EXPLAINER

How to Design Safe Roads for Wildlife

Wildlife passage structures are often the cornerstone of successful strategies to reduce the effect of roads on wildlife. Photo credit: Steve Gandomski

Integrating road ecology principles and green infrastructure designs can balance construction with environmental conservation.

Introduction

Asia harbors immense biodiversity that is increasingly threatened by expanding road and rail networks across the region. Much of the world's terrestrial biodiversity is concentrated within the rainforest landscapes of Asia, which hosts half of the eight global biodiversity "hotspots." Biodiversity is of tremendous importance to the region's teeming population that depends on natural and diverse ecosystems for livelihood and well-being.

Roads and railways are widely regarded as a primary driver—gateway and catalyst—for the loss of natural ecosystems even if they are considered essential for economic development and support to vital human activities. Transport development projects must consider the habitats and wildlife species present in project areas if they are to properly address and conserve biodiversity values.

Adapted from *Green Infrastructure Design for Transport Projects: A Road Map to Protecting Asia's Wildlife Biodiversity*, this piece highlights the variety of green infrastructure and other conservation measures available—from environmentally sensitive road design to animal passage structures and management guidelines—to reduce negative impacts of transport projects on wildlife.

Ecological impact associated with roads, highways, and other transportation infrastructure

Roads are widely regarded as a “gateway” to the loss of biodiversity within roadless areas. Poorly planned and implemented roads have been characterized as the “enemy” of rainforests (Laurance et al. 2009). Tropical forests, including those prevalent in Asia, are especially susceptible to the impacts of linear infrastructure since they have evolved as stable, complex ecosystems exhibiting minimal forest edge effect. Associated species are often quite specialized in their use of contiguous forest habitats and are not well adapted to the presence of narrow, linear openings in the forest canopy.

In particular, roads within Asia’s tropical forests are regarded as the primary driver of habitat destruction and the catalyst for the spread of major threats, including modification of forest habitats, intensification of forest destruction, and illegal hunting and trade in animal parts (Clements et al. 2014). New roads that permeate pristine, biodiversity-rich areas have been identified as the potentially most dangerous, with paved roadways exhibiting much greater impact than unpaved roads due to enhanced access (Laurance 2015). The most rapid rates of deforestation occur within 10 kilometers (km) of roads, especially if they are paved (Selva et al. 2015). In East Asia’s developing countries, the percentage of paved roads increased dramatically from 16% to 51% during 2005?2010, which correlates with the region’s high rate of tropical forest destruction and fragmentation (Clements et al. 2014).

While poorly planned roads are characterized as the “enemy” of rainforest biodiversity, roads are still recognized as essential for economic development and support to vital human activities in developing nations (Laurance et al. 2009).

Green infrastructure and other measures available to minimize the effects of highways and roads to wildlife and biodiversity

The ability to implement road projects in high-biodiversity areas may hinge on the commitment to pursue comprehensive transportation and conservation strategies that employ a range of measures from environmentally sensitive road design to passage structures and management activities.

The components of any comprehensive road and conservation strategy are most effective if planned and implemented as integrated systems. Such components include but are not limited to wildlife passage structures, associated funnel fencing, wildlife escape measures, and motorist-?alert signage. It is critical to properly design and maintain not only the functionality of the individual components, but more importantly, to also maintain the functionality of the entire integrated system. When any one component of the system is not adequately constructed or maintained, it becomes a weak link that can compromise the entire system with potential road safety implications from wildlife–?vehicle collisions to failure to meet biodiversity objectives.

Motorist Alert Signage

- Found and Boyce (2011) found that wildlife-vehicle collision incidence in locations where deer warning signs were installed was 58% lower than unsigned locations. Their success was tied to erecting signs at limited, place-specific "hotspot" locations.
- In Asia, signage that alerts motorists to the likelihood of encountering the region's unique and in some instances very large animals (e.g., Asian elephant)—particularly when erected in potential hotspots—can be effective in eliciting motorist response. Warning signs that illustrate the area's unique wildlife species (e.g., tiger) may not only be informative and educational, but also contribute to their increased effectiveness.
- Wildlife warning signages with flashing lights and variable message boards have the potential to be more effective than static warning signs (Pojar et al. 1975, Sullivan et al. 2004, Gagnon et al. 2018, Huijser et al. 2015a).

Reduced Design Speeds and Traffic Calming Treatments

- Kloden et al. (1997) reported that the risk of wildlife-vehicle collision increases exponentially with increasing vehicular speed.
- If planning a new road (or road reconstruction) where wildlife-vehicle collision are a concern, lower design speed (versus posted speed) considerations can be integrated into road design and construction.
- In situations where roads exhibiting wildlife-vehicle collisions are already in place and integrating design speed standards is not feasible, various traffic calming devices or treatments can be applied to roadways to reduce vehicular speeds. Traffic calming treatments, such as chicanes to create serpentine curves, curb extensions, raised medians, rumble strips in the pavement, speed bumps or humps, and traffic circles, are generally applicable to low to moderate traffic situations.

Wildlife Passage Structures

- Wildlife passage (or crossing) structures are typically the most visible and engineering intensive green infrastructure employed to address wildlife needs along roads and highways, and often are the cornerstone of successful strategies to reduce the effect of roads on wildlife.
- In conjunction with wildlife fencing, these structures have dramatically reduced the incidence of wildlife-vehicle collisions as much as 98% (Clevenger et al. 2001, Dodd et al. 2007a, Olsson et al. 2008, Gagnon et al. 2015), thus enhancing motorist safety and reducing direct impact on wildlife populations.
- Passage structures can either be "underpasses" or "overpasses":
    - **Underpasses** refer to structures that facilitate animal passage "below grade" or under a highway or railway. Underpass design (and cost) can range from large bridges and viaducts, to prefabricated arches, and to dual-use drainage structures such as concrete box culverts.
    - **Overpasses** provide for "above grade" wildlife passage over highways or

railways (Clevenger and Huijser 2011). They typically (at least historically) have been more costly than underpasses often due to the amount of fill required to create gentle approach slopes where the terrain is flat. However, structures can be positioned between large cut slopes or tied into terrain features, cutting costs and providing continuity with preferred animal travel routes (e.g., ridgelines). Some wildlife species exhibit strong preference for overpasses as opposed to underpasses when both are present (Clevenger et al. 2009). Overpass types include girder bridge and concrete arch designs, and their size may range from relatively small to very large land bridges or "ecobridges" that have long been integrated into the landscape over highways and railways in Europe.

There are several key criteria and considerations for designing effective underpasses and overpasses, which include openness, size, spacing, and approaches. You can find them on this page.

Wildlife Fencing and Alternatives

- The funneling role of fencing that guides animals to passage structures that otherwise may be minimally effective, along with limiting access to roadways and thus reducing wildlife-vehicle collisions, justifies their use despite concerns on cost and maintenance.
- The most widely used has been wildlife exclusion fencing 2–2.4 m high, intended to deter highway crossings by ungulates (deer, elk, moose). The fence is constructed of woven wire attached to metal pipes or wooden support posts with intermediate metal T-posts or wooden posts. To prevent small-animal highway passage and roadway mortality, options include small mesh wire up to 1 m high, often buried to prevent digging under the fence by some species; smooth plastic or metal flashing that prevents climbing; and concrete barrier walls.
- One of the biggest challenges to funneling animals to passage structures in much of Asia is presented by Asian elephants for which fencing can have limited deterrent effect and/or may require substantial maintenance, especially electrified fence used extensively to protect agricultural areas.
- Road management strategies (e.g., closing road at night) that limit traffic during animal activity periods may also reduce the need for fencing and its associated maintenance. And as stressed by Pan et al. (2009), Chogyel et al. (2017), and Clevenger and Huijser (2011), locating passage structures in established, natural wildlife travel corridors will reduce the need for fencing to funnel animals while improving structure use and effectiveness.
- More design considerations are listed here.

At-Grade Crossings and Wildlife "Crosswalks"

- Where passage structures are not feasible to address wildlife-vehicle collision "hotspots" due to cost, unsuitable (e.g., flat) terrain, or other factors, a potential alternative is to create at-grade crossings with wildlife fencing to funnel animals to designated location-specific crossings, or wildlife "crosswalks," as done by Lehnert and Bissonette (1997).

- At-grade crossings integrated with animal-activated detection systems (Huijser et al. 2015) intended to modify driver behavior, using time-specific flashing signs to warn when animals are adjacent to a roadway, have the potential to avoid motorist habituation (Huijser et al. 2015a), as accomplished by Gagnon et al. (2018) over a 9-year period in the US.
- One limitation of at-grade crossings is the impact that high-traffic volume has on animal crossing passage rates, as animals typically repel away from roads as traffic increases.

Road design and management guidelines for incorporating effective green infrastructure and other measures

Overarching Design Principles

When planning and designing roads, highways, and railways through biodiversity-rich areas, the following design principles should be kept at the forefront. After due diligence has been exercised to consider alternative alignments that altogether avoid impact on high biodiversity areas, these principles along with green infrastructure and active management in the case of roads can help minimize impacts. In some, and likely in most instances, adherence to these principles will add cost to the construction of a new road or railway on the short term. But these higher upfront costs potentially represent a tradeoff in yielding longterm benefits such as maintenance of ecosystem service values (Turner et al. 2007) from minimizing transport infrastructure's impact on biodiversity and preserving ecological functions and services.

<u>1. Build the roadbed formation once and be done</u>

The initial construction of the roadbed formation should be done to meet anticipated future design standards (e.g., forecasting traffic levels out for 30+ years) so as to minimize future need for road reconstruction, especially the removal of native vegetation and slope excavation. The width of the paved carriageway is of relatively minor concern compared to excavation and forest clearing during creation of the initial roadbed formation. Once the roadbed is constructed to meet anticipated future needs, carriageway paving can be widened with minimal environmental impact to accommodate increasing traffic volume.

<u>2. Build to the minimum width necessary</u>

The narrower the zone of impact and the greater the degree of canopy retention, the better the prospect of minimizing the potential establishment and proliferation of invasive plant species (Goosem 2015). In addition, maintaining canopy integrity minimizes the impact on connectivity and movement of canopy-dependent arboreal mammal species (Soanes and van der Ree 2015, Rajvanshi et al. 2012).

<u>3. Limit lateral road access</u>

- Lateral road access can further cause habitat loss, result in increased disturbance to wildlife with traffic and noise, and promote both legal and illegal harvest of wildlife and other natural resources (e.g., timber). All of these impacts can affect biodiversity over a much larger area than that influenced by the new road itself.

- The decision to provide for lateral access should be well reasoned and predicated on need (e.g., access to a remote village), both economic and social, coupled with active management and enforcement to ensure that lateral access is used only as intended. Lateral access for agency or administrative use can be limited to controlled access by proper gating or similar measures.

4. Focus infrastructure investment where land tenure and access is secure

Many green infrastructure measures, especially wildlife passage structures, can be costly to construct. Impacts from human land use patterns that occur immediately adjacent to such infrastructure can severely limit or even preclude intended use by wildlife, as documented by Chogyel et al. (2017) at an underpass used by elephants in Bhutan. As such, consideration should be given to focusing costly infrastructure in areas where adjacent land use may be controlled and/or regulated to maximize return on investment.

5. Keep it simple – minimize maintenance

To minimize maintenance needs in the face of limited post-construction budgets and logistics, strategies should integrate measures and approaches anticipated to require as little short- and long-term maintenance as possible. Often the best low-maintenance approach is to pursue the simplest solution. There are significant benefits, albeit some with modest increased up-front construction cost, for oversizing (e.g., dual-use concrete box culvert to prevent washouts from extreme weather events) or over-engineering (e.g., fencing alternatives) to maximize infrastructure functionality and minimize future maintenance needs.

Road Management Activities

The manner in which a road is managed after construction has the potential to further minimize road impacts and complement the benefits of green infrastructure. Aside from posting lower speed limits within protected and high-biodiversity areas where potential wildlife-vehicle collisions are a concern (Rajvanshi et al. 2001), there are also a wide range of management activities that may be pursued to reduce impact on, and even achieve a net benefit to biodiversity.

1. Evening/Dusk-to-Dawn road closures

Eliminating public conveyance on the road during nighttime and crepuscular hours when animals are typically active would effectively eliminate the traffic-associated impact on both wildlife-vehicle collisions and permeability of all taxa of wildlife, including the most susceptible reptiles and amphibians (Laurance et al. 2009).

2. Seasonal road closures

Typically, seasonal closures are utilized to address lateral access off highways or to address seasonal weather issues (e.g., snow accumulation during winter) or peak and concentrated wildlife migrations. Some low-traffic highways are seasonally closed for the benefit of endangered species in North America, though in these cases there are often alternative travel routes. Seasonal closures could also employ just dawn to dusk closures during key wildlife movement periods, such as breeding season for ungulates when they move furthest or for elephant migrations.

3. Road as a resource protection asset

With the construction of roads, enforcement personnel can conduct intensified patrols to address illegal incursions for poaching and damage to resources. Enhanced infrastructure such as observation towers and anti-poaching outposts (ADB 2018, Rajvanshi et al. 2001) to support law enforcement can further enhance resource protection as well as enforcement personnel safety.

4. Monitoring and adaptive management

Sound monitoring need not be an expensive proposition yet should yield dividends from helping evaluate and make appropriate modifications and improvements to green infrastructure efficacy, strengthen future conservation strategies, and generate public awareness and support. One area where monitoring is particularly appropriate is in evaluating the efficacy of wildlife funnel fencing and/or alternatives to fencing where wildlife passage structures have been constructed.

Reconstruction and retrofitting opportunities

Many roads in Asia were constructed in the past, there was a propensity to implement initial design standards that reduced upfront construction costs but necessitate subsequent upgrading and widening of the roadway to accommodate increasing traffic volume. And while such reconstruction of existing roads may impact vegetation and soil stability associated with widening of roadbed formations, such projects also present excellent opportunities to address ongoing impact on wildlife and biodiversity, including wildlife-vehicle collisions and connectivity/barrier effects.

Where existing drainage structures are present

Including bridges and large concrete box culverts, they may be linked with wildlife fencing (or alternatives) to create costeffective and potentially effective wildlife passage structures (Kintsch and Cramer 2011; Gagnon et al. 2015).

Where existing structures suitable for wildlife passage are not present

- “Drop-?in” applications of prefabricated underpasses (metal-plate or precast concrete arches) can be accomplished with minimal disruption
- Integrate passage and drainage function into upgraded drainage structures during widening and reconstruction projects when drainage structures are being enlarged or even oversized

Many green infrastructure measures may be pursued and implemented as standalone “retrofit” applications to address priority wildlife biodiversity issues outside of road construction or reconstruction projects (Gagnon et al. 2015, 2017), though funding such projects can be problematic. However, where roads or other linear infrastructure (railways, canals) are limiting recovery efforts for threatened or endangered wildlife species, funding for standalone retrofitting may be more readily available. The downside of such projects, however, is since they are not part of a larger road construction or reconstruction project, they will have to bear the full costs of project mobilization, overhead, and contingencies.

Resource

Asian Development Bank. 2019. *Green Infrastructure Design for Transport Projects: A Roadmap to Protecting Asia's Biodiversity.* Manila.

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Asian Development Bank (ADB)

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