sites located at one side of the highway, thus avoiding mitigation measures.

measures in the vicinity of the highway may increase the connectivity of habitats on either side of the infrastructure. Such a strategy requires effective mitigation as well as compensation sites located within the effect zone of the infrastructure (Fig. 4A). From metapopulation perspectives, however, intensifying habitat-network components on just one side of the highway may sometimes yield greater benefits, as this avoids the risks of ineffective mitigation (Fig. 4B).

4.2 Out-of-kind compensation measures

Unlike in-kind compensation, out-of-kind compensation provides scarcely any scope for objective identification of equivalent habitats or species, since there is seldom any strict ecological relationship between impacted and trade-off habitats. As a rule of thumb, habitats may be traded by employing a nature conservation strategy in which habitat exchange is permitted only within the context of equivalent ecosystem or management properties. In the Dutch situation this would imply that habitat exchange to compensate for impacts on the National Ecological Network is permitted within a number of individual network units, but not between these units (Table 1).

5. Realization of ecological compensation in the Netherlands

5.1 Realization and evaluation of compensation measures

Compensation measures should support current nature management policies and should be physically located outside areas where specific nature-policy objectives are already operational, for example the core areas of the Dutch National Ecological Network (Bal *et al.* 1995). Compensation objectives should take account of the habitat conditions and the actual habitat qualities of the site prior to acquisition, design and management (the 'pre-compensation site') as well as the long-term quality of the site to be pursued under the terms of current policies. In practice, sites for ecological compensation are determined by a combination of administrative goals set by the competent authorities, the availability of suitable soil conditions and other criteria determining the ecological potentials of the site (cf. MTPW 1995). Once the site or sites are acquired, design and management plans must be drawn up if necessary on the basis of the habitat-quality objectives envisaged and subsequently implemented. Ideally, these plans should be operative

Table 1: Features of the four units of the Dutch National Ecological Network (adapted from: Bal et al. 1995).

	nearly natural unit	**managed natural unit**	**semi-natural unit**	**multi-functional unit**
conservation strategy	no human interaction, only design and external maintenance	imitation and stimulation of specified processes	maintenance of a vegetation stage	joint use of area functions
succession stage	several stages	several stages	one stage/mosaic nature reserves such as:	one stage
examples	- natural woodland - dynamic dunes - sea, incl. coastal zones	- tidal waters - river beds, basins and banks - sand-drifts	- heathlands - peat bogs - oligotrophic grasslands	- multifunctional woods - flower-rich arable lands - water-catchment areas - military exercise areas

prior to highway construction, thus allowing compensation sites to be colonized by source-habitat fauna and vegetation through dispersal or, in the case of vegetation, via seed banks (Bakker *et al.* 1996). Purchased compensation grounds will be transferred to well-equipped conservation trusts.

5.2 Legislation and instruments

In the Netherlands, the compensation principle is the policy line adopted by the national government. There is not yet any statutory legislation in place through which the compensation principle can be enforced by law if necessary, however. Compensation measures are instead to be realized on a voluntary basis, rooted in agreements between affected parties. This voluntary character has several operational implications. Land-use changes are permitted only on the basis of authorized zoning plans, for which municipalities bear prime responsibility. Highway initiators and municipalities must therefore agree upon implementation

of permit-related measures in zoning plans, thus furnishing the initiators with legal grounds for the expropriation of land for compensation purposes. Under the terms of these agreements, land may be acquired through purchase from individual owners. In addition, though, project initiators may otherwise create opportunities for land to be exchanged among two or more cooperating owners, to achieve better spatial organization of the compensation lands. In order to accomplish this, the initiator must then himself own sites in order to act as a negotiating party in the real-estate market. As land-owners will sell real estate on a non-committal basis only, opportunities for initiators exist mainly in (rural) regions that are economically weak. In such regions land-owners are more likely to be willing to sell properties since they do not depend entirely on revenues from their lands. In the case of potential purchase of compensation sites by the initiator, it is favourable to tie in with existing spatial plans, such as ongoing land re-allotment projects. Alternatively, one may initiate new plans, for example by using the concept of Land Adaptation (*aanpassingsinrichting*), developed under the Dutch Land Use Act (Official Gazette 1985) to compensate for the adverse effects of large-scale infrastructure works on agricultural, nature and recreation functions (MANF 1993).

5.3 Costs

Compensation costs are all those involved in transforming a pre-compensation site to one with suitable long-term habitat qualities. Acquisition costs are determined primarily by the regional availability of real estate. Site design and long-term management costs are variable and depend on actual and potential habitat conditions, the long-term quality objectives being pursued and the time available to develop the site. Supplementary to the design and management costs, the Dutch government has added a variable per-hectare quality allowance for compensation sites, to be paid by the initiator. The exact allowance depends on the replaceability of the lost habitat quality; it is intended for preparatory work such as top-soil removal, for example. Quality allowances, donated by the initiator, will be awarded to the conservation trust involved through the so-called 'Green Fund' (MANF 1995).

The total costs of the mitigation and compensation measures have been computed in some detail for several actual highway projects. The estimated costs of

offsetting the adverse impacts on nature associated with construction of highway A50 between Eindhoven and Oss (30 km) run to 5.0% of total construction costs of the highway (mitigation US$ 11.5 million, compensation US$ 5 million, construction US$ 330 million); in the case of highway A73 South (40 km) 5.8% of construction costs are earmarked for mitigating (US$ 10 million) and compensating for (US$ 14.5 million) adverse impacts on nature (MTPW 1995, 1997, respectively). In both projects, long-term management is incorporated in the compensation costs as a one-off lump sum capitalization over a period of 10 years.

If compensation measures are physically unfeasible, owing to non-cooperation on the part of landowners or municipal authorities or an absence of suitable habitat conditions, the government agency involved imposes a financial charge, to be donated to the Green Fund. This charge can be used to finance projects that would not otherwise have been realized, and must be proportional to the costs of restoring or recreating the ecological values impacted by the development. Because measures financed by the charge are unrelated to the ecological and spatial aspects of the development in question, a physical no-net-loss situation will never be achieved. The financial contribution should therefore be postponed as long as possible, since it can readily be interpreted as a 'redemption' of the development by the initiator. In the context of Dutch highway planning, the intention thus far has been for the portion of the earmarked compensation costs that could not be invested in compensation measures until after opening of the highway to be treated as financial contribution (MTPW 1995, 1997).

6. Discussion

6.1 Dilemmas in planning and realizing compensation measures

6.1.1 Planning aspects of ecological compensation

On-site, in-kind compensation will generally prevail over the other alternatives. This option is more likely to offset the lost functions of impaired sites, since habitat conditions are then already in place (Brinson & Rheinhardt 1996), the potential for minimizing disruption of remaining ecological functions will be higher (Race & Fonseca 1996) and compensation sites are often part of a larger system (Hashisaki 1996a). Nevertheless, there are also motives for adopting off-

site compensation: in this way larger ecosystems can be connected (Hashisaki 1996a) and better results achieved, since the compensation sites are not adversely influenced by the infrastructure itself (Mitsch & Wilson 1996).

General standards and guidelines for choosing between 'on-site/off-site' and 'in-kind/out-of-kind' compensation cannot be given, as these depend on the availability of suitable compensation sites and must therefore be determined on a case-by-case basis. In the USA 'mitigation banking' has recently been introduced, a scheme whereby large areas of 'reserve land' are built up from which initiators can buy a compensation site once a project has gained approval (cf. Glickfield *et al.* 1995, Zedler *et al.* 1997). Banking of credits in advance favours acceleration of the approval procedure, apart from the 'redemption' issue, because the compensation site is acquirable; furthermore, it lowers mitigation and compensation costs, and increases compensation efficiency, as one large compensation site avoids the fragmentation associated with smaller sites (Hashisaki 1996b). These arguments — and particularly the fact that acquisition of Dutch real estate will be difficult in some regions — make it worth considering the application of mitigation banking in (parts of) the Netherlands.

Equivalences in species diversity and the regional, national or even international rarity of habitats and species may form the basis of out-of-kind compensation (Rossi & Kuitunen 1996). Although these criteria may be appropriate tools for the design and management of replaceable nature areas, it should be realized that in assessing ecosystem functions, compensation ratios (i.e. the ratio of replaced to lost area) and interchange of habitats are based on institutional mandate or public input (Abbruzzese & Leibowitz 1997). Compensation resulting from habitat trade-off should be consistent with the composition of the landscape. Calculation of the theoretical in-kind compensation costs that need to be incurred to obtain a standard for out-of-kind compensation, as exemplified by Von Kiemstedt *et al.* (1996), can serve as a practical tool for trading dissimilar habitats or species.

6.1.2 Realization and evaluation of compensation measures

Successional trends of habitat types are generally predictable only in broad terms (cf. Atkinson *et al.* 1993). A compensation plan should therefore be based on processes (e.g. erosion, sedimentation, humus formation, grazing) and species

groups as representatives for the ecosystem that it is intended to develop. In such a compensation plan, initiators and conservation trusts should — prior to transfer of lands — reach agreement on mutual responsibilities, compensation objectives, valid monitoring activities (Howald 1996) and the one-off lump sum to be paid to the managing body (Box 1996). Complex issues involving timing and responsibility arise, however, whether initiators are freed of their obligation to meet no-net-loss objectives at the moment of transfer, or after a substantial period, once biological evaluations and adjustments have been carried out.

The Dutch government should become intently aware of potential pitfalls associated with compensation projects. Practical American and German experience indicates that compensation measures may be relatively ineffective for several reasons: lack of proper ecological input, incorrect habitat conditions at compensation sites, inappropriate site design and management, inadequate compliance with compensation requirements on the part of the initiator, inadequate liaison of authorities and initiators with environmental groups, and lack of an accurate registration system allowing the controlling authority to adequately supervise compliance (cf. Hoffmann & Hoffmann 1990, Race & Fonseca 1996). Failures due to ecological factors and insufficient compliance can be minimized by introducing evaluation and monitoring criteria in the compensation plan, and by attaching stringent compliance conditions to a bank guarantee, including contingency measures for use in the event of unsatisfactory results (cf. Treweek & Thompson 1997). The guarantee might be significantly higher than the estimated cost of restoration or recreation of the ecological values, stimulating the initiator to meet his obligations (cf. Province of Overijssel 1998). If the compensation measures fail to comply with the permit conditions, the guarantee will accrue to the relevant authority. This will then be responsible for guaranteeing that compensation is properly made. It should be noted that compensation credits are probably sensitive to economic cycles (Glickfield *et al.* 1995). This will never provide complete guarantee in practice that compensation plans will be eventually realized (Hashisaki 1996b). In the Netherlands, registration and progress of compensation plans will be supervised by provincial authorities (e.g. Province of Overijssel 1998, Province of Zuid-Holland 1997), since the national government has decentralized policy implementation.

Another aspect of achieving compensation objectives is the role of public interests as related to specific compensation projects. In some cases surplus value can be created by moulding 'win-win' situations in which compensation objectives are combined with other regional nature conservation projects, and with agricultural, recreational or other landscape functions. When such integrated solutions can be designed to achieve surplus value, they may enjoy greater public support and thus be more sustainable over time and space, than, for example, nature reserves enforced by expropriation as a means of compensation.

6.1.3 Legislation and instruments

Legislative embodiment of the compensation principle — as in the US Clean Water Act and the German *Eingriffsregelung* — is under discussion in the Netherlands. The Dutch government is to decide in the near future whether or not to give the compensation principle a legislative footing (MANF & MHPE 1993, MANF 1997). Serious consideration should be given to developing more appropriate legislation on compensation in the Netherlands to provide due guarantees to society that no-net-loss will indeed be achieved, in the final case by citizens filing a notice of appeal. Such a legal, national basis may be provided through adaptation of the Nature Conservation Act (Official Gazette 1967) or Environmental Planning Act (Official Gazette 1965). Although still premature at the moment, legislation may include provisions for audits, fines and civil penalties in cases where a compensation plan is not ultimately achieved (cf. Race & Fonseca 1996).

Furthermore, as a procedural step within the Routing Act (Official Gazette 1994), decisions on highway routes are based on elaboration of the 'preferential' route, i.e. the alternative intended to be chosen by the Minister of Transport, Public Works and Water Management. To date, in the preferential alternative and the routing decision, the mitigation (not compensation) measures associated with the route are to be specified in terms of exact spatial occupation. Under the terms of the Routing Act, municipalities unwilling to act on a voluntary basis can be obliged to adapt their zoning plans to the development, thus giving initiators a legal basis to expropriate land for highway construction and — to a certain extent — mitigation measures. If the government were empowered to incorporate the compensation sites into the routing decision (which is not the case at present), a legal basis would be procured for expropriation for the purpose of

compensation. Such a procedure would put greater pressure on initiators, however, because elaboration of the preferential alternative in the routing decision, including due environmental measures, is subject to a statutory timetable. In addition, the procedure would also confront society with the radical consequences of land expropriation for compensation purposes.

6.1.4 Costs

There is growing international experience with financing compensation projects (cf. Glickfield *et al.* 1995, Torok *et al.* 1996). Today, Dutch highway initiators estimate the approximate costs of measures in environmental impact assessment studies and in compensation plans. However, the true compensation costs cannot yet be assessed, for more knowledge must be gained in the realm of habitat creation and population restoration at compensation sites (Treweek & Thompson 1997). Furthermore, there is a potential for undesirable inflation of regional land prices being triggered by compensation and current nature-policy activities, such as realization of the National Ecological Network or establishment of farm re-allotment areas. Initiators and other affected government parties should therefore agree upon the desired time schedule of land purchase (spread in time) and suitable potential target areas for compensation measures (spread in space).

In the German context, Schemel *et al.* (1995) have developed a detailed system for calculating additional fees at the federal level. Besides the technical costs, overall compensation payments include a 'time fee' to counteract the functional breakdown of a habitat, a 'value fee' to compensate for the loss of ecological values and a 'risk fee' to cover possible failures during restoration. Depending on the follow-up to the first evaluation of several compensation plans in the Netherlands (MANF 1997), it may be desirable to supplement the Dutch quality fee with the 'risk fee' of the German approach.

6.2 Dealing with uncertainties

Research is in progress on the forecasting of infrastructure impacts, on ecological modelling in which temporal and spatial scales can be expanded artificially, and on evaluation of the effectiveness of mitigation and compensation measures. There are several high-priority problems that are still to be solved, e.g. habitat isolation effects of infrastructure (Canters 1997), prediction of species succession

rates in created or restored habitat sites (Atkinson *et al.* 1993), and the real cost of replacing habitats (Treweek & Thompson 1997). The reliability of predictive and evaluative research is the subject of ongoing criticism, however (Atkinson *et al.* 1993). After years of research, some authors (cf. Wilson & Mitsch 1996) continue to argue that ecologists and engineers need better, scientifically-based guidelines for compensation, while others (cf. Race & Fonseca 1996) dispute the possibility of creating guidelines that are 'scientifically defensible and fair'. We believe that, notwithstanding a number of unresolved problems, our overall knowledge of restoration processes, e.g. key factors determining succession trends in specific habitat types, justifies the use of assumptions for identifying compensation measures. These assumptions can be used until new ecological information, gained in ongoing field and modelling studies and from evaluation of compensation projects, reopens the debate on modification. Moreover, unpredictable effects and uncertain effectiveness of measures should be tackled; therefore, compensation ratios greater than one may be employed in the Netherlands for in-kind as well as out-of-kind compensation (cf. Allen & Feddema 1996). This approach will also increase the public support for compensation plans.

6.3 Strategic considerations

6.3.1 Ecological compensation, not redemption

By enforcing the compensation principle, governments may inconsistently entangle two successive goals: (a) introduction of conservation interests in the decision-making process, and (b) realization of compensation measures once a development has been approved. Within Dutch highway projects there is a strong tendency to draw up an environmental impact assess-ment in which alternative routes, including associated compensation measures, are compared and assessed. By authorizing one specific alternative of the development, both the above goals are tackled simultaneously. In this ambiguous situation compensation measures can easily be interpreted as a redemption of the development ('buying off'), which contradicts the aims of the principle. To date, the moment of questioning the legitimacy of a Dutch development is not quite clear. To counter this, decision-making should be preceded by official establishment of the development's legitimacy, independent of the consequences for ecological compensation. This may be achieved, for example, by tying in with a strategic environmental assess-

ment (cf. Bina *et al.* 1997), which explores the rough implications of a highway project for nature conservation at an early stage.

6.3.2 Nature conservation versus other interests

When land-owners such as farmers voluntarily agree to manage parts of their land according to compensation objectives, conservation and agricultural interests may coincide. On the other hand, realization of measures aimed at restoring or recreating ecological functions may not always be compatible with agricultural interests. In such cases, the problems associated with no-net-loss for nature impinge upon agriculture, as the no-net-loss principle is not among the policies formulated for this sector. However, this last observation is a consequence of a policy that explicitly opts for prevalence of ecological over other interests in specific areas.

6.3.3 Achieving no-net-loss

Within the context of the decision-making process for Dutch infrastructure, the replaceability of ecological values is rarely discussed. Some ecological values are replaced quickly, given relatively short development times, less stringent habitat conditions and high management efficiency; this is the case with meadow-bird reserves, for example. More difficult to replace are the ecological values associated with ecosystems that have longer development times or involve more complex processes such as pedogenesis and nutrient cycling, e.g. oligotrophic grasslands, peat moors and ancient woodlands. With these systems, evaluation of functional replacement is complex, although some studies indicate a lower degree of biodiversity compared with the replaced ecosystems (see, for example, citations by Allen & Feddema 1996). At the moment it is unknown whether compensation measures associated with impacts on ecological values that are difficult to replace will lead to no-net-loss in the distant future. Moreover, questions remain concerning the contribution of compensation ratios greater than one to long-term ecosystem health (cf. Atkinson *et al.* 1993). One thing is clear, however: no-net-loss for highways implies not only one-to-one replacement of each hectare destroyed through land development, but also substantial compensation for areas of habitat that become degraded and isolated.

7. Conclusions

Policies on ecological compensation, as a third concept following avoidance and mitigation of adverse impacts, move highway initiators to broaden their activities beyond the traditional management realm of infrastructure and negotiate with parties for compliance. Compensation measures aim to replace ecological values and functions that are affected through the loss, degradation and isolation of habitats. This article presents guidelines associated with ecological compensation for the negative impacts of highways on nature, and addresses problems and potential solutions. A coherent framework has been developed that enables compensation measures to be planned through derivation from infrastructure impacts and to be realized using ecological, spatial-planning and financial instruments. The guidelines offer viable opportunities for practical implementation of the Dutch compensation principle. The principle relates to various aspects of restoration ecology, and its implementation is linked closely with other societal interests such as spatial planning, including landscape and nature conservation, as well as agriculture and outdoor recreation. Future experiences with compensation projects may help elucidate the problems addressed.

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