Issues and Methods for Transdisciplinary Planning of Combined Wildlife and Pedestrian Highway Crossings

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Highways are increasingly understood as barriers to wildlife and pedestrian movement and as significant causes of landscape fragmentation—especially in suburban and periurban areas. FHWA's Transportation, Community, and System Preservation (TCSP) Program encourages innovative solutions to reduce the impact of highways on the communities they link and traverse. This paper is based on research and public participation as part of an FHWA–TCSP sponsored feasibility study for a combined wildlife and pedestrian crossing to mitigate highway impacts on wildlife and recreation, and on the communities of Concord and Lincoln, Massachusetts. The interdisciplinary study team included representatives from landscape architecture, urban planning, wildlife biology, civil engineering, and landscape history. The study included diverse public participation and collaboration throughout the project. The paper defines significant planning issues likely to pertain to similar projects and offers a transdisciplinary method for conducting planning or feasibility studies for combined wildlife–pedestrian crossings. The method is innovative for its interdisciplinary integration and its inclusion of public officials, nongovernmental representatives, citizens, and other stakeholders. The study is being considered for further research and possible implementation by FHWA with support from the host communities and a private conservation organization.

In 2004, the FHWA awarded a Transportation, Community, and System Preservation (TCSP) program grant to fund a feasibility study for a combined wildlife–pedestrian crossing of Massachusetts SR-2 in the vicinity of Walden Pond in Concord and Lincoln, Massachusetts. The TCSP was authorized by the federal Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU). The TCSP program provides research to investigate and improve the relationships between transportation, community, and system preservation plans and practices and to explore the integration of transportation programs with community preservation and environmental activities. Since the inception of the program in 2001, this is the first project to consider a combined wildlife–pedestrian crossing (*1*).

The study was administered by Boston's regional planning agency, the Metropolitan Area Planning Council (MAPC), which contracted with an interdisciplinary team from the University of Massachusetts Amherst to conduct the study along a 2.5-mi (4-km) section of SR-2 bordering Walden Pond State Reservation. Land use in the study area includes protected and private forests, single-family homes, condominiums, wetlands, and agricultural land. The study area includes four recently installed wildlife-crossing tunnels beneath SR-2 (Figure 1).

The SR-2 study area is part of a larger cultural landscape of international significance. Thousands of people visit the area annually to learn about the American Revolution at the Minute Man National Historical Park; to learn about Henry David Thoreau, Ralph Waldo Emerson, the Transcendentalists, and Walden Pond and Walden Woods; and to visit the historic towns of Concord and Lincoln. Other people experience the study area by hiking the metropolitan Boston regional Bay Circuit Trail and other recreational trails in Concord and Lincoln. The SR-2 corridor is a four-lane limited-access highway that acts as a barrier, separating Concord Center from Walden Pond and negatively affecting the perception of the larger cultural landscape both for residents of the area and for the tourists who come from all over the world to appreciate it.

The study analyzed wildlife distribution in the study area by using Massachusetts Natural Heritage data and field wildlife monitoring of species presence in the highway right-of-way zone and species use of the existing tunnels by the Wildlife Passages Task Force (a local volunteer citizen group). The analysis determined that there were no known endangered or state-listed species in the study area that would make use of an additional wildlife crossing. Furthermore, the monitoring found that the existing wildlife-crossing tunnels under SR-2 were being used successfully by a majority of species that might be served by an additional crossing. However, the study concluded that an additional crossing could serve as a demonstration project at which arboreal species could cross. Such crossings have not yet been implemented in North America but are being used in Australia.

Three potential alternative crossing locations were explored and analyzed [Figure 1, Sudbury River Bridge Underpass 1, Fitchburg Railroad Bridge Underpass 2, Vegetated Overpass Structure 3, and a no-build alternative (not numbered)]. The alternatives were determined after the study team analyzed historical and new data on the study area including wildlife, traffic and highway information,

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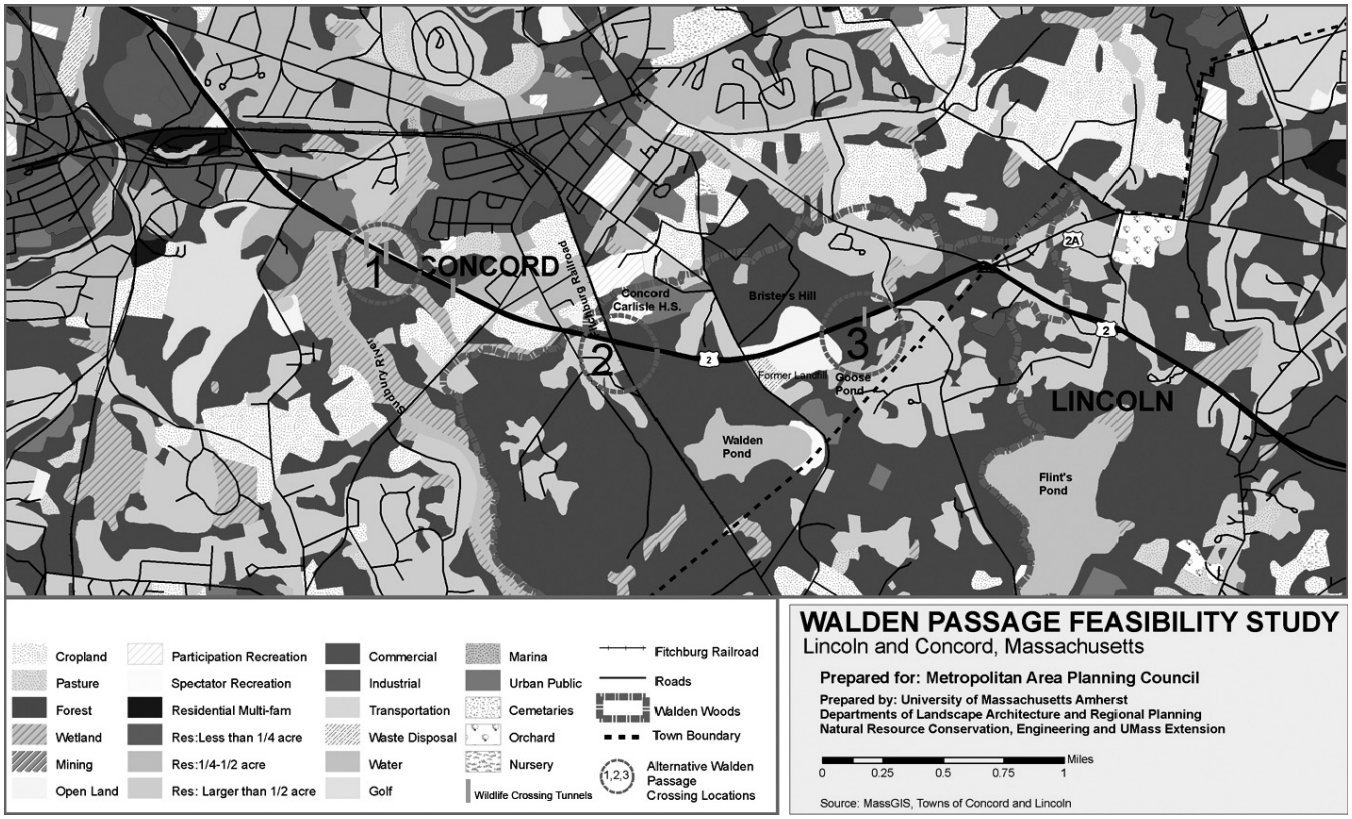

FIGURE 1 Walden passage study area, land use, 1999.

adjacent land uses, recreational activities, and cultural landscape significance. These alternatives were presented and discussed with the steering committee and at public workshops.

On the basis of the study team's investigations, input from the steering committee, and significant input from citizens, a vegetated overpass structure for pedestrian–recreational and wildlife use was recommended (Figure 2). This combined wildlife–pedestrian passage is designed to demonstrate a passage structure for arboreal species and provide significant recreational linkages with existing local trails, the nearby Minute Man National Historical Park, and the regional Bay Circuit Trail.

On the basis of this project, an outline–overview is offered of issues to be addressed and methods for conducting feasibility studies for other combined wildlife and pedestrian crossings. Transportation infrastructure, by definition, cuts across a heterogeneous matrix of land use and ecosystems—particularly in urban and periurban areas. Conflicts (and opportunities) with these diverse land uses are inevitable. The Walden Passage Feasibility Study may serve as a model for planners, wildlife biologists, engineers, and others who seek to reduce or mitigate conflicts for wildlife and pedestrian crossings and to find better ways to integrate highways with the communities they serve—and separate.

KEY ISSUES IN PLANNING FOR COMBINED WILDLIFE–PEDESTRIAN CROSSINGS

State highways with high traffic volumes may represent a significant barrier for wildlife and human crossing. The loss of habitat connectivity caused by roads disrupts the natural movement of wildlife and causes physical isolation, increased wildlife mortality, and traffic hazards for drivers. To mitigate the effect of major highways on wildlife, ecologists, landscape architects, and engineers have joined together in projects across the United States and Europe to help wildlife gain safe passage over and under roads (*2*). Open-space connectivity is important not only for wildlife; it is also important for humans who benefit from the opportunity to travel through connected and protected green spaces for recreation or cultural landscape interpretation.

Passage structures for wildlife across roads and highways are vaunted as partial solutions to these problems. Passage structures can take many forms, from broad overpasses, often known as "ecoducts," to underpasses that aim to allow movement of smaller species, such as salamanders traveling to critical breeding ponds. Most of these structures have been implemented in remote areas or in areas with little human traffic. Here, the main issues are examined that are to be addressed for planning a joint wildlife passage and human recreational corridor in a periurban location where large areas of remnant open spaces are interspersed with towns and suburban development. The issues are discussed in a suggested order of priority and relevance to similar projects.

Wildlife and Need for Passage Structures

The most direct and visible impact of roads on wildlife is the increased mortality from vehicles, commonly known as roadkill. Roadkill can have a significant impact on local populations, especially when the species are rare or have low recruitment rates (*3*). Slower-moving organisms such as amphibians are more vulnerable to roadkill (*4*). Aside from the effects on wildlife, there are human costs of roadkill. In the United States, collisions with larger animals, most commonly deer, have been estimated to cost over $1 billion in vehicle damage and personal injuries and to result in more than 200 human fatalities annu-

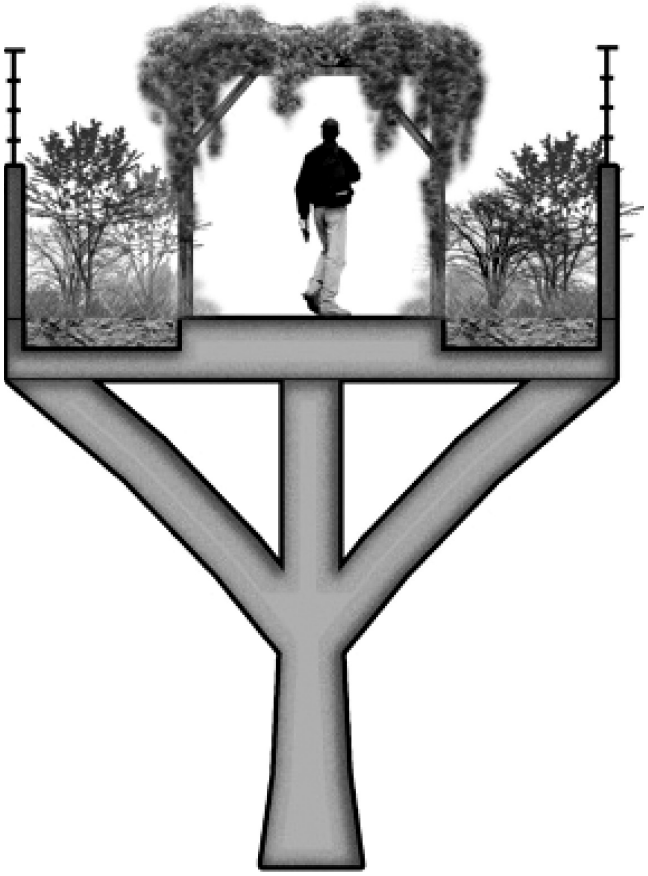

FIGURE 2 Conceptual design for Walden passage structure.

ally (*5*). Solutions to roadkill that protect both wildlife populations and humans are therefore of paramount importance.

Highways have impacts on wildlife at three important levels of biological organization: individuals, populations, and metapopulations, which are networks of interconnected populations (*6*). Ameliorating road impacts at each of these levels represents a distinct set of goals with distinct solutions. At the individual level, an important goal is avoiding road mortality or providing access to a full home range or critical habitat for one individual or a breeding pair. Reducing roadkill may be of interest either for public safety (e.g., deer) or to protect rare or endangered species in which every individual is critical to persistence of the species. Roadkill is thus also important at the population level to prevent loss of whole populations from road mortality. This is commonly a concern for amphibian and reptile species (*4*). Fencing appears to be the most effective tool for preventing roadkill.

Other population level issues include maintaining population continuity or providing access to vital habitats required by a population, such as amphibian breeding habitat, turtle nesting habitat, and snake hibernacula (*6*). Population continuity is of greatest significance when habitat fragments are too small to support a breeding population. In contrast, increasing connectivity through passage structures will achieve the objective only if (*a*) the linked habitat fragments across the road provide sufficient habitat to support a viable population and (*b*) enough individuals pass through the structure to maintain a cohesive gene pool.

At the metapopulation scale, issues include maintaining gene flow, supporting source-sink relationships among populations, and providing sufficient opportunities to recolonize habitat fragments after local extinction events (*6*). Metapopulation dynamics are of greater significance when habitat fragments are large enough to support small but viable breeding populations but are vulnerable to genetic drift and local extinction (*7*). Because metapopulation dynamics may require only a few individuals per generation to move between populations, achieving this objective does not require passage structures to be as efficient as for the individual or population level.

Researchers are beginning to understand which features of passage structures are important for successful mitigation of the impacts of roads on wildlife. Effectiveness of passage structures is thought to depend on species-specific responses of wildlife to a variety of passageway design variables, which include crossing location, vegetative cover, size, openness (ratio of cross-sectional area to length), substrate, noise levels, moisture, temperature, light, human disturbance, and the placement and height of associated fencing (*8–13*). Wildlife overpasses may accommodate more species of wildlife than underpasses because they are less confining and quieter and maintain ambient environmental conditions and because the structure itself can serve as intervening habitat for small animals otherwise unlikely to move long distances (*8*). By contrast, underpasses are likely to be better suited for animals that prefer cover (*8, 9*), or semiaquatic organisms (*10*).

Impacts of Humans on Wildlife Use of Passage Structures

Conventional wisdom holds that animals are less likely to use a wildlife crossing in areas with high levels of human activity. Very little empirical research exists, however, to support or reject this statement. A review was conducted of examples of existing structures that combine human and wildlife passage, research on the effectiveness of combining the two, and information about the design of such structures. Wildlife crossings are a relatively new phenomenon, especially in the United States. While there are numerous tunnels and underpass structures, there are still few examples of overpass structures and even fewer examples of structures that are designed for combined human and wildlife use. Very few combined structures are monitored after they are built for animal and human use (*8, 10, 14, 15*).

Most literature cites a study in Banff National Park, Alberta, Canada (*9*), when discussing the human impact on wildlife crossings (e.g., *10, 16, 17*). The Banff study found that even the best designed and landscaped underpasses may be ineffective if human activity is not controlled. In crossings with higher human activity, carnivores were less likely to use underpasses than were ungulate species.

More recent research reexamined the performance of wildlife crossing structures at Banff National Park (*9*). They found that, contrary to their previous analysis, structural factors were the most important ones influencing wildlife use of crossing structures. Landscape variables including human activity were of secondary importance (*9*). Human activity was quantified by counting the number of people on foot, bike, and horseback. However, the researchers pointed out that studies addressing the efficacy of wildlife structures often led to spurious results because of the difficulty in separating out confounding variables.

Phillips et al. (*18*) studied an underpass on I-70 in Colorado. After construction of a pedestrian–cyclist path next to I-70 on an elevated bridge near the underpass, the researchers found that highway traffic and the presence of humans walking near the crossing disturbed deer trying to use the underpass. A temporary screen to reduce the view of humans was installed and helped reduce the disturbance to the deer. The result of the I-70 Colorado study was a recommendation for a permanent screen (*18*).

South of Ocala, Florida, a combined wildlife, pedestrian, and equestrian land bridge was completed in 2000 over I-75. This crossing was 50 ft wide and designed so that wildlife and people share a common path. Raised planters of native Florida vegetation line both sides of the land bridge to screen the highway and to reduce highway noise. The central path is covered with crushed shells for compatibility with wildlife and trail users. Monitoring of the bridge recorded sporadic use by a variety of medium-sized animals and two endangered species (V. Naylor, unpublished data).

In Europe, researchers have recently reviewed the use and effectiveness of highway crossings to improve landscape connectivity (*2*). The use of crossings was researched in Slovenia, Germany, France, Switzerland, and the Netherlands. Research in France found that an overpass was not used because of human presence and small passage size (*11*). Researchers examining wildlife bridges in Poland found that only one in five wildlife bridges over a particular stretch of highway was used by wildlife. The main reason for failure was the lack of information about animal migration routes in the area, which resulted in improper locations for the crossings. Two other important reasons cited were the narrow structure of the bridges and their regular use by people (*19*).

Studies have shown that animals avoid the proximity of humans at points where wildlife cross roads, preferring to approach roads sheltered by tree and shrub cover (*20–24*). Human traffic has also caused activity shifts or avoidance by sensitive species near trails and increased numbers of unaffected or habituated species (*25*).

Issues of human activity clearly need to be considered in designing any wildlife crossing structure. However, a variety of strategies appear to be able to minimize human impacts on wildlife, particularly in more developed areas where wildlife have fewer crossing options or are already habituated to human activities.

Community Planning

Understanding community planning issues, particularly with respect to community–highway relations, is important to planning for combined crossings. As with most community planning exercises, it is advised to start with as complete as possible an understanding of the nature and drivers of community change (e.g., land use change, new development, population change, economic development). This understanding helps project planners understand how these drivers of change could influence, or even be influenced by, a combined wildlife–pedestrian passage. A well-established method for rapid assessment of community issues is a strengths–weaknesses–opportunities–threats (SWOT) analysis method. A well-conducted SWOT exercise is a powerful strategy to identify key issues but also to engage officials and stakeholders early in a transdisciplinary planning exercise.

In addition to the SWOT exercise, community issues can be understood and documented by reviewing public documents including census data, comprehensive plans, zoning plans, open space and recreation plans, and economic development plans. Because combined crossings are located within highway corridors, it is often important to analyze specific land parcels adjacent to the highway that could change in land use or to be developed for housing, commercial, or industrial uses.

Cultural Landscape Issues

Cultural landscapes are the result of human–landscape interactions over time. They may be read as narratives of the history of a community and often contribute to a sense of place and regional identity (*26*). They range broadly in scale and character and may be recognized and valued by communities, or not understood or even recognized as cultural landscapes.

Issues related to the interactions of cultural landscapes and highways include potential trail linkages, historic preservation, view shed protection, architectural design control, and tourism. A combined crossing has the potential to complement or detract from the cultural landscape character and should be carefully analyzed and considered in the planning process. Highways and highway crossings significantly engage the landscape character and become an important element in the cultural landscape character that must be addressed in the planning process.

Highway Safety

A combined crossing project will affect traffic flow and safety on the roadway. The project team should evaluate current and predicted traffic volume, accidents, future highway repair or reconstruction plans, and bridge work. An underpass crossing is not likely to be visible and thus raises minimal concern for driver safety impacts. Overpass crossings, however, should be designed and located so as not interfere with existing ramps or intersections or decrease vehicle safety by impeding vision or causing a distraction to drivers. Appropriate distance between existing intersections and a proposed wildlife–pedestrian overpass should be provided. Design issues, such as avoidance of overpass midspan supports, can affect the overall safety of the project. Side abutments should be placed away from existing or future roadway limits.

Project Cost and Funding

Combined crossings are expensive and vary in cost on the basis of the topography and project scope. Preliminary cost estimates and alternate plans can be essential to the success of a project and should be developed early in the process. Many factors influence the cost, including type of crossing, length and width, earthwork for access and integration, and, for overpass crossings, type of vegetation provided. Once preliminary cost information is in hand during the planning process, sources of funding can be explored, including FHWA, SAFETEA-LU, TCSP, and state and local highway funds. The amount and source of funding for a combined crossing should also be understood in the context of its potential impact on availability of funding for other highway projects.

METHODS

This section introduces the more specific methods that were used for conducting this planning exercise and that may be useful for conducting similar crossing studies elsewhere.

Public Participation and Transdisciplinarity

The FHWA defines an effective public involvement process as an open exchange of information and ideas between the public and transportation decision makers [FHWA Sections 23CFR450.212(a) and 450.316(b)(1)]. The overall objective of a project's public involvement process is that it be proactive, provide complete information and timely public notice, provide full public access to key

decisions, and provide opportunities for early and continuing public involvement. It also provides mechanisms to solicit public comments and ideas, identifies circumstances and impacts that may not have been known or anticipated by public agencies, and, by doing so, builds support among the public, who are key stakeholders in transportation investments.

A planning process for a combined wildlife crossing should be transdisciplinary, defined as a collaborative process in which knowledge, information, and decision-making responsibility flow between professionals and stakeholders and vice versa (*27, 28*). Planning for complex projects like a combined wildlife–pedestrian crossing arguably requires a transdisciplinary approach that goes beyond communication with stakeholders; it integrates them in meaningful ways, more as peers in the process than as clients for whom professionals and academics act—or to whom they provide information.

Recommendations for transdisciplinarity in the context of planning for a combined highway crossing include the following actions:

- Establishing a diverse project-steering committee with broad representation, including community officials, leaders of non-governmental organizations, state and federal legislators, interested citizens, and project neighbors;
- Encouraging and recording stakeholder–participant contributions from public meetings;
- Developing a publicity–communication plan to publicize meetings and workshops in local and regional media;
- Maintaining a visible, accessible public project record;
- Providing ongoing public access to project documents, draft reports, and references in the host–local community (e.g., public library, school, town hall); and
- Maintaining an up-to-date project website, including project summary, schedule, contact information, downloadable draft documents, maps and images, and address for e-mail communication.

Evaluating Need for Wildlife Passage Structure

The central issue to be addressed in relation to wildlife in a feasibility analysis is whether the addition of a passage structure would enhance the existing potential for wildlife crossings. Answering this question depends first upon knowledge of the species present and second on quantifying their use of any other crossing locations or structures.

If mortality of wildlife attempting to cross highways is the primary issue, highway fencing is recommended as the primary mitigation solution to prevent wildlife–vehicle collisions. If the major issue is the highway as barrier, passage structures may be considered. Ultimately, permeability is linked to mortality, and the two principle mitigation solutions—fencing and passage structures—are most effective when combined.

The framework in Figure 3 is presented as a method for evaluating a proposed crossing structure. The starting point should be an assessment of the habitat surrounding the roadway (Figure 3, Item 1A). If unique habitats exist on only one side of the road, then it is necessary to identify the species needing access to this unique habitat and the frequency with which they would need to cross the road to access this

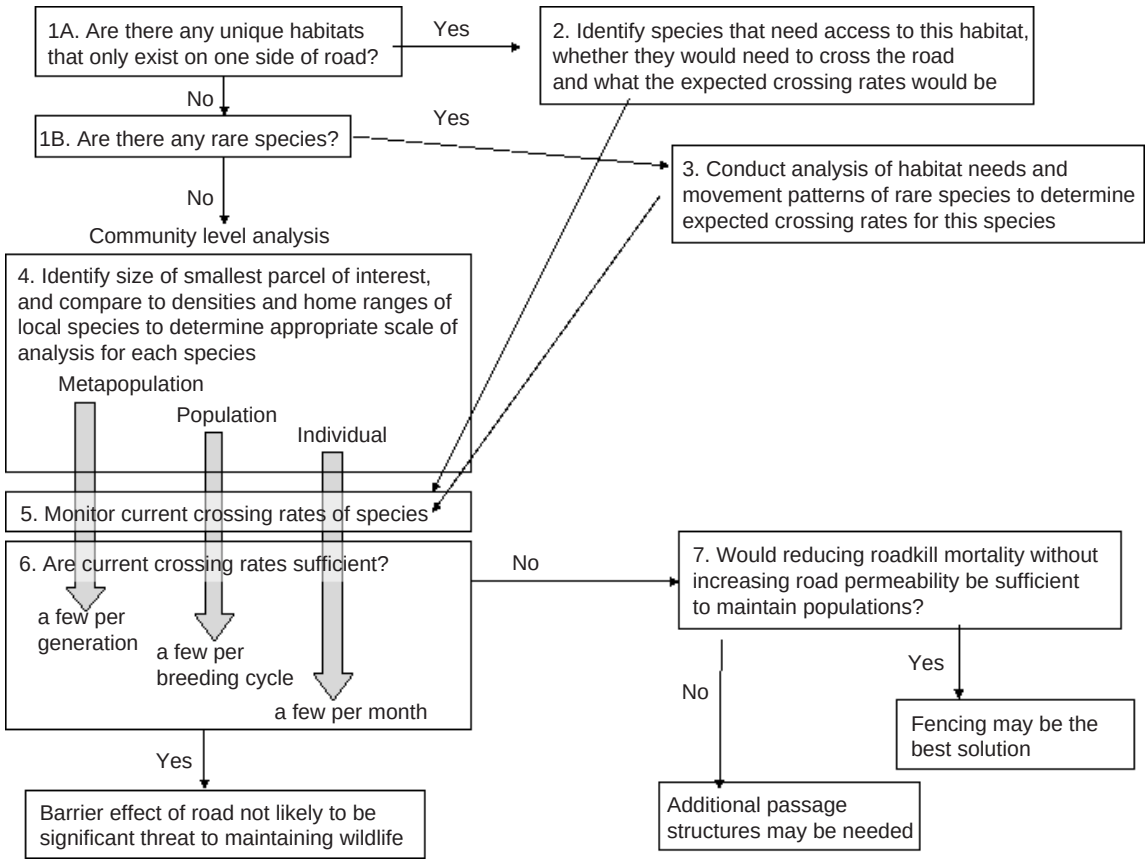

FIGURE 3 Method for evaluating need for structure to enhance wildlife crossing.

habitat (Item 2). Also required is a thorough analysis of the needs of any rare species present (Item 1B). If no rare species are identified, then the emphasis is presumably on maintaining good connectivity for a suite of animals representing multiple trophic levels in the community. To determine if there is sufficient status quo connectivity, a metric is used to determine the approximate expected rates of crossing for each species (Item 4). These expected crossing rates should reflect the appropriate scale of analysis for each species, given the size of the habitat patches in consideration. Once these expected rates have been determined, monitoring of status quo crossing rates should be conducted (Item 5) and compared with the predicted rates (Item 6). If the present crossing rates exceed the expected rates, then the barrier effect of the roadway is not likely to be a significant threat to the wildlife. If the observed crossing rates are lower than expected, then further action may be necessary. Further mitigation would entail a passage structure only if reducing mortality via fencing would not be sufficient to mitigate the effects of the roadway on the population.

Design Considerations for Combined Wildlife–Recreational Crossing Structures

Human use of combined structures is relatively straightforward to attract. Successfully attracting wildlife is a more complex question. There is a growing body of research that examines the characteristics of wildlife-crossing structures that are most frequently used by a wide variety of species (*2*, *12*, *17*, *29*, *30*). Researchers are quick to point out, however, that the structural and landscape characteristics preferred by one species might not be the best for another species. It is therefore important to incorporate information about the species present and planned in designing a combined wildlife–recreational crossing. Design considerations for combined human–wildlife crossing structures include those concerned with both location–context and the specific design.

Locational–Context Considerations

A number of locational–context considerations should be examined in designing a crossing, including the following:

1. Siting in the landscape context to be built in natural travel corridors (e.g., stream valleys or migration routes),
2. Drift fencing to guide animals to passageways,
3. Integration with roadside–landscape context (vegetation, topography, moisture) and management of adjacent land use to support human recreational use, and
4. Adjacent land uses and their potential for change and development.

The locational–context features are similar to those listed earlier solely for taking wildlife into account. Table 1 shows some of the ways that these design considerations have been implemented for overpasses in Europe and North America. Only the Florida crossing, however, has targeted both humans and wildlife.

Specific Design Considerations

Particular of overpasses and underpasses fall into the category of specific design considerations:

1. Overpasses. Shape (hourglass, straight), length, width, vegetation cover, soil depth, side walls and fencing, target species and species expected, other users (pedestrians, equestrians, bicyclists), and monitoring and
2. Underpasses. Openness (height, width, and length), substrate, other users (pedestrians, equestrians, bicyclists), and monitoring.

Most previous studies of the use of passage structures aimed only to determine which species were using a structure and how often. These studies did not evaluate the effectiveness of the structures at the population or metapopulation level. However, a number of researchers have compared differing structures and their levels of use (*10*, *12*, *13*, *30–36*). From these were derived four main recommendations for the design and implementation of passage structures (Table 1).

Engineering Design and Structural Principles of Wildlife–Pedestrian Crossing

This section discusses general issues that may affect the structural design of the wildlife–recreational crossing. Wildlife crossings can consist of an overpass (bridge), an underpass, or an at-grade crossing. Each of these structure types will have significantly different design considerations and objectives. A successful design must satisfy functional requirements and provide an aesthetically pleasing structure at a reasonable cost. The ideal solution would be one satisfying all major design requirements, which will depend on issues relating to the soil conditions and topography in the immediate area.

The overall function of the crossing will drive most of the decisions, as the size of the structure must be determined on the basis of requirements for the expected species' use and the need for separation of wildlife and human access. Overpasses can be designed bridgelike with supports and decking or as a filled section with a tunnel for vehicular traffic passing underneath. This latter type of structure works well when the in-fill required can be minimized, such as when the roadway runs between two steep embankments. An underpass structure would typically consist of a precast culvert of required dimensions or provision for a bridge structure in the highway design.

Cost can be reduced or minimized by decreasing the load, span, or width of the structure. Shorter spans can be obtained in an overpass

TABLE 1 Connectivity Objectives and Recommended Solutions

Wildlife Objective	Recommendation	Example Species
Reduce or avoid roadkill mortality	Greater importance of effective barriers than passage	White-tailed deer, Blandings turtle
Access to vital habitats	Passage for all or most animals	Salamanders using vernal pools
Population continuity	Passage for enough individuals to maintain a cohesive gene pool	Bobcat, bear, moose, fisher
Metapopulation dynamics	Occasional passage for a small number of individuals, perhaps juveniles	Many small mammals, snakes, frogs

NOTE: Each objective addresses increasing levels of biological organization, from individuals to populations.

through the provision of intermediate supports, though this can interfere with roadway safety and aesthetic concerns. The least width possible should be provided while still maintaining optimal function for the structure. The width should be based on species use, whether pedestrian use is anticipated, and methods of dividing the two uses on the overpass.

An overpass must provide a minimum vertical clearance of approximately 16 ft and 30 ft of clearance from the edge of the traveled roadway (*37*). The foundations for the structure have a significant impact on overall cost, and requirements are related to soil conditions and topography at the site. Certain structural configurations may lend themselves to shorter construction times or to minimal interference with traffic.

The load that the structure must resist is directly related to acceptable structural solutions. Higher load will result in higher costs and may drive a solution toward certain materials or structural configurations. The highest variable related to loads on the overpass is the type of vegetation to be established on the structure. Larger vegetation will require thicker layers of soil to support root structure, increasing the load on the structure. Decisions must be made on whether larger vegetation (such as trees and shrubs) can be contained at distinct locations along the span or whether design loads should consider these to be sustainable over the entire area. Other issues, such as the drainage system provided under the soil and control of soil buildup, will also affect the loads considered in design. Loads in underpass structures are controlled primarily by vehicular loading requirements as dictated by existing highway codes.

Aesthetics affect the functionality of the structure. Slender structures are often preferred, as defined by the span-to-depth ratio, because they give a sense of transparency that is generally pleasing to users. A proposed structure should include several options that provide aesthetic alternatives. Aesthetics for a combined crossing project will be vary depending on whether a solution is an apparent overpass–bridge type structure, has the impression of being a natural feature that the highway passes beneath, or provides an underpass that is not observable to highway traffic. The aesthetic appeal to pedestrian traffic is also essential, as these users will have a close view of the structure. A structural solution should therefore address the overall aesthetics of the structure as well as the detailing, which will be observed by pedestrians. Finally, the aesthetic features that are incorporated into the structure must not in any way deter wildlife's use of the structure. Presentation and discussion of design alternatives in a public forum are essential throughout the design process.

Significance of Cultural Landscape

The methods recommended for assessing cultural landscape significance are based on cultural landscape assessment procedures of the National Park Service (*38*). To consider how historical and cultural values could constructively inform the discussion of potential locations for a combined wildlife–recreational crossing, first principal themes and periods of a region's history should be identified through relevant literature, archival research, and interviews and public meetings. The observation and description of existing landscape features and characteristics can be enhanced and contextualized by referencing and locating the sites of historical activities (during several periods of significance) as well as associations with cultural figures and literature. Through examination of historical maps and photographs, quick comparisons can be made between the appearance of the landscape during the historic periods and today.

Through public meetings and other contacts, local residents may articulate their interest and knowledge of local history and of historical associations with various features and locations within and around a proposed crossing.

Assessment of the significance of the cultural landscape should also be considered in the context of planning a combined wildlife–recreational crossing. In other words, if the cultural landscape was found to be of great significance and possessed integrity, what are the implications for the other location and design factors for a combined wildlife–pedestrian crossing?

The analysis should also consider the locations and significance of historical routes near or across the highway corridor and the relative significance of their associations. These locations can be cross-referenced to the planning issues involving the different potentials of alternative crossing locations for enhancing and interpreting the many narratives and layers of significance that occur in a cultural landscape.

Evaluation of Alternatives

Multiple realistic and viable alternatives for combined crossings should be developed in a transdisciplinary process with mutual collaboration of professional–academic experts, the public, and stakeholders. Before evaluation of specific alternative types or locations, the evaluation criteria should be similarly discussed and agreed upon. All discussions about the development and evaluation of alternatives should be part of a transparent, replicable, and public process, with due consideration of potential impact on highway safety; passage type (overpass, underpass, culvert, or other); potential wildlife usage (particular and target species, habitat linkage); impacts on neighborhoods and adjacent land uses; archaeological resources, wetlands, and sensitive ecosystems; trail connections; cultural landscape interpretation; aesthetics; and construction and maintenance costs. Alternatives may also be evaluated for their potential to demonstrate, model, and test new approaches or designs for combined wildlife and pedestrian crossings.

CONCLUSIONS

While the twentieth century was known for highway and infrastructure construction, the twenty-first century faces the challenge of integrating highway infrastructure into communities and resolving some of the conflicts and impacts that highways cause. Managing or eliminating conflicts of wildlife and pedestrian crossings is one of the key issues, and it will be increasingly addressed in new and reconstruction projects.

The Walden passage structure holds the distinct potential to support the central purpose of the FHWA's TCSP program: "to address the impacts of highways on communities." Because of the unique cultural landscape of the study area, a combined wildlife–pedestrian passage also holds the potential to provide a twenty-first-century solution to a twentieth-century infrastructure problem and thereby provide a cultural link with an important nineteenth-century environmental philosophy.

The authors believe that the issues addressed and the methods developed and applied to the Walden passage study can provide guidance for similar projects elsewhere. Perhaps the key take-home message from the Walden project is the value of a transdisciplinary approach. The project's needs go beyond those of any few disciplines: they demand a legitimate and sustained involvement of stakeholders, decision makers, and others, each of whom both learns from and contributes to the process. And if transportation infrastructure planning

continues to move in the direction of sustainability, transdisciplinarity will likely become the norm.

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