Commission Briefing Paper 4D-04

Impacts of Surface Transportation Infrastructure Development on Habitat Connectivity and Resilience

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Introduction

This paper is part of a series of briefing papers for the National Surface Transportation Policy and Revenue Study commission authorized in Section 1909 of SAFETEA-LU. The papers synthesize the state of the practice on the issues relevant to the Commission's charge as outlined in Section 1909 and provide background material in developing the final report to the Commission. The paper summarizes the key findings from several NCHRP reports, the published literature, and other research developed by FHWA (see Supplemental Readings listed at end).

Background

The importance of the effects of highways on ecosystems, wildlife, and habitat was recognized in Section 5107(b)(4) of TEA-21, which required the Secretary of Transportation to "study the relationship between highway density and ecosystem integrity, including the impacts on habitat integrity and overall ecosystem health…." This mandate resulted in the report *Assessing and Managing the Ecological Impacts of Paved Roads* (NAS, 2005), one of many research efforts to further improve our ability to assess and mitigate the effects of highway projects on the productivity and health of our natural ecosystems. Other efforts to improve our management of highway impacts to ecosystems and habitats include the International Conference on Ecology and Transportation, the only professional conference of its kind in the world, and *Eco-logical: An Ecosystem Approach to Developing Infrastructure Projects*, a federal, interagency guide to developing effective early coordination and planning strategies to include natural resource management into highway system planning and development. The NAS report and other related reports (see Supplemental Readings) and research products were used as the basis for the briefing paper.

Effects of highways and railroads on ecosystems, habitats, and wildlife are assessed and managed through the National Environmental Policy Act process, the Endangered Species Act Section 7 consultation process, the Migratory Bird Treaty Act, which addresses takings of migratory birds, and through various sections of the Clean Water Act (404, 401, 402, 303) concerning pollution control, storm water runoff, and placement of fills into waters of the United States, as well as state and local laws and regulations.

Key Findings

Highways and railroad affect ecosystems, habitat, and wildlife in many ways:

1. direct habitat loss by land use change from roadway and railroad construction;
2. direct mortality due to roadkill/railroadkill;

3. introduction of exotic and non-native species, both deliberate and accidental, along rights of way;
4. indirect alteration of habitats and vegetation through secondary effects such as noise, pollution, and associated land use changes; and
5. fragmentation of habitats and ecosystems through barrier effects, both from the roadway/railroad infrastructure and from development and local land use decisions.

- *Impacts and Mitigation*: The most important ecological impacts of highways/railroads are those of habitat fragmentation, habitat loss and degradation from secondary land use changes, and introduction of exotic species. These impacts are mitigated through various measures implemented with highway/railroad projects, such as wildlife crossings of various kinds, habitat replacement and restoration, preservation of critical habitat elements and land use controls, pollution controls, and re-vegetation strategies, among others. All of these impact modes affect the resilience (stability), productivity, and persistence of habitats and species populations. Most efforts to address these impacts are currently implemented to meet the requirements of federal and state wildlife protection laws. Although there are some federal initiatives such as *Eco-Logical: An Ecosystem Approach to Developing Infrastructure Projects*, Context Sensitive Solutions, and Green Infrastructure Planning, which attempt to look holistically at infrastructure needs, natural resource conservation needs and land use options, in many jurisdictions these efforts remain separate and mitigation is not coordinated to meet multiple needs.

- *Tools to Assess Impacts*: Numerous new tools are available for impact assessment and natural resource management, including GIS mapping products, resource inventories, habitat use and wildlife population models, water quality inventories, and human population/development growth scenario models. These tools are not generally used to maximum effect due to other priorities of State DOT staff with project-level management responsibilities.

- *Planning to Preserve Ecosystem Conservation*: Costs of planning and design for ecological concerns on future transportation will generally increase as these resources become more rare and valuable. Avoidance of key ecosystems and critical habitats for endangered species will become more important as a strategy. Planning for habitat connectivity and ecosystem integrity will become more important, and public input will play a bigger role in decision-making and in funding. Already, several states have passed bond issues to fund both transportation system development and conservation planning needed to build roadways/railroad infrastructures that are compatible with healthy, productive ecosystems. Wildlife crossings, acquisition of habitat corridors to ensure habitat connectivity, habitat replacement, and exclusion devices (fencing) to keep wildlife off roads and enhance safety will become more common in future projects. These features will be important considerations not only to satisfy legal requirements, such as the Endangered Species Act, but also to ensure the survival and productivity of a wide variety of wildlife species and their natural habitats.

- *Future Opportunities*: Growth in our ground transportation system will continue; however, most capacity improvements for highways/railroads will occur as upgrades along existing rights of way. These upgrade projects will offer the opportunity to improve habitat connectivity across the rights of way, depending on the potential to preserve linkage zones adjacent to the road and other land based modes that will allow wildlife to move through developed areas while traveling

from one habitat unit to another. Planning for new transportation corridors will require early consideration of ecosystem connectivity needs so that they can be incorporated early in the design and right of way acquisition process.

Direct Habitat Loss

There are about 3.9 million miles of public roads in the United States, approximately 80 percent of which are in rural areas. These roads occupy about 0.45% of our surface area. If the entire width of the right of way is included, the percentage increases to about 1.0 percent of our total land area. Road density has also been used to measure the effects of roads on ecosystems. The average road density in the United States has been calculated as 1.2 miles per square mile (Foreman, 2003). Secondary impacts of highways, such as those due to noise, pollution, disturbance, invasive plant species and habitat fragmentation can reach many yards, even miles, from the roadway; thus it is apparent that the secondary and indirect impacts of highways are much more significant than the direct loss of habitat due to the roadway itself.

Urbanization associated with highways is the other great impact on natural ecosystems and their ability to maintain their normal structure and function. Metropolitan development has been spreading much faster than the population growth rate would indicate. In the 1990s, open space was converted to developed land at the rate of 2.2 million acres per year, or 252 acres per hour. This is 50 percent greater than the rate of conversion in the 1980s. While we are in no danger of "running out of land", much remaining open land is desert or mountains, suited only to low-density development. The land most affected by the pace of urbanization is that close to existing cities, towns and farms, which is often the land which supports the most productive and useful ecosystems, land which originally had been hardwood forests and tall grass prairies with good soils and moderate climates.

Roadkill and Wildlife Vehicle Collisions

Roadkill can be a significant cause of wildlife mortality, particularly with rare or declining species, such as the Florida panther, grizzly bear, and kit fox. These and similar species are wide-ranging, have suffered extensive habitat loss, and have generally low reproductive rates. Losses of a few individuals have significant impacts on overall population dynamics. Roadkill can also be a significant factor in population dynamics of such species as mule deer when migratory corridors cross large highways, such as in Wyoming and Utah. These situations also have significant potential for causing severe accidents due to the size of the animals and speed of collisions. With the intrusion of more development, roadways, and traffic into wildlife habitat, wildlife vehicle collisions are becoming a more frequent cause of human injury, death, and property damage, particularly in suburban areas where the association of wildlife and humans is ever closer.

The numbers and factors related to wildlife vehicle collisions have been reported extensively in the recent literature and auto insurance statistics. A frequently quoted statistic is that there are over one million wildlife vehicle collisions with large animals annually in the United States. (This number originally comes from a survey of states done in 1996. Thirty-five states reported approximately 500,000 known deer vehicle collisions, which are estimated to be under reported by at least 50 percent.) The numbers of small mammals, birds, amphibians, and reptiles killed on

highways is likely much greater, but there is no accurate data from which estimates of total numbers can be made.

Actual road kills impact all species but collisions with larger wildlife species (deer, elk, moose, and large carnivores such as bears) pose the most risk to driver safety and result in higher auto damage and human injury. Wildlife vehicle collision (WVC) numbers are increasing reference and the costs to the public will only increase unless more effective mitigation and control practices, such as fencing and wildlife crossings, are included in project designs. Based on reported crashes for large animals, wildlife vehicle collisions occur more commonly:

- On rural, two-lane, low volume, high speed roads
- During early morning and late evenings
- In spring and fall
- Among young and medium age drivers
- In locations with high wildlife populations
- With deer (mule deer and white-tailed deer combined)
- Near forested cover and drainages
- On dry, straight, roads where speeds are higher
- As single vehicle accidents.

Light rail has similar effects on wildlife as highways, with the caveat that most light rail lines operate in urban areas where the need and potential for habitat connectivity is minimal due to land use characteristics. Were a light rail line to extend into rural areas where habitat values remain high, the concerns with fragmentation would be very similar to highways. Light rail row is almost always fenced, thus excluding wildlife and enhancing safety, but increasing the effect of habitat fragmentation on mammals, reptiles and amphibians.

As for heavy rail, it has disproportionately greater effects on smaller, less mobile animals such as amphibians, turtles, small mammals. Some small mammals will try to cross under a train if highly motivated, with usually fatal results. Larger mammals will avoid the tracks when trains are present, however, in rural areas may be attracted to spilled grain – example the Glacier Park/Banff areas where grizzly bears are commonly killed on the rail road tracks when foraging for spilled grain. Trains kill many more bears in this region than cars do. Rail (both light and heavy) presents many of the same concerns that highways do, and can be expected to face many of the same environmental issues in the future.

Habitat Fragmentation and Barrier Effects on Habitat Connectivity

Habitat fragmentation is the breaking of natural habitat units into smaller and smaller parcels, or isolating one habitat unit or element from another. Habitat fragmentation (the inverse of connectivity) and habitat loss or conversion have been identified as some of the most serious impacts of highways and human development by ecologists nationally and internationally (NAS; 1995, 2003). Fragmentation and barrier effects are caused by the physical characteristics of the road, by traffic volume, and in streams, by hydraulic crossings (culverts, improperly designed bridges). These effects are most significant in natural, pristine, areas with little human development. Physical characteristics of the road include width, traffic containment structures such are concrete barriers and rails, and location. Width becomes an issue for smaller animals

(amphibians, small mammals, reptiles such as turtles) that lack the mobility to cross large roadways without excessive exposure to road-kill, even at low traffic densities. Width is a deterrent to larger animals at higher traffic volumes, and traffic itself becomes a virtual barrier to most species at densities of around 10-15,000 vehicles per day (1 vehicle every 4-8 seconds average). Barrier structures, such as concrete traffic barriers, can block wildlife movements across otherwise accessible highways. Culverts and poorly designed bridges cause barriers to fish and other aquatic species due to high current velocities, shallow depths, and outlet "waterfalls" which are impassable to many species. These barriers have caused the loss of much spawning habitat for migratory salmon species on both coasts, and have played a role in the decline of these species to the point of being listed as endangered under the Federal Endangered Species Act. The following are examples of barrier effect and habitat fragmentation.

Fragmentation and barrier effects are most immediately critical for migratory species such as deer and elk, which move from summer to winter range, for aquatic migratory species which must move up and downstream to complete their reproductive cycle, such as salmon, and for amphibians and other less mobile species where critical habitat elements are isolated by roadways, particularly larger, more heavily used roads. There are various ways to mitigate these effects, through the placement of wildlife crossings of various kinds, through proper design and rehabilitation of culverts and bridges, and by restoration or replacement of important or key lost habitat.

Fragmentation and habitat isolation also prevents the re-colonization of habitats where random events such as droughts, floods, disease, etc, can cause small scale, local extirpations of species. Isolation from other similar habitats also removes sources of re-colonization, and greater fragmentation of species populations, with associated potential genetic degradation due to inbreeding.

Fragmentation also increases edge effects. The "edge effect" is a term used to describe the various consequences, on vegetation and wildlife induced by constructing a road through a forest or undeveloped area. First, species that have particular habitat requirements may be lost from the area. Second, “vacancies” that are created by the new “edges” at the interface of grassed rights of way and adjacent forests may be filled by species that have a wider tolerance range and the new edge created at the interface between right of way and natural habitat may introduce species that would not normally be found in core or larger habitat blocks. Third, aggressive edge-dwelling species may invade the habitat and displace prior inhabitants.

There are some species that prefer edge habitat. Many birds will use edges for perching. Frequently, however, pest animals such as foxes, cats and dogs tend to move in and live along roads and cleared areas adjacent to or in bush areas. Edges, by providing improved access to predators or non-native species, both plants and animals, can cause a decline in wildlife populations through predation, competition, and invasion by non-native plants. Edges also provide opportunities for the invasion of natural vegetation by weeds. Disturbance creates opportunities for weeds to establish, replacing the natural vegetation that is a critical part of the habitat. Edge effects are also associated with an increase in traffic and or human activity. Many wildlife species rely on the seclusion of undisturbed habitat to breed and rear young successfully.

Wildlife Crossings and Habitat Connectivity

Recent surveys show there are over 550 terrestrial and 10,000 aquatic wildlife/fisheries crossings in North America that were specifically intended for that purpose, with millions of other bridges and culverts constructed for other purposes but which could be and are used by wildlife and fish or other aquatic species (Utah State University, 2006). Planning and construction of such crossings has grown so rapidly that each decade since the 1970s, when the first wildlife crossings were incorporated into highway plans, has seen a doubling in the number constructed per decade. This trend is so robust that there are projected to be over 500 new terrestrial passages built specifically for wildlife in the next 10 years. With this rapid progress in the placement of wildlife passages, and the critical need that has been recognized, it is necessary that passages be planned for the long term and incorporated into existing infrastructure where possible. Inclusion of wildlife and ecosystem needs into transportation plans has not been the typical model based

on surveys of transportation planners about how and when wildlife and ecosystem needs were incorporated into the planning process. Surveys of planning processes for long range plans (20-30 years), State Transportation Improvement Plans (4 years), and project plans (near future) showed that the majority of the states and provinces did not consult natural resource professionals concerning wildlife and ecosystems needs or use other appropriate tools such as GIS inventories, until the project development stage. This late consideration does not typically allow adequate time to preserve important wildlife corridors, include mitigation measures, and to work with surrounding land use authorities to protect corridors leading to the wildlife crossings. Protection of the crossing by limiting development in the corridors on either side is necessary to assure that the crossing will be effective in the future. The following pictures illustrate underpasses and overpasses designed to accommodate wildlife.

The need to incorporate wildlife mitigation early in the programming, planning, and design processes has also been recognized in Section 6001 of SAFETEA-LU, which requires consultation and comparison of natural and historic inventories and plans to transportation plans. A number of states have developed more integrated processes for including these considerations, and the *Eco-logical* handbook provides guidelines for this effort. Pilot projects are being proposed that will provide examples of how this planning integration can best take place.

Effects of Noxious Weeds on Habitat Resilience

Noxious weeds reduce natural habitat productivity, ecosystem resilience and stability, natural diversity, and impair wildlife values. They often spread along highway rights of way (roadsides). Roadsides are disturbed habitats which many such noxious weeds can easily invade and which often prove convenient corridors for their spread, both by indirect invasion from adjoining areas, and from contaminated vehicles and cargo. In addition, roadside re-vegetation and management often focuses on non-native plant species that are tolerant of disturbance and severe conditions. These plants themselves are often invasive exotic species (such as crested wheatgrass and European smooth brome, European imported grasses) that tolerate drought and pollution, establish easily in disturbed soils, and can out-compete native species under artificial conditions. These species often have low wildlife values and effectively reduce ecosystem resilience and productivity.

In some cases, under proper management, roadside corridors can also play an important role in the protection of rare and endangered plant species. An example is a southeastern sunflower, Helianthus schweinitzii. This tall sunflower is known from only 35 populations in North and South Carolina, and most of the known locations are on road rights- of- way. Road rights- of-way could also play a role in the recovery of rare or endangered animals if native habitats are

encouraged along roadsides. The fragments of native vegetation within the 12 million acres of highway corridors in this country are valuable parcels of habitat for many rare, native plants and animals.

Summary

Surface transportation systems, particularly roads, will continue to leave an ever-increasing footprint on the landscape. In planning, designing and building our transportation projects there is a need to consider and plan for compatibility with surrounding ecosystems in order to both minimize the effects on wildlife and the ecosystems on which they depend, as well as reducing the need for costly continual maintenance, such as cleaning out poorly designed culverts or mowing and applying herbicides to rights of way that are infested with noxious weeds. Additional time and cost resulting from the inclusion of mitigating measures is difficult to estimate. Many of the mitigation measures identified here are already requirements due to existing federal and state environmental laws. The goal should be to include the measures that will offer the biggest benefit to the species, habitats, and critical ecosystem functions at reasonable cost.

This is very difficult to do on a project-by-project basis, or by a transportation agency acting alone. In order to establish ecological mitigation in the areas where mitigation funds can effect the greatest benefit to both the and natural environment, it is necessary to work in collaboration with local planners and land use agencies, natural and cultural resource agencies, tribes and the public in order to develop sustainable, comprehensive plans that address multiple needs and combine mitigation opportunities.

Supplemental Readings

Forman, Richard T. T, et al. Road Ecology: Science and Solutions. 2003. Island Press, Washington.

National Research Council. Assessing and Managing the Ecological Impacts of Paved Roads. 2005. National Academy Press, Washington D. C.

National Research Council. Wetlands, Characteristics and Boundaries. 1995. National Academy Press. Washington D. C.