"Landshape"—Modular Constructions of Wildlife Crossings

Marieke Berkers, Rob Torsing, Martin Knuijt, and Sjef Jansen

ABSTRACT

In 2010, the American organization ARC held an international competition to design a series of 25 wildlife crossings across highways to connect the southern and northern Rocky Mountains. Zwarts & Jansma Architects, in collaboration with *OKRA* landscape architects, Iv-Infra, and Sjef Jansen Plan Ecology, won 1 of the 5 finalists' places with their "Landshape" design. For the designers and ecologists, the main challenge was to create a series of wildlife crossings that would be buildable, affordable, and adaptable to context. To meet the set criteria, the team made an important technical invention. They designed a repeatable, modular structure. For its construction, the team developed a flexible formwork, which can be used to create variable shells. The formwork is made of cable nets, over which a fabric (textile membrane) is placed. Its unique property is that the cable nets can be re-used many times in varying forms. The ecological composition of an area is the decisive factor in the composition of a wildlife crossing. The most important organizational feature of the architecture is the extrapolation of existing curves in the landscape. With "Landshape," the team produced a physical entity that connects culture and nature.

Keywords: ecological design, fragmentation, Landshape, modular constructions, wildlife crossings, wildlife-vehicle collisions

Safe Crossings

The desire for a series of wildlife crossings arises from a variety of needs. The most important motive is to create a safe environment. Safety can be viewed from 2 perspectives. On the one hand, humans, as road users, are eager to reduce roadkill. Road accidents and traffic jams are frequent in natural surroundings, such as the Rocky Mountains. On the other hand, there is the vantage point of animal protection. An added advantage is that crossings used by wildlife may save money on insurance premiums and repair costs, money that can be used to improve safety further by building more wildlife crossings.

Wildlife crossings also help to connect fragmented habitats. Aside from roadkill accidents, infrastructure also divides wild animals. The survival of entire animal populations is jeopardized by the barriers created by highways. Once fragmentation increases beyond a certain point, it poses a threat to genetic diversity within species. The isolation of too small a population leads to inbreeding. Wildlife crossings diminish barriers, expanding the animals' habitat. Finally, wildlife crossings meet the human need to protect nature, connecting natural areas helps to stretch the boundaries of ecological units.

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Nature Meets Culture

The importance of wildlife crossings and ecological structures is widely acknowledged in the Netherlands. This is not because the Netherlands is so rich in natural scenery, but because the country's landscape is largely man-made. In the Netherlands, everything is "culture," even the natural surroundings. The desire to create nature entails a cultural act. Public authorities frequently designate particular areas where nature is to be left undisturbed. And since the country is criss-crossed by a dense network of infrastructure, wildlife crossings are essential to connect the relatively small fragments of natural scenery.

In the U.S., the building of wildlife crossings is still in its infancy. The country has less of a tradition in sculpting the natural world; as a result, nature and culture interact less often. In view of the growing need to create wildlife crossings, building up knowledge on innovative ways of building and designing wildlife crossings is very important in North America.

ARC designated a specific location for the design commission: West Vail Pass in Colorado, U.S. (Milepost reference coordinates: 39°33'51.18"N, 106°14'7.68"W). The choice is based on results of monitoring by the state and members of the public, from which it appears that it is a popular crossing for animals. In addition, the plant community is sufficiently robust here to survive the construction of a wildlife crossing. The region is a subalpine life zone, with a mix of conifer forests, alpine tundra, deciduous forests, and low brushwood. The fauna include Canadian lynx (*Lynx canadensis*), American marten (*Martes americana*), mule deer (*Odocoileus hemionus*), coyote (*Canis latrans*), bighorn sheep (*Ovis candensis*), mountain goat (*Oreamnos americanus*), snowshoe hare (*Lepus americanus*), moose (*Alces alces*), black bear (*Ursus americanus*), and yellow-bellied marmot (*Marmota flaviventris*).

With "Landshape," the team produced a physical entity that connects culture and nature. For the designers and ecologists, the main challenge was to design a *series* of wildlife crossings that would be buildable, affordable, and adaptable to context. In addition, the construction must be as sustainable as possible. They also wanted to create a certain unity within a series of wildlife crossings, without making all the structures identical in appearance so that road users would not be confronted with an overly repetitive picture. This approach would make it possible to tailor each wildlife crossing to the specific geographical situation. Devising appropriate designs that would meet all these criteria proved extremely challenging. If wildlife crossings are to be designed for 25 different places, each one structurally unique, there is a risk of incurring heavy expenses in the design and construction phases.

The team explored ways of designing a series of wildlife crossings that would bear a family resemblance to each other while retaining individual characteristics. In doing so, they rejected more standard procedures: designing prefabricated structures that could then be copied and set down in different places. Although prefabricated structures keep costs low, they have many disadvantages. Besides creating a dull and repetitive view from the road, they are also inefficient, as the most common crossings consist, to put it simply, of a bridge over which a patch of land is placed. They use straight bars. This will always require more material than in the case of a more efficient structure.

"Landshape"

To meet the set criteria, we made an important technical invention, a repeatable, modular structure. For its construction, we developed a flexible formwork, which can be used to create variable shells. The formwork is made of cable nets, over which a fabric (textile membrane) is placed (Figure 1). Its unique property is that the cable nets and fabrics can be re-used many times in varying forms. In more traditional construction methods, the formwork is generally discarded after construction. With the aid of a parametric model, designers can generate a unique geometry for each location (Figure 2). Using designated software, they cut out the appropriate textile membrane, each one tailored to the geographic context. These cuts give the membrane its shape, in the manner of an air balloon or a parachute. This shell structure is an innovative mode of construction in bridge building. The materials used for the bridge and the construction mold are very common and easily available internationally. This helps to keep costs down.

This mold has the added advantage that it scarcely impedes traffic while the wildlife crossing is being built. This eliminates traffic jams in the construction phase, which are harmful to the environment. This is a significant advantage, certainly when 25 wildlife crossings are being built.

In designing "Landshape," the team opted for a double arch structure, with calculations based on the weight that the crossing needs to bear and surface areas in "ideal" symmetrical proportions. This man-made structure entwines the asymmetrical geocontours that are derived from the morphology and topology of the surroundings. A hypar surface was chosen as the main theme for the structure. Seen from the road, it creates an inviting arch spanning 81.5 m for the traffic passing underneath while extending the flowing lines of the landscape (Figure 3). In cross section, the upward facing arc protects the wildlife against noise and lights from the highway (Figure 4).

Together these 2 perpendicular organizing curves define a double-curved, anticlastic surface, the hyperbolic paraboloid, or hypar. Initially chosen for its architectural and functional qualities, this shape also has good structural potential. By executing it as a thin concrete shell, a large span can be realized, efficiently carrying the required loads with minimal material usage. The hypar as a thin shell structure is an idealized surface. It is completely symmetrical and has very low stress. Reality is not so neatly organized. Applied in the nonsymmetrical and irregular nature of the site topology, this idealized geometry is transformed into a shape that is context specific. The curves in the landscape serve as an outside influence. They combine with the internal logic of the flow of forces in the shell to shape the bridge into a natural form; a 'Landshape' is created.

Bridge, Ground Level, and Natural Layer

The ecological composition of an area is the decisive factor in the composition of a wildlife crossing. The ARC provided the Ecological Program, which was based on a technical report by Felsburg, Holt & Ullevig (2009). Elements derived from the surroundings are used to provide continuity, but positioned and organized so as to make it safe for wild animals to cross (Figure 5). The composition of the vegetation of the crossing in turn affects the construction and hence the design of the overall structure. The wildlife crossing should have an entrance width of 70 m (200 ft), while its functional width needs to be at least 50 m (150 ft). According to Felsburg, Holt & Ullevig (2009), research in Europe has suggested that structure widths less than 20 m are used significantly less than larger structures, whereas structures that are 50 to 60 m are preferable. These widths are suitable for the target species of the ecoduct in Vail, such as elk, black bear, and a variety of forest carnivores, such as lynx. To make a good connection of the ecoduct to the habitats on entrance and exit side, however, extra space will be used that goes beyond the border of the road trace. Deer need extra space up to 2 ha on both sides of the track.

The most important organizational feature of the architecture is the extrapolation of existing curves in the landscape. The design consists of 3 curves. The first arch is the bridge itself, while the second is the ground level of the surrounding land, which continues over the bridge, and the third is the natural vegetation that will cover the deck of the bridge (Figure 3). The natural planting on the wildlife crossing should consist of the following elements:

- An embankment or screen blocking light, noise, and movement from the road;
- Trees or bushes planted on and along the embankment as a structure facilitating the movement of species, such as small mammals, birds, and bats;
- Vegetation along the sides, rich in herbs and shrubs, for the benefit of small mammals and insects;
- Short, dry, nutrient-poor soil tolerating vegetation with open spaces for warmth-loving species, such as reptiles and insects;
- Tree trunks and stumps to be used as protective cover by martens and other small mammals;
- A layer of varied, local soil material, at least 30 cm thick.

To encourage use by moisture-loving creatures, it is advisable to include a moist strip along the entire length of the wildlife crossing, with ponds of 500 to 1,000 m^2 (5,000 to 10,000 ft^2) on either side (Figure 5). The moist strip should be 1–2 m wide and at most 30 cm (12 in) deep. Surplus rainwater from the wildlife crossing can then drain off into the ponds. The banks of the ponds should be nature-friendly. A maximum of 30% of the pond's surface should have a depth of 1.5 m (5 ft). In the Netherlands, crossings with this pond system are very successful and are now state of the art. The last dozen crossings constructed at least are all equipped with 2 ponds and a connecting moist strip. They appear to attract more animals, among them deer. The depth of 1.5 m prevents the ponds from drying out in summertime.

The wildlife is guided towards the crossing by a fence made of biodegradable material. Deer and other species use tracks, following them faithfully. Within a few months, most species can find their way to the crossing themselves. So it is not a problem that after about 3 yr have passed, the fence has gradually decayed and become part of the landscape.

The system is easy to maintain. Monitoring and nature management will be necessary at the beginning to register the crossing's use. If the crossing stays behind expectations, corrections can be made by changing the vegetation on the crossing and at the 2 accesses. Depending on monitoring results, the corridor may be made more open or closed. Restricting human activities in the neighborhood can also be an additional measure. However, in the longer term, the system will become self-supporting. The aim is to eventually reduce to a minimum the need for human intervention. With this aim in mind, the team submitted a proposal for an observation post, accessible from the crossing's visitors' center, from which to carry out a kind of passive surveillance. A little more maintenance may be needed when the crossing first opens than later on. Cutting the grass short, keeping the water clear by removing debris or leaves, and felling any trees that take root are all important measures to retain the mix of heights and densities of the overgrowth.

Iconic Structures

Creating wildlife crossings is a very visible way of promoting the need to conserve nature; the structures themselves become conspicuous icons of nature conservation. This is also an advantage for the parties commissioning them, who can communicate to local residents or to taxpayers through these iconic structures that they are active in nature conservation and opting for sustainable, money-saving construction.

The team also proposed ways of providing information to visitors to the area. In the visitors' center, the public will find modern resources, such as apps, enabling them to watch the animals moving around their natural surroundings. Those who desire to can climb a flight of steps right up to the edge of the structure and look out over the crossing from a protected vantage point. This enables visitors to learn as much as possible about their environment without disturbing it.

Consultation Culture: "Poldering"

Designing additions to the natural landscape is still in its infancy in the U.S., certainly when it comes to innovative solutions. Much remains to be done if certain improvements are to be made. For instance, more account could be taken of animals and their behavioral needs when designing infrastructure. Not all those commissioning new structures are open to thinking things through in this way. Some are afraid of incurring high costs, and those designing the new structures, as well as their clients, are often ignorant of the ecological conditions. The appropriate use of technologies and sharing of expertise can help to dispel fears and boost enthusiasm for the building of wildlife crossings.

A jumbled infrastructure sometimes produces a pleasant habitat for certain animal species quite by accident. For instance, a pond in the middle of a busy infrastructural junction at

Holendrecht, in the Netherlands, has unexpectedly turned out to be a congenial home for a colony of gulls (*Larus* spp.). The birds settled here because they were able to brood and nest here undisturbed. The spot was out of reach for natural predators, such as feral and free-ranging cats (*Felis catus*) and foxes (*Vulpes* spp.). Instead of leaving such things to chance, a conscious effort could be made to create a habitat for animals during the design process.

When planning wildlife crossings, it is also important to study the legislation. There are no separate regulations for designs of wildlife crossings. In most countries, the public authorities generally apply the regulations set in place for bridge construction. This means that the architect is faced with regulations covering matters, such as classes of traffic and gradients, which are irrelevant to designs for wildlife crossings. When planning a wildlife crossing, it is important to look carefully to see what species are likely to use it because each requires different conditions. For instance, a red deer will not cross unless it has a clear view of the path ahead. For deer, it is also advisable to have a water hole in the vicinity of the crossing; this gives them an opportunity to look up and see where they can cross.

Applying regulations devised for bridges makes it harder to design a customized crossing structure than when the plans are looked at from the way specific wildlife will use it. Different rules should apply according to the animals for which the crossing is being built. For this reason, too, we advocate involving experts such as ecologists more closely in commissions involving animals. The Dutch favor working with multidisciplinary teams in this way (Figure 6). In the Netherlands, planning involves constant consultations with different parties, a process that has been dubbed *polderen*—"poldering." The name reflects an important part of Dutch history. From the 15th century onwards, the Dutch started reclaiming land from their watery surroundings, building polders, literally creating land. They soon discovered that land reclamation was only possible if the diverse stakeholders joined forces, and that cooperation generated innovative solutions. The same applies to building projects impinging on the field of ecology.

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Marieke Berkers, Zwarts & Jansma Architects, Postbus 2129, 1000 CC Amsterdam, The Netherlands, info@mariekeberkers.nl.

Rob Torsing, Zwarts & Jansma Architects, Postbus 2129, 1000 CC Amsterdam, The Netherlands, rjt@zja.nl.

Martin Knuijt, OKRA landscape architects, Oudegracht 23, 3511 AB Utrecht, The Netherlands, mail@okra.nl.

Sjef Jansen, Sjef Jansen Planecologie, Ir. Munterlaan 52, 6869 TE Heveadorp, The Netherlands, sjef@planecology.com.

(Zwarts & Jansma Architects, OKRA landscape architects and Sjef Jansen Plan Ecology. In cooperation with Diederik Veenendaal ETH Zürich)