Reconciling Mobility: Redesigning the Road, Reweaving Landscape

By NINA-MARIE LISTER

A road is a thoroughfare designed to connect two places—a route to link communities. Virtually every definition of road implies connectivity. Yet the unintended consequence of centuries of road building has been to divide as much as to connect. In the current era of unprecedented urban expansion and road building, perhaps it’s time to revisit the road and to design for connectivity, rather than fragmentation.

There are many strategies we should pursue in rethinking the road, not least the fundamental question whether to build a road. But my aim here is to pursue a set of approaches to transportation planning that focus on retaining, reclaiming, and re-establishing connectivity. We can and we should reconcile our notion of mobility such that we (re)imagine the road as a device for (re)connection between humans and wildlife, culture and nature.

Roads connect humans but they fragment the landscape, and with it, ecosystems and habitats for all species. The TransCanada Highway and the Canadian Pacific railroad compromise an essential transportation corridor running through the Bow River Valley, a critical habitat in the Rocky Mountains. Photo: Tony Clevenger, Parks Canada.
In the last sixty years, the number of cars in the United States has increased more than threefold, and settlements have sprawled out from urban centers in unprecedented growth: roads have fragmented our landscapes, divided habitats, and grown ever more congested. Today, new roads are often built for the primary (but misguided) intention to alleviate congestion. Yet it’s clear that more routes lead to more traffic, and inevitably to further fragmentation. Divided habitat and severed landscapes degrade both nature and culture: not least, the wildlife among us.

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The prevalence of roadkill is an obvious and disturbing result of the conflict between the needs of humans and animals. The human need to get to where we are going safely and quickly is a basic expectation of modern society. Yet wild animals need connected landscapes: they must cross our roads in search of food, mates, and shelter. Our expanding network of roads, highways, and interchanges criss-crosses the continent, interrupting and disconnecting our landscapes—and with these, the territories of wild animals. Many are routinely struck and killed by vehicles in the most basic quest for survival.

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Today, there are more than 4.8 million miles (7.8 million km) of roads on the continent. Americans have one of the highest rates of private automobile ownership on the planet, with more than a quarter billion vehicles using these roads. Given the dominance of the road in North America and the fact that we now spend, on average, 1.5 hours per day in the car, it has become disturbingly commonplace—even acceptable—for wildlife to be killed on our roads. Collisions between wildlife and vehicles have increased by 50 percent in the past fifteen years. These accidents now cost Americans a staggering $8 billion every year.

Large mammals pose significant risks to motorists and are also themselves vulnerable where their paths cross motorways. Photo: Sandra Jacobson.
But this is not merely a wilderness or rural issue—it is a problem that affects everyone; those of us living and driving in busy suburban semi-rural and urbanizing landscapes are more likely to witness or experience the conflicts first-hand. In fact, growing numbers of wildlife-vehicle collisions are leading to higher levels of personal injury and property damage, and with this, rising insurance premiums. While human deaths are not high compared with other accidents, wildlife-vehicle collisions are also increasing as a proportion of the total accidents on the continent’s roads. Even if not physically hurt or economically affected by a collision, many people report feeling traumatized after hitting an animal.

Alongside these obvious concerns for motorist safety are serious implications for wildlife. Road mortality is documented as one of the major threats to the survival of twenty-one federally listed threatened or endangered species in North America. On a much larger scale, conventional road building results in significant losses of habitat for wild animals. Road networks fragment our landscapes into ever-smaller, disconnected patches in which wildlife must live and move, faced with declining genetic fitness as populations become separated and isolated. Worse yet, basic wildlife mobility often conflicts with major transportation routes. Most of North America’s major highways cross the continent in an east-west orientation, but wildlife movement patterns tend to flow north-south following mountain topography, such as the Rockies, the Appalachians, and the coastal ranges. These landforms have always been important habitat and migration corridors, and they may become still more significant. Research on climate change suggests many wildlife species may be forced to migrate in changing patterns across our landscapes in search of new habitats as resources become scarce in their current home ranges.

But roadkill is not simply “bad luck” or an unfortunate consequence of driving; it’s an avoidable cost and a preventable loss. If we stop and rethink our dominant model of mobility to understand that both humans and wildlife share a common need to move, we can redesign the road to provide safe passage for all. Indeed, an emerging priority for transportation and natural resource agencies is to make highways safer for both drivers and wildlife. One of the proven solutions is to build wildlife crossing structures. Also called mitigation structures, wildlife crossings include a range of built forms over and under roadways which are usually implemented in tandem with warning signs for motorists and exclusionary fencing to stream wildlife towards the structures. Deployed correctly and in the right context, wildlife crossing structures have a near-perfect success rate in preventing roadkill.
Wildlife underpasses and overpasses have been built and implemented in a variety of sizes and designs. While Europe has many, indeed hundreds, of wildlife crossing structures—usually referred to as “ecoducts”—North America has relatively few. The best studied and well-established overpass crossing structures are in Banff, Alberta, along the TransCanada highway in Banff National Park. However, these structures were not designed specifically for wildlife; rather, they were conventional transportation-engineered bridge structures which were adapted by adding a vegetated surface. They have proven remarkably successful in restoring ecological connectivity and in improving road safety. After a decade of study and demonstrated success, road ecologists are researching new opportunities to evolve the design and function of these prototype structures by asking: could their capacities expand and the cost of their construction contract with a redesign expressly for their purpose?

New solutions to wildlife crossing infrastructure are needed to reduce the costs and to tailor each type of crossing to the specific species in various landscape contexts. In today’s climate of decreasing public investment in civic infrastructure, we are faced with an increasing need to repair existing and often crumbling transportation infrastructure; there may well be opportunities to adaptively reuse or retrofit some structures for wildlife crossing purposes, whereas new structures may test alternative and emerging sustainable materials at lower lifecycle costs. New solutions to the construction approach and material of crossing structures must also be considered in the context of long-term ecosystem change. We may need to move, enlarge, or downsize these structures based on changing wildlife movement patterns due to changes in habitats, climate, or other factors that become apparent over time.

In the broadest sense, a key step in reconciling mobility means capitalizing on the potential for crossing structures to tell a story—the story of a renewed relationship among humans, wildlife, and landscapes. In this context, wildlife crossing structures present a timely opportunity to communicate both the problems
with roads and the solutions to the general public. By making crossing structures visible, people can experience first-hand—and identify with—engineered landscape designs that create safer roads for both humans and wildlife.

Superhighways allow us to move so far and so quickly that it’s possible to forget about the landscapes on either side of the road. As we extend and expand the network of roads, more motorists are moving faster through remote areas: areas that were once wilderness have become essentially urbanized. Our transportation networks have had the unintended consequence of rendering more of North America’s living landscape invisible. In rethinking mobility, we ought to strive not only to reduce the number and frequency of wildlife-vehicle collisions, but to use crossing infrastructure to change the way we see and understand our roads and the places through which they travel.

Wildlife mitigation structures have the capacity to act as a new, visible layer of functioning landscape, weaving over and under highways, in and out of the natural landscape. In this way, crossing structures can reveal and highlight the landscape and habitats our road networks have fragmented; they have the potential to express this remarkably, even beautifully. Just as suspension bridges can be elegant and delicate in appearance but strong in function, wildlife crossings—whether overpasses or underpasses—can be beautiful in their simplicity while effective in linking habitats.

When designed and implemented strategically, wildlife crossing structures can radically reduce the number of collisions to save money and, most significantly, human and animal lives. Better still would be to rethink mobility at a continental scale and to redesign our transportation infrastructure to include a network of wildlife crossing overpasses and underpasses all along key migration corridors. Eventually, with an integrated network of many crossing structures in place, it may be possible to reconnect our landscapes and ultimately retain—and in some cases restore—the vital functions of North America’s wild ecosystems.

It’s important to emphasize that this is not a new idea, nor is it unsubstantiated. Providing crossing infrastructure at key points along transportation corridors has been shown to improve safety, reconnect habitats, and restore wildlife movement. Throughout Europe, Asia, Australia, and North America, hundreds of crossing structures, or “ecoducts,” have already been implemented with demonstrable success.15 These include underpasses and overpasses that have been constructed in a variety of sizes and designs. Although wildlife underpasses are generally less costly to build and more commonly used by a wide diversity of species, wildlife overpasses are preferred by certain wide-roaming and iconic species-at-risk, such as lynx, grizzly bears, and wolverines, for example. Overpass structures are also more visible and noteworthy to motorists, which suggests that these structures may have the potential to engage the public in ways that advance conservation education, landscape awareness, and environmental literacy.

In terms of structural engineering, wildlife overpasses are the reverse of most conventional bridges. This has implications for how they are designed and the materials from which they can be made. Conventional vehicular bridges are typically longer in span than width; that is, they are narrow enough to accommodate maybe two to four lanes of traffic but may have a long span to cross a river, a highway, or a harbor. Wildlife bridges are typically shorter in span but much wider. They also necessarily include a thick layer of soil and vegetation—a landscaped surface—that must emulate local habitats. This means that crossing structures could be designed differently from conventional bridge structures. They might include lighter, flexible, and more adaptive materials or a system of construction that is modular or even dynamic.

Each of these innovations has the potential to result in more sustainable and affordable construction. For example, an adaptable, modular structure can also expand, contract, or be moved to respond to changing habitats and climate conditions that are difficult to predict. As a new category of infrastructure, wildlife crossings are an opportunity to explore new materials, features, and approaches to building and construction. This exploration is important, given the diversity of habitats and wildlife species that must be accommodated affordably and safely.
In 2010, the ARC International Wildlife Crossing Infrastructure Design Competition was launched to explore new materials, new methods, and new thinking about wildlife crossing infrastructure. The ARC competition engaged the world’s leading engineers, landscape architects, and ecologists to create the next generation of wildlife crossing infrastructure for North America’s roadways. Designers were challenged to develop new solutions for animal road-crossing structures that would be cost-efficient, ecologically responsive, safe, and flexible; they developed concept solutions that could be readily adapted for widespread use in various locations and under many conditions, including climate change. As such, the ARC competition was an opportunity to investigate and propose a range of new solutions to the problem of congested roads, fragmented habitat, and vehicle-wildlife collisions.

Based on state-of-the-art engineering and the best available data in road ecology, the ARC competition advocated for a set of best practices in considering wildlife overpass structures. The competition began with the basic premise that any crossing design must be safe for humans and wildlife alike, but it must also demonstrate other important functions and benefits. In particular, crossing structures must be cost-effective in terms of materials, construction, and maintenance, while also ensuring ecological responsiveness to current and anticipated conditions—yet structures should also be flexible or modular for possible use in other locations, and ideally, they should be adaptive, to facilitate mobility of wildlife under dynamic ecosystem conditions. An important criterion to advance the design of crossing structures is that they must be sustainable in terms of materials and energy use and responsive to climate change. Well-designed and properly planned structures must also have an important civic value: they must be educational, revelatory, and communicative to the public, and therefore, they ought to be beautiful, engaging, and remarkable. From a pragmatic perspective, new solutions for crossing structures should be considered as early as possible in the transportation planning process so as to ensure context-specific design for target species.

In the context of these criteria set out by the ARC competition, wildlife crossing structures represent a new category of infrastructure for designers, engineers, and scientists. As such, they require a collaborative, interdisciplinary systemic approach for effective planning and design. Yet highway engineering and transportation planning have traditionally been highly compartmentalized activities in which various experts work separately on distinct aspects of a project. Wildlife crossing infrastructure cannot be planned this way for the simple reason that there is more than one “client” for the project. Both humans and animals have different (and sometimes competing) needs related to any given crossing structure; some species prefer overpasses, while others prefer underpasses. All require safety.

Resolving such a design challenge requires more creativity and expertise than any one specialist affords. For this reason, wildlife infrastructure design is necessarily a collaborative craft, one that requires the input of many different types of experts, from ecologists to architects to landscape designers to engineers and transportation specialists. Road ecologists who study and understand animal interactions with highways must work proactively with the federal agencies and state departments of transportation that are responsible for everything from planning and engineering the roads to handling collision emergencies and cleaning up roadkill. The ARC project provided a proactive opportunity for these and other related experts to come together and collaborate in designing a new approach to wildlife and human safety.

Five finalist teams in the ARC International Design Competition were short-listed from a field of more than one hundred firms participating on thirty-two qualifying entrant teams from nine countries. The finalist teams advanced a variety of strategies, materials, and design concepts for a new kind of mobility for
both humans and wildlife. Their creative, collaborative, and interdisciplinary design processes resulted in an innovative range of ideas. Some of the key advances in crossing design and rethinking mobility from a landscape scale included:

**Diversity of building materials.** Concept designs employ a wide diversity of building materials, including glued laminated timber, steel, Ductal concrete (which is more compressive and resistant), glass-reinforced plastic, and wood-core fiberglass, as well as more innovative usage of everyday materials such as precast concrete.

**Layered construction techniques.** Designs incorporate layered construction techniques—for example, using stacked convex and concave “arcs” or steel lattice with modular landscape inserts.

**Shape.** Concept designs are based on an inverted arc shape, which conveys the feeling of a valley for animals and results in more light for drivers and the roadway; pillar-free designs improve highway safety.

**Viewing platforms for the public.** These range from highway pullouts at a safe distance to a “periscope” for discreet observation that is integrated into the bridge structure.

**Explorations of modularity.** Some concepts extend the crossing span or width through landscaped ramps or a structural system of pieces that appear to snap together. Another concept is based on pre-fabricated, pre-vegetated habitat modules that respond to local conditions. In all cases, modules can be added or removed as needed and can be switched out if local habitat conditions change. Modular designs and flexible structural solutions ensure efficient construction that saves time and is easy to build without highway closures, or with limited interruption of traffic.

**Monitoring of wildlife.** Designs accommodate real-time monitoring of wildlife movement for both scientific and public educational purposes through various features. These include placement of cameras on the bridge that will download images to smartphone apps, websites, information kiosks, or local schools. Monitoring strategies are designed to permit adaptive management of vegetation and habitat—and in several cases, adaptation of the structure itself.

Through these concepts, the five finalist designs in the ARC competition offer tangible examples of how we might reconcile mobility for both humans and animals, in various contexts and circumstances. Each of the concept designs is profiled briefly here to illustrate the innovation and advances in design thinking and practice for this new typology of infrastructure.

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**Finalists in the ARC International Design Competition**

*Modular Crossing System, by Balmori Associates.*

The goal of this design is to create a modular and efficient “kit of parts” using sustainable materials. To achieve this, the design strategy specifies using locally manufactured, laminated timber girders made from timbers killed by the pine beetle. The resulting bridge is a sustainable free-form structure that stores more CO2 than was used in the manufacturing process. The topography of the local landscape is reflected in the underside contours of the structure, while the surface habitat, with its wide ramps, is designed to blend seamlessly into the surrounding landscape.
**Wild X-ing**

The goal of this design is to create a modular structure that can be locally assembled and adapted as habitats change. To achieve this, the design strategy creates a double-curved inverted arc structure, composed of a steel and Ductal grid overlaid with a rhomboid-shaped micro-grid lattice. The lattice is composed of pre-vegetated, lightweight, glass-reinforced plastic habitat modules—inserts that can be adapted, replanted, replaced, or expanded as conditions dictate. Customized to local habitat conditions, the modules can be planted off-site and readily transported by flatbed trailer to the site for insertion or replacement.

**LANDSHAPE**

The goal of this scheme is to create a cost-effective, lightweight, pillar-free structure that appears to float across the highway. To achieve this, the design strategy involves using concrete formwork to create a thin-shell, double-curved, pillar-less structure. The formwork can be reused many times and results in a cost-effective structure due to the thin layer of concrete required and the intention of repetitive construction to create a series of bridges. The upper curve of the “landshape” contains the habitat for the crossing, including a system of ponds to serve as a draw for wildlife.

**RED/Research Evolve Design**

The design goal for this concept is to build a lightweight, flexible structure that is iconic, yet almost invisible. To achieve this, the design strategy uses lightweight, resilient wood-core fiberglass for the bridge structure, which is designed in flexible, modular configurations, or “strands,” in the landscape. This strategy makes use of the existing tree canopy as additional habitat between strands and proposes multiple connections into the site with varied possible routes across the bridge, based on the travel habits and preferences of each target species. Notably, the bright red bridge is intended to be an iconic structure for humans, signifying the crossing, the landscape, and its non-human inhabitants, but is unremarkable to wildlife that cannot see the color red.
Hypar-Nature

The design goal for the winning design in the ARC competition is to develop a sustainable, modular, flexible, cost-effective crossing system that appears to weave over and under the road and that can be made locally and assembled on site. To achieve this, the design strategy employs thin-shell, precast concrete forms based on a three-hinged arch. These hypar-forms allow for minimal site disturbance and relatively easy on-site assembly and deployment, given the widespread availability of local precasting facilities across North America. The hypar-forms can be readily expanded or adapted as wildlife movements and habitats change or as site-specific conditions dictate. The scheme is a landscape and structural collaboration, bridging both under and over the road, effectively layering both the drivers’ experiences and animals’ preferences.

Although the ARC project began with a competition for a specific location near Vail, Colorado, it’s important to emphasize that the only way to solve the problem of vehicle-wildlife collisions for good—and to truly reconcile mobility—is to have a system of crossing structures, including overpasses and underpasses, bridges and tunnels. No single structure alone will solve more than a localized problem; wildlife crossings must become a ubiquitous part of the North American roadscape if they are to be successful on a landscape scale. To do this, an adaptable, flexible, and modular design is needed—one that can be readily modified to different contexts and circumstances.

One of the simplest and most elegant ways to begin this infrastructural transformation is to first use everyday materials that are readily available, but to use these materials in an uncommon and modular way. This is precisely what the winning team in the ARC competition proposed (see Hypar-Nature in the adjacent box). Designed by HNTB with Michael Van Valkenburgh Associates Inc., the winning concept for the ARC competition demonstrates how a reliable, predictable, and proven material can be deployed in an uncommon or novel way. Precast concrete is one of the most common building materials in North America, meaning that every state has the capability to make it, and no location in the United States is more than 250 miles (400 km) from a fabricating plant. Although concrete is not considered a sustainable material, there are improvements being made in its composition. Precast concrete is readily available to use on a large scale, in many locations, which lowers the production cost for the crossing structures.

The ARC competition’s winning design is only one example of the innovation needed for new solutions for wildlife crossings. The HNTB+MVVA scheme uses ordinary materials and technology, as well as construction techniques that are well established and, in particular, accessible in many locations across the continent. This has significant potential to reduce construction costs and improve construction accessibility. This solution combines emphases on wildlife habitat, behavior, and viability, with a practical intelligence and concern for long-term sustainability. The ARC jury noted in particular that this scheme “marries well a simple elegance with a brute force. It effectively recasts ordinary materials and methods of construction into a potentially transcendent work of design. In this regard it gives us confidence that it could be credibly imagined as a regional infrastructure across the inter-mountain west.”

As more crossings are built, continuous learning through ongoing monitoring is expected. Wildlife crossings are being designed as living experiments, complete with data-gathering technologies built into the structure. The crossing infrastructures offer rich potential for learning: infrared cameras installed at crossing sites capture and record animals in transit; Web cams transmit real-time wildlife movement data to science labs and classrooms alike; and hand-held applications bring the data to passengers in a passing car. From scientist to student to tourist, wildlife crossings reconnect us all to the landscapes that surround us, and in so doing, have the capacity to improve environmental awareness and engage a new culture of ecological literacy and practical conservation.
Wildlife crossing locations and structures are already monitored by scientists and citizens’ groups using motion-triggered and infra-red cameras to track wildlife movement and public sightings of wildlife on roads. These data could be shared more broadly using websites and handheld applications made accessible to schools, zoos, and conservation groups to improve public awareness, environmental education, and ecological literacy. Sources: Russ Sands (left) and HNTB + MVVA (right).

In turn, the design of future crossing structures will improve. Based on the lessons learned from the monitoring data gathered, structural designs can and should be adapted to the site conditions and wildlife dynamics with each successive implementation. Over time, we can expect more of the radical and prototypical designs advanced by the ARC competition, along with other innovations in materiality, technology, and ecological approaches. These new solutions will be welcome additions to what is already a promising new category of infrastructure.

Over time, as wildlife crossing structures become more commonplace, the public sector may be more willing to take risks with new materials and embrace more experimentation in different contexts and applications. In the immediate future, the ARC project goal is to see a variety of prototypical structures built and to demonstrate to state and federal agencies and to the public at large that these crossings work on a larger scale. They will reduce animal-vehicle collisions by between 80 to 100 percent if designed correctly; with time, wildlife crossings can eliminate the problem and the cost of such collisions.

Clearly, modern highway design must meet many different needs. The ARC project has demonstrated that it is possible to design not only successful crossing structures, but also a process that meets the diversity of today’s transportation needs. In particular, the ARC project has already made considerable progress toward the (re)design of highways to maintain the integrity and connectivity of our ecosystems, reduce the carbon footprint, minimize the consumption of non-renewable materials, recycle resources, and extend the life cycle of transportation infrastructure—all while providing safe and efficient mobility for humans and wildlife. But we know that single, iconic bridges will not accomplish much. To be effective at the most functional level, we need a network of crossings—what some have called “an interstate for wildlife”—just as highways are a network of roads.

By redesigning the road for two “clients”—animal and human—wildlife crossing infrastructure presents a timely opportunity to communicate both the problem and the solution to the public. In building crossing structures that are visible and legible, we may empower motorists to experience engineered landscape designs that create safer roads, while simultaneously demonstrating the importance of (re)connected landscapes. Widespread deployment of this relatively simple redesign tactic may change the way we move and live, and with this, change the dominant model of mobility.

We have proven solutions to reweave our landscapes, protect our wildlife populations and their habitats, and ultimately restore the essential functions of North America’s wild ecosystems. In redesigning the road for safe passage for all, we take one of many steps to honor the landscapes that sustain us and the places we call home. It’s time to reconcile mobility and redesign the road.

Reconnecting our landscapes with safe passage for all. Source: Yves Leblanc.
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NOTES

14. See, for example, ongoing work by Dr. Tony Clevenger and the Road Ecology Unit at Montana State University’s Western Transportation Institute, at http://www.westerntransportationinstitute.org/research/roadecology/default.aspx.
17. The five finalist teams in the ARC design competition and their submissions are posted at http://www.arc-competition.com/finalists.php.
19. For more on the current and ongoing work of the ARC project, see http://arc-solutions.org.
20. The “interstate for wildlife” is advocated by conservationist Harvey Locke, ARC partner and a founder of the Yellowstone to Yukon Conservation Initiative; see http://www.y2y.net.