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# BUILDING A FOUNDATION FOR LINEAR INFRASTRUCTURE SAFEGUARDS IN ASIA

## Training Manual

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## ACRONYMS

| | |
|---|---|
| CBA | Cost-Benefit Analysis |
| IFI | International Financial Institution |
| LI | Linear Infrastructure |
| LISA | Linear Infrastructure Safeguards in Asia |
| NGO | Non-governmental Organization |
| USAID | United States Agency for International Development |
| WFLI | Wildlife-Friendly Linear Infrastructure |

# ACKNOWLEDGEMENTS

## MODULE 1

Speakers: Rob Ament, Road Ecologist (Center for Large Landscape Conservation [CLLC]/ Western Transportation Institute [WTI]); Aditya Gangadharan**,** Consulting Ecologist; Chaitanya Krishna**,** Energy and Ecology Consultant

## MODULE 2

Speakers: Kim Bonine, Training Director and Former Program Director of USAID's Biodiversity Understanding in Infrastructure and Landscape Development (BUILD) program (Conservation Strategy Fund [CSF]); Thais Vilela, Senior Economist (CSF)

## MODULE 3

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## MODULE 4

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Contributed Videos: Pramod Neupane, Sustainable Infrastructure Programs Manager (WWF Nepal); Wenjing Xu, Fifth year PhD candidate (University of California, Berkeley)

## MODULE 5

Speakers: Tony Clevenger, Senior Wildlife Research Scientist (WTI); Benjamin (Ben) Dorsey, Ecosystems GIS Specialist

## MODULE 6

Speakers: Terry McGuire, P. Eng., Transportation Engineer

# INTRODUCTION


Asia is home to some of the world's most diverse and complex ecosystems, which provide natural capital, underpin economic vitality, and increase resilience to climate change. Yet, much of Asia's rich natural heritage is threatened by development. Without proper safeguards, the ongoing and anticipated expansion of linear infrastructure (LI) will further fragment vital habitats, impact biodiversity, and increase wildlife mortality.

The purpose of the Linear Infrastructure Safeguards in Asia (LISA) project is to build a foundation of information and knowledge to develop wildlife-friendly linear infrastructure (WFLI). It aims to increase the adoption and implementation of environmental mitigation and monitoring measures related to the planning, design, and construction of LI—roads, rails, and power lines—in Asia, including avoiding and preventing environmental impacts.

These training modules will weave together information gathered, analyzed, and synthesized by more than 20 experts in seven countries over the course of the 14-month project. The series will present information that seeks to inform policy makers, financiers, governments, linear infrastructure practitioners, conservationists, and others interested in developing Asia's ability to meet the needs of wildlife and people as it expands its roads, railways, and power line systems.

## PROJECT OUTPUTS

All project outputs and recordings of training modules can be found at:
**https://largelandscapes.org/LISA-project/**

### FINAL REPORT

The final report provides key information regarding the findings of the LISA project. It explains Asia's LI challenge, citing the explosion of new infrastructure being built across the continent. Next, it describes the state of Asia's biodiversity, highlighting iconic species that are under threat from rapid development. The report then explains why LI is a problem for biodiversity and introduces the concept of ecological connectivity. The economics of WFLI is then discussed, followed by a brief assessment of Asia's capacity to address the impacts of LI to biodiversity. The report concludes by offering a path forward, which includes key findings and recommendations to improve the implementation of WFLI in Asia.

### ANNEX 1: SPATIAL ANALYSES OF LINEAR INFRASTRUCTURE THREATS TO BIODIVERSITY IN ASIA

This annex identifies and maps Asia's most biodiverse landscapes across the 28 countries in the study area. It also examines where hundreds of proposed linear infrastructure (LI) projects from international development initiatives might intersect these highly biodiverse landscapes. It then takes a finer-scale approach to evaluate six landscapes in Asia where future LI projects could adversely affect a particular species (e.g., tigers, snow leopards, antelope) or a particular landscape with multiple species (e.g., a Thai power line's impacts on birds). Finally, the annex summarizes eleven published studies from across Asia that performed exemplary evaluations of future LI impacts to biodiversity and set a high standard for spatial assessments for the continent.

### ANNEX 2: CASE STUDIES OF WILDLIFE-FRIENDLY LINEAR INFRASTRUCTURE

This annex reviews a series of eight case studies from seven different Asian countries and demonstrates the processes, principles, and practices that differentiate LI projects that were successful in implementing wildlife-friendly linear infrastructure (WFLI) safeguards from those that weren't. The case studies represent road, railway, and power line development projects, as well as two that incorporated economic evaluations.

### ANNEX 3: EXISTING CAPACITY AND CONSTRAINTS TO UNDERTAKE WILDLIFE-FRIENDLY LINEAR INFRASTRUCTURE IN ASIA

This annex summarizes developing Asia's existing capacity to provide WFLI safeguards, including laws, regulations, best practices, workforce training, guidelines, and other forms of expertise and information. The annex evaluates capacity through the compilation and review of personal interviews, surveys, websites, published literature, and other sources across 28 Asian countries and four constituent groups—government, industry, financing, and non-governmental organizations. To help identify barriers and bottlenecks to WFLI safeguard implementation, electronic surveys were conducted in five representative countries—Bangladesh, India, Mongolia, Nepal, and Thailand—and resulted in more than 300 responses. The annex also contains recommendations for future capacity building for each constituent group.

### ANNEX 4: THE IMPACTS OF LINEAR INFRASTRUCTURE ON BIODIVERSITY AND HABITATS IN ASIA

This annex reviews published literature to determine what is currently known about the direct and indirect impacts of roads, railways, and power lines on Asian wildlife and their habitats, as well as on the effectiveness of mitigation measures that seek to alleviate any adverse impacts to wildlife. The results are a synthesis and summary of what is currently known for each transportation mode, based on primarily peer-reviewed papers published since 2000 on roads (162 papers), railways (49 papers), and power lines (78 papers). The annex also contains recommendations for how to address existing shortcomings in available data.

# MODULE 1: LINEAR INFRASTRUCTURE AND BIODIVERSITY IN ASIA

ROB AMENT

The Linear Infrastructure Safeguards for Asia (LISA) project lays the groundwork for a capacity-building program that seeks to promote the implementation of measures that avoid and mitigate environmental impacts through better planning, design, construction, and monitoring of LI expansion across Asia. In this module, we examine the potential impacts of proposed linear infrastructure on biodiversity across Asia and explore how spatial analyses can help practitioners to understand these impacts. We also introduce the concept of ecological connectivity and explain how linear infrastructure causes habitat fragmentation and impacts species' ability to adapt to climate change. Finally, we present the state of the knowledge on the impacts of roads, rails, and power lines on wildlife in Asia. The module concludes with key recommendations for decreasing the impact of linear infrastructure on biodiversity.

### LEARNING OBJECTIVES

- Explore the potential impacts to Asian ecosystems and species from LI development
- Review how Asian biodiversity and the impacts of LI have been evaluated spatially
- Based on 20 years of published papers, determine what is known about the direct and indirect impacts of roads, rails, and power lines on Asian species and ecosystems. Also, decide what solutions have been studied and which are effective.

## PART 1. LINEAR INFRASTRUCTURE DEVELOPMENT: THE BIG PICTURE, ADDRESSING ADVERSE IMPACTS TO ASIA'S BIODIVERSITY, ECOSYSTEM SERVICES, AND SPECIES' ABILITY TO ADAPT TO CLIMATE CHANGE

### INTRODUCTION TO THE LISA PROJECT

This 14-month project seeks to understand the challenges and barriers that slow the adoption and implementation of safeguards that protect Asia's diverse wildlife species and their critical habitats from the region's rapidly expanding linear infrastructure. A broad overview of the LISA project will be provided, along with the resources that the research team has generated for sharing with those interested in safeguarding wildlife during the development of LI in Asia.

### POTENTIAL IMPACTS OF LINEAR INFRASTRUCTURE ON ASIA'S BIODIVERSITY

The impacts of linear infrastructure (LI) development on biodiversity are inherently spatial. Without knowing the locations of LI routes and the biologically important features they influence (such as protected areas, critical habitat patches, and wildlife corridors), our understanding of LI impacts will remain very limited. Spatial analyses allow us to characterize the magnitude and type of impacts, identify the locations where impacts are (or will be) most severe, and objectively prioritize efforts to avoid or mitigate impacts.

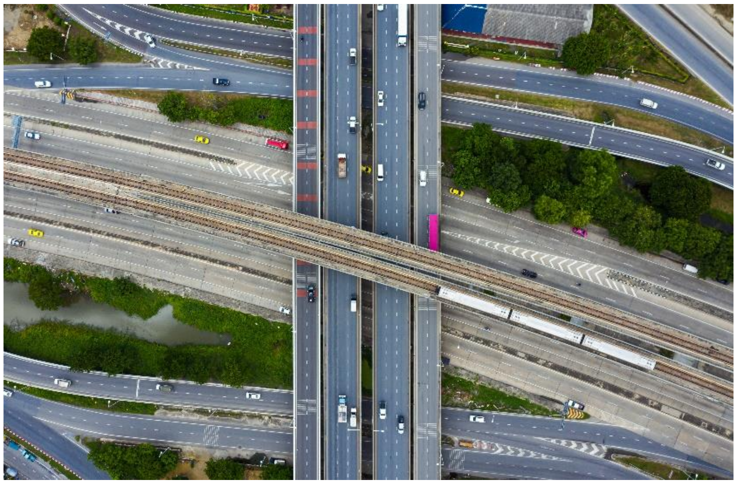
### INTRODUCTION TO ECOLOGICAL CONNECTIVITY

One recent definition of ecological connectivity is from the Convention on Migratory Species, which states that it is "the unimpeded movement of species and the flow of natural processes that support life on earth." Without careful planning, LI has the potential to form partial or total barriers to wildlife movement and ecological functions.

## PART 2. SCIENCE AND SOLUTIONS: THE STATE OF KNOWLEDGE ON ROADS, RAILWAYS, AND POWER LINES IMPACTS AND POTENTIAL SOLUTIONS.

### ROADS

The road ecology literature concentrates on documenting direct impacts (i.e., collisions; recorded for at least 611 species), with far less focus on both indirect impacts (34 species) and on the population-level consequences of direct and indirect impacts (41 species). Mitigation measures (mainly structural separation of vehicles from wildlife) are widely implemented, but they are rarely monitored well, making it difficult to draw robust conclusions on their effectiveness.



### RAILWAYS

The rail literature is around one-third the size of the road literature and is dominated by impact studies on a few mammals of high conservation concern (e.g., Asian elephants in India and migratory ungulates in China and Mongolia). Mitigation measures other than structural separation (such as changing human or animal behavior) are better documented than for the road literature, although these tend to be in the grey literature.

### POWER LINES

The power line literature is almost entirely focused on direct impacts, that is, power line electrocution and collision fatalities have been documented for 113 species, of which a third are threatened as per the IUCN Red List. Mitigation measures have been more commonly implemented in Central Asia and focus more on separating species from power lines.

**QUIZ QUESTIONS**

*Answers on page 37*

1. The top ranked strategy recommended by biologists to conserve biodiversity in the face of climate change is:
    a. Increase the number of protected areas
    b. Improve habitat connections and reduce barriers to movement
    c. Integrate climate change into planning
    d. Improve monitoring programs

2. Which one of the following landscapes did not appear in continental Asia's highest areas of biodiversity (90th percentile)?
    a. Western Ghats, India
    b. Sumatra Island, Indonesia
    c. Hokkaido Island, Japan
    d. Borneo Island, Malaysia and Indonesia
    e. Terai Arc Landscape, Nepal and India

3. What fundamental differences between roads and railways must inform the design of mitigation measures for railways?
    a. The frequency of trains on railway tracks is less than the frequency of vehicles on roads
    b. Trains are driven by a few specialized professionals, while vehicles are driven by the general public
    c. There is less public scrutiny of railway tracks than roads, possibly leading to less detection of impacts
    d. All of the above

4. The locations for placement of wildlife crossing structures across roads or rails should ideally be guided by which of the following types of data (check as many as apply)?
    a. Locations of road or rail kills
    b. Observation of crossings by animals
    c. Statistical models of animal movement
    d. Engineering convenience

5. Which taxa are most impacted by power lines, choose all that apply?
    a. Birds
    b. Arboreal mammals
    c. Bats
    d. Herpetofauna

6. In which ways do power lines impact biodiversity?
    a. Electrocution
    b. Collision
    c. Habitat loss and fragmentation
    d. All of the above

# MODULE 2: ECONOMIC TOOLS FOR EVALUATION

Energy and transportation infrastructure such as roads, railways and transmission lines are essential backbones of economic development, increasing access to markets, healthcare, education, and other services. However, traditional large-scale linear infrastructure also fragments ecosystems and induces conversion of habitats, resulting in the loss of biodiversity and ecosystem services worth millions of dollars.

Without a clear understanding of the full costs, governments can invest in infrastructure projects that generate more costs than benefits for society. In this module, we explain how economic analysis can compare the tradeoffs of proposed infrastructure projects and quantify in monetary terms the cost to society of environmental damage. We provide case studies from Asia, Africa, and Latin America to illustrate how economic information is important for justifying investments and expenditures in less damaging linear infrastructure alternatives and in safeguards to mitigate unavoidable impacts of development.

### LEARNING OBJECTIVES

- Gain an understanding of why it is important to evaluate the economic benefits and costs of linear infrastructure projects as part of a strategic planning process.
- Learn and discuss how the benefits of avoidance and mitigation to safeguard biodiversity can be measured and incorporated into project planning and implementation through valuation, cost-benefit analysis, and other economic tools.
- Learn how cost-benefit analysis can illustrate the benefits of implementing wildlife safeguards from case studies in Asia.
- Learn how economic analysis can be used in regional and national strategic development planning to avoid and reduce financial, social, and environmental losses from LI projects.

## PART 1. ECONOMIC ANALYSIS OF LINEAR INFRASTRUCTURE

### WHY DO WE NEED ECONOMIC ANALYSIS OF LINEAR INFRASTRUCTURE AND SAFEGUARDS?

It is important to evaluate the full economic benefits and costs of linear infrastructure projects as part of a strategic planning process. Key considerations include the importance of identifying tradeoffs and indirect impacts, assessing the net economic benefits at various scales, and focusing on ways to avoid and reduce both environmental impacts and financial costs through better planning and routing.

### ECONOMIC ANALYSIS TOOLS: VALUATION

Calculating the economic valuation of the environment requires understanding the conceptual underpinnings of why valuation is needed to address the market failures that leave ecosystem services out of many economic and development decisions. A review of total economic value and valuation methods is useful, along with several case studies of wildlife valuation for projects in Asia that highlight best practices and lessons learned.

### ECONOMIC ANALYSIS TOOLS: COST-BENEFIT ANALYSIS

A thorough cost-benefit analysis (CBA) can compare the estimated costs and benefits of a planned LI project to determine whether to proceed, amend, or avoid. Key factors to recognize include perspectives of analysis, the difference between financial and economic analysis, and important strategic considerations and limitations.

### OTHER ECONOMIC ANALYSIS TOOLS

Additional economic analysis tools are available to assist in considering a proposed LI project, including cost-effectiveness analysis, economic impact analysis, multi-criteria analysis, and least-cost path analysis.

## PART 2. ECONOMIC ANALYSIS CASE STUDIES OF LINEAR INFRASTRUCTURE SAFEGUARDS IN ASIA

### TRANSMISSION LINE IN INDONESIA

This case study describes an economic feasibility study conducted by the Asian Development Bank in 2016 of the Java-Bali 500 Kilovolt Power Project. The study included the costs and benefits of the indirect impacts to third parties as well as the benefits of the environmental safeguards implemented by the project. A rigorous cost-benefit analysis that is incorporated into a project's evaluation process can demonstrate that environmental safeguards not only protect environmental and wildlife values but can also add to an infrastructure project's overall net value.

### HIGHWAY DEVELOPMENT IN MALAYSIA

This case study describes a cost-benefit analysis of environmental safeguards conducted in 2009 by the Department of Town and Country Planning as part of a Master Plan to create several ecological corridors in Peninsular Malaysia. The economic analysis first identified the safeguard measures that would need to be implemented to mitigate negative impacts resulting from Federal Route 4, constructed in the 1970s by the Federal Government. Second, the analysis estimated and compared the costs and benefits of implementing environmental safeguards, showing that the safeguard benefits were greater than the costs.

## PART 3. REGIONAL AND NATIONAL ROAD DEVELOPMENT PLANNING IN LATIN AMERICA AND AFRICA

### REGIONAL ROAD PLANNING IN THE AMAZON BASIN

This study describes a cost-effectiveness analysis of a set of road projects in the Amazon region and proposes an analytical framework to assist decision-makers to improve their decision process. The authors find that 45 percent of the projects will generate economic losses, even without accounting for social and environmental externalities. Canceling economically unjustified projects would avoid 1.1 million hectares of deforestation and US$ 7.6 billion in wasted funding for development projects. For projects that exceed a basic economic viability threshold, the authors identify the ones that are comparatively better not only in terms of economic return but also have lower social and environmental impacts. This study shows that it is possible to have efficient tradeoff decisions informed by legitimately determined national priorities.

### NATIONAL ROAD PLANNING AND GORILLAS IN UGANDA

This case study describes a cost-benefit analysis conducted in 2014 of proposed road paving through Bwindi Impenetrable National Park in Uganda, an important habitat for nearly half the world's remaining mountain gorillas. The study conducted surveys with local communities, GPS data collection in the field, and cost modeling using the Roads Economic Decision Model. Results of the study conclude that paving alternative routes around the park would provide benefits for more communities and help safeguard lucrative tourism revenues by avoiding negative impacts on gorilla populations.

## QUIZ QUESTIONS

*Answers on page 37*

1. Why is environmental valuation needed for many ecosystem goods and services?
    a. Price does not equal value
    b. Missing markets and information
    c. Lack of property rights
    d. Environmental goods are often public goods
    e. All of the above

2. Which of the following does an economist try to value?
    a. A forest
    b. Forest functions like slowing down water
    c. Forest services like storm protection
    d. People's benefits from forest services

3. Which of the following does an economist try to value?
    a. Tigers
    b. Healthier ecosystems due to the ecological role of tigers as top predators
    c. People's benefits from healthier ecosystems
    d. People's benefits from seeing tigers
    e. People's benefits from knowing that tigers exist

4. How is an economic CBA different from a financial CBA?
   a. Uses only market prices
   b. Excludes benefits of project owners
   c. Includes external costs and benefits such as pollution

5. What is the recommended order of addressing the following questions when conducting a cost-benefit analysis?
   a. Is the project financially feasible?
   b. Is the project equitable?
   c. Is the project technically feasible?
   d. Is the project economically feasible?
   e. Are there better alternatives?

# MODULE 3: CAPACITY BUILDING FOR WILDLIFE SAFEGUARDS IN ASIA

USAID

Building capacity to implement wildlife-friendly linear infrastructure is recognized as highly important as Asian countries work to meet the needs of economic development and biodiversity conservation. In this module, we present the results of capacity assessments at two scales: Asia-wide and in five representative countries (Bangladesh, India, Mongolia, Nepal, and Thailand). We introduce four key constituent groups, explain their roles and existing capacity to address wildlife safeguards for linear infrastructure, and identify challenges to overcome in order to align goals for wildlife and people across the continent. This module will highlight opportunities for future capacity-building efforts, both constituent-specific and across all groups, that will help Asia implement wildlife-friendly linear infrastructure in the future.

### LEARNING OBJECTIVES

- Awareness of key stakeholder groups and opportunities for collaboration
- Understanding of Asia's existing capacity for implementing wildlife safeguards
- Identifying barriers to implementing wildlife safeguards
- Identifying opportunities for capacity building

## PART 1. CAPACITY ASSESSMENT METHODS AND CONTEXT

### METHODS

The capacity assessment was conducted at two scales: Asia-wide for all 28 countries, and at the national to local or project-level scale in five representative countries (Bangladesh, India, Mongolia, Nepal, and Thailand). Asia-wide, capacity was assessed through web-based searches and supplemented by interviews and electronic surveys. In the five representative countries, an electronic survey was conducted of more than 300 stakeholders.

### INTRODUCTION TO CONSTITUENT GROUPS

This project focused on four major constituent groups: Government, International Financial Institutions (IFIs), Industry, and Non-governmental Organizations (NGOs). The capacity of each group to implement WFLI was assessed at both the Asia-wide and national scales.

### THE LI PROJECT DEVELOPMENT PROCESS

The LI Project Development Process consists of seven key phases: Selection, Funding, Planning, Design, Permitting, Construction, and Post-Construction. The electronic survey was used to assess capacity and barriers at all stages of the project development process.

## PART 2. EXISTING CAPACITY TO IMPLEMENT WILDLIFE SAFEGUARDS FOR LI

### EXISTING EFFORTS TO BUILD CAPACITY FOR WFLI

Asia has already begun building capacity for implementing WFLI through workshops, trainings, and guidelines. Constituent groups agree that WLFI is important but feel that additional capacity building is necessary to adequately implement wildlife safeguards for LI. Constituent groups have also begun to partner with one another during the project development process but feel that additional partnerships could increase capacity.

### WFLI LEGISLATION AND GUIDELINES

Policy provides an important opportunity for countries to institutionalize best practices regarding wildlife safeguards for LI. Policy may exist in multiple forms, such as international multilateral environmental agreements, national legislation, IFI safeguards standards, or industry standards.

## PART 3. BARRIERS TO IMPLEMENTING WFLI

### BARRIERS IN THE PROJECT DEVELOPMENT PROCESS

Barriers to implementing WFLI arise throughout the project develop process. Survey respondents indicated that barriers were especially pronounced during the planning, design, and construction phases. Survey respondents also indicated key intervention points for future capacity building and training.

### CONSTITUENT-SPECIFIC BARRIERS TO IMPLEMENTING WFLI

Each constituent group faces its own specific barriers to implementing WFLI. By identifying these barriers, capacity-building efforts can be tailored to help each group overcome these challenges.

## PART 4. OPPORTUNITIES FOR BUILDING CAPACITY FOR WFLI IN ASIA

### CONSTITUENT-SPECIFIC CAPACITY BUILDING

The Asia-wide and national assessments revealed capacity-building needs specific to each constituent group. Governments need to formalize commitments to wildlife safeguards or LI through nationwide laws and regulations as well as ensure collaboration between infrastructure and wildlife departments. IFIs need to include funding for wildlife safeguards in project budgets, and also for capacity building in recipient countries. Industry needs specific training in WFLI design and construction, as well as increased public recognition and incentives for voluntarily providing safeguards. NGOs need increased opportunities to engage in the project development process through partnerships with other constituent groups to improve incorporation of wildlife data and analysis expertise. Additionally, NGOs and others with wildlife expertise need to be included in early planning stages of the project development process.

### TRAINING TOPICS AND DELIVERY

All constituent groups are overwhelmingly interesting in training opportunities for safeguarding wildlife from LI impacts. Topics such as policy, planning, design, mitigation, and monitoring are all of interest, and a variety of delivery methods are desired, including workshops and guidelines documents. Many stakeholders also suggest the need for centralized knowledge platforms in countries across Asia.

## QUIZ QUESTIONS

*Answers on page 37*

1. Which constituent group is expertise-rich but rarely formally included in planning or permitting?
   a. Government
   b. IFI
   c. Industry
   d. NGO

2. Which constituent group has the most decision-making power with regards to permitting and LI siting?
   a. Government
   b. IFI
   c. Industry
   d. NGO

3. What is the first step in the mitigation hierarchy?
   a. Mitigate
   b. Offset
   c. Avoid
   d. Minimize

4. In which phases of the project development process do the barriers to implementing wildlife safeguards for LI arise most?
   a. Selection
   b. Funding
   c. Planning
   d. Permitting
   e. Design
   f. Construction
   g. Post-Construction

5. True or False: Currently, adequate public recognition is given to industry institutions that safeguard wildlife to incentivize their efforts.

6. Which is the best way for LI funders to enhance the implementation of WFLI?
    a. Set aside funding for capacity building in recipient countries
    b. Rely on the recipient country's safeguard policies

7. Why are trainings that bring all constituent groups into the same room important?
    a. Provides an opportunity to break down the silos between groups
    b. Ensures that all constituent groups are building from the same general knowledge base
    c. Paves way for easier collaboration in the future
    d. All of the above

8. How could a central online repository on WFLI in Asia be useful?
    a. Access to high quality wildlife data for impact assessments
    b. Access to WFLI mitigation measure design
    c. Access to case studies of WFLI throughout Asia
    d. Facilitate collaboration across different constituent groups
    e. All of the above

# MODULE 4: WILDLIFE SAFEGUARDS FOR LINEAR INFRASTRUCTURE PRACTITIONERS



In this module we cover the entire spectrum of wildlife crossing mitigation, from a description of the impacts of linear infrastructure to planning, data collection, analyses for informing management, and resources available today to assist practitioners. The module is intended for practitioners with, at minimum, a basic level of ecological studies, impact assessments, and formulation of mitigation recommendations. Case studies are presented to show how these examples of state-of-the-art measures are being deployed in Asia. Key aspects of planning wildlife crossings are discussed, including several misconceptions regarding performance and utility. The module concludes by identifying the five most important principles of wildlife crossing planning and design for practitioners to take with them after the module is completed.

### LEARNING OBJECTIVES

- The Mitigation Hierarchy and sequential steps to reduce linear infrastructure impacts on wildlife
- Mitigation objectives and data needs to inform project planning and impact reduction measures
- Case studies from Asia as good or bad examples of linear infrastructure project planning
- Evaluating performance of mitigation measures to reduce wildlife mortality and increase population connectivity
- Wildlife crossings as proven measures: the types, monitoring methods, and how best plan their implementation
- Streamlining mitigation for wildlife in the early stages of linear infrastructure project planning
- Key aspects of planning and design of wildlife crossing structures

## PART 1. IMPACTS, PLANNING, AND PRE- & POST-CONSTRUCTION DATA NEEDS

### LINEAR INFRASTRUCTURE IMPACTS AND WILDLIFE POPULATION CONSERVATION

Wild animals need to move in order for populations to survive. Linear infrastructure can impact populations by direct mortality, reduced population connections, and loss of habitat.

### MITIGATION HIERARCHY

Planning begins with a hierarchical method of how projects will best address the impacts of linear infrastructure projects. These range from avoidance to mitigation to compensation offsite. A case study from a planned railway alignment project in Nepal will be presented.

### PRE-CONSTRUCTION DATA COLLECTION FOR BIODIVERSITY ASSESSMENTS

Biodiversity baseline assessments help identify the key impacts of linear infrastructure and use the most current methods of data collection and analyses to inform planning. Different data outputs are provided and it is shown how these inform recommendations for mitigation. A case study from Bhutan is presented as model for data collection and informing new road alignments through the Phipsoo Wildlife Sanctuary. Spatial analyses are valuable tools to predict impacts and inform planning; examples are provided from Mongolia (snow leopard) and Uzbekistan (saiga).

### POST-CONSTRUCTION DATA COLLECTION

Once mitigation measures are implemented, monitoring is required to assess performance and adaptively manage future project mitigation measures. Mitigation objectives are to reduce mortality and increase connectivity (movements) among populations. Study designs using before-and-after comparisons can provide strong evidence of whether measures meet these goals.

## PART 2. THE CASE FOR WILDLIFE CROSSINGS: THE MEASURES, EVALUTIONS, AND MAINSTREAMING

### THE CASE FOR WILDLIFE CROSSINGS

Many types of mitigation measures are available today, the most effective being wildlife crossings and fencing. Exemplary wildlife crossings from Asia are presented along with different methods of monitoring animal use of passages and a look at whether measures are effective in reducing animal mortality.

### PLANNING CONSIDERATIONS

There are many things to consider in planning wildlife crossings: How many and how far apart? What is the best design for wildlife? Are overpass better than underpass? Are fences needed? How does human activity affect wildlife usage?

### RESOURCES

Increasingly there are more technical guidelines available today in Asia to assist practitioners with the different phases of linear infrastructure projects, from initial planning of alignments to mitigation design, monitoring performance, and maintenance. Several guidelines or best practice documents from Asia are presented.

### STREAMLINING AND LESSONS LEARNED FROM ASIAN PROJECTS

Some of the most important lessons learned from case studies in the USAID project are presented along with examples of how future projects can integrate wildlife concerns early in planning stage. A case study from the Qinghai-Tibet Railway mitigation is presented with an explanation of how it has affected Tibetan antelope migration. Some common misconceptions and questions regarding wildlife crossings are discussed.

## THE 5 MOST IMPORTANT POINTS TO REMEMBER ABOUT WILDLIFE CROSSINGS

Five important points are presented for practitioners to remember for planning and designing the most effective wildlife crossing structures.

## QUIZ QUESTIONS

*Answers on page 37*

1. True or False: The mitigation hierarchy is used in the late stage of planning to help locate mitigation measures.

2. True or False: Biodiversity Baseline Assessments provide greater detail than Environmental Impact Assessments.

3. Which of these methods of data collection is not used to detect wildlife species?
   a. Camera traps
   b. Observations
   c. Satellite imagery
   d. Surveys searching for sign (e.g. faeces, tracks)

4. It is important to evaluate mitigation measures because:
   a. Others can learn from project results
   b. Mitigation measures are costly
   c. Results of evaluations can help adjust future designs
   d. All of the above

5. Which mitigation measure(s) is most widely used to reduce mortality and increase movements across linear infrastructure? Select one or more.
   a. Signage
   b. Educational materials
   c. Wildlife passage structures
   d. Slowing down vehicles and trains
   e. Fencing roads and railways

6. True or False: Wildlife crossing structures should be designed exclusively for focal species.

7. Which of these is a critical part of the success of wildlife crossing structures?
   a. Government endorsement
   b. Local community support
   c. Fencing
   d. Hunting near wildlife crossing structures
   e. None of the above

8. True or False: Wildlife crossing structures are placed randomly along roads and railways as wildlife will adapt to these new locations to cross.

9. True or False: Biologists and subject matter experts are needed at the early stage of project planning.

10. The USAID LISA project identified which of the following as critical to improving Asia's approach to environmental safeguards on linear infrastructure projects?
    a. More funding for government agencies
    b. Increased training and improving capacity among governments and lending institutions
    c. Greater local community education and awareness of linear infrastructure impacts
    d. More involvement of local politicians in project planning

# MODULE 5: WILDLIFE CROSSING STRUCTURES – PLANNING, DESIGN, AND EVALUATION


TERRY MCGUIRE

In this module we share tools and best practices to conduct pre- and post-construction wildlife evaluations for transportation infrastructure projects (roads and railways). We describe best practices such as study designs, methods, and data collection tools used to understand the impacts of transportation projects on ecosystems that inform planning and design. We then describe the types of data, analyses, and modern tools used to collect relevant data and communicate the results.

In the first part, we cover wildlife crossing mitigation, focusing on the well-studied understanding of the impacts and solutions for roads. In the second part, we outline the cycle of data collection, assessment, and communication that is repeated for a project, from pre-construction planning to post-construction monitoring.

Attendees will more fully appreciate the current practices and methods used to select, design, and locate effective wildlife crossing mitigation measures. They will receive information to determine their needs for selecting existing tools, including Free and Open Source Software (FOSS) and Software as a Service (SAAS), that enable projects to rapidly collect the diverse types of information required to plan, deploy, and evaluate effective wildlife safeguards.

### LEARNING OBJECTIVES

- Understand how to determine spacing and sizing of structures based on species, home range, etc.
- Learn how to identify data needs based on mitigation objectives.
- Understand the information and data required to inform project planning of wildlife crossings.
- Gain awareness of case studies from Asia as examples of established wildlife crossing infrastructure projects.
- Learn about current methods of monitoring and evaluating performance of mitigation measures to reduce wildlife mortality and increase population connectivity.
- Understand where to access and how to use new web mapping technologies for sustainable transportation infrastructure projects.

### PART 1. WILDLIFE CROSSINGS: PLANNING, DESIGN, AND EVALUATIONS

### IMPACTS OF ROADS AND EMERGENCE OF ROAD ECOLOGY

Roads are increasingly seen as important sources of habitat fragmentation. They impact populations in many ways, primarily by direct mortality and reduced population connections. Road ecology emerged over 20 years ago with the realization of these impacts and the needs for science-based solutions.

### PLANNING OF WILDLIFE CROSSINGS: SCALES AND METHODS USED

Planning requires consideration of regional and project-level scales. Many methods are currently used to assist practitioners, and different techniques exist based on the availability of data.

### INFORMING ROAD MITIGATION PROJECTS WITH BEST PRACTICES

Pre-construction data collection and analysis are key components in selecting appropriate mitigation measures. These data outputs need to be merged and synthesized to identify the most suitable locations for mitigation work, including the best way to prioritize locations. A case study from Nepal is used to demonstrate these different approaches.

### DESIGN OF WILDLIFE CROSSINGS, MONITORING METHODS, AND EVALUATIONS

There are a variety of wildlife crossing types that are used today, including those designed specifically for terrestrial and arboreal species, and others that retrofit existing culverts or bridges. Monitoring is critical and required to determine whether the measures are functional and meet the desired objectives for safe wildlife passage. A sliding-scale criteria can be used to determine performance based on ecological complexity and the costs and duration of monitoring required.

### PART 1: SUMMARY & KEY POINTS

Implementing effective mitigation requires an understanding of the basic principles of wildlife crossing design. Asia is already beginning to use wildlife crossings to preserve critical species habitats.

## PART 2. DATA ANALYSIS, MANAGEMENT, AND REPORTING

### THE ITERATIVE SPATIAL ANALYSIS FRAMEWORK

The information used to plan and assess transportation infrastructure projects is inherently spatial, thus much of the work is conducted in a Geographic Information System (GIS) and relies on spatial analysis tools and techniques. A typical project requires an iterative approach to the GIS workflow of data collection, analysis, and sharing. Understanding the cyclical nature of spatial analysis and decision making provides teams with the understanding needed for project planning and management.

### DETAILED DATA NEEDS, CONSIDERATIONS, AND TOOLS

Many projects have typical data requirements and considerations to help prevent project delays due to acquisition time and processing. These considerations include understanding the tradeoffs of what and how much data to collect, and purchasing vs. relying on free information and tools. Understanding common pitfalls is crucial to a successful project, as is an awareness of available tools and how to choose what is right for your project based on funding, timing, and technical complexity.

### MODERN TOOLS ENABLE INCREASED EFFICIENCY, COLLABORATION, AND TRANSPARENCY

The modern spatial analyst has access to a vast array of tools that can streamline workflows, automate repetitive tasks, and ensure reproducible results. Thanks mostly to web 2.0 technologies and near-global access to the internet, today's tools are increasingly collaborative and transparent. Web GIS and mobile data collection tools can enable rapid data collection, communication, and transparency that can accommodates the needs of complex mitigation projects.

### SUMMARY & KEY POINTS

Many practitioners are already using applications and tools in transportation infrastructure mitigation and biodiversity baseline assessment projects. Demos are shown for a rapid data collection tool, a live project collaboration dashboard, and a reproducible analysis.

## QUIZ QUESTIONS

*Answers on page 37*

1. True or False: The discipline of road ecology began over 20 years ago as a means to examine how roads impact the environment. Road ecology encompasses biotic (ecological) as well as abiotic (chemical and physical) impacts.

2. True or False: Planning the location of wildlife crossings requires good data on where species occur and where they are most vulnerable to roads in terms of mortality (roadkill) and population connectivity.

3. There are many designs used to get animals safely across roads. What are some of the main factors used to determine the most appropriate design? (More than one choice may apply.)
   a. Species habitat requirements
   b. The design with the lowest cost
   c. The design most used by engineers on past projects
   d. Terrain and type of habitat the crossing is planned for
   e. None of the above

4. What are some criteria that have been used to determine that wildlife crossings are functional?
   a. Wildlife tracks have been seen passing through the wildlife crossing
   b. Breeding males and females are detected using the crossing
   c. Population-level benefits such as gene flow are documented
   d. Ecosystem processes, such as predator-prey relationships, are restored because of the crossing
   e. All of the above

5. What is the most important problem with ensuring proper maintenance of wildlife crossings?
   a. Workers don't like to visit wildlife passages because of potential wildlife conflicts
   b. Supervisors don't believe maintenance is a high priority
   c. Road agencies rarely have funding set aside to ensure annual maintenance checks
   d. Wildlife crossing structures are usually far away and require long travel

6. Why would the process of data collection, analysis, and reporting be repeated in a LI mitigation project? (Choose all that apply)
   a. Because the project changed in design, extent, or scope.
   b. New data became available or was located during the project.
   c. Because the data and reporting needs vary for each stage of a project.
   d. To ensure the findings are robust and hold up to varying scales or analysis methodologies.
   e. All of the above

7. True or False: SAAS Web GIS tools are faster and less technical to set up.

8. True or False: Data stored on a FOSS Web GIS are less secure than data stored on a SAAS GIS.

9. Within the two primary types of GIS data (raster and vector) what are five subtypes of GIS data?
   a. Raster (continuous and discrete), Vector (points, lines, and polygons)
   b. Raster (classified and raw), Vector (2D, CAD, and dynamic segmentation)
   c. Raster (satellite and aerial photos), Vector (roads, land cover, and roadkills)

10. Which statements are true about using web GIS? (Choose all that apply)
    a. Web GIS can increase project efficiency by improving data collection, QA/QC, and collaboration.
    b. It can be used by traditional GIS software programs such as QGIS and in desktop analysis programs such as R and Python.
    c. Data stored on a web GIS are less secure, more costly, and requires highly trained technical staff.

# MODULE 6: ENGINEERING CONSIDERATIONS IN THE DESIGN OF WILDLIFE CROSSINGS AND THEIR INFRASTRUCTURE

Linear infrastructure such as railways and highways are not necessarily barriers to wildlife movement on their own. It is the traffic using them, such as trains and cars, that cause wildlife-vehicle collisions (WVCs) resulting in wildlife mortality. Traffic volumes and their associated sensory disturbances can also sever wildlife corridors by inhibiting animal movement. Fencing, in combination with dedicated, well-designed wildlife crossing structures, is a mitigation strategy to help lessen this environmental impact. This module explores in more detail the engineering considerations that must be taken into account in the design of these structures.

TERRY MCGUIRE

### LEARNING OBJECTIVES

- Review design and construction considerations for wildlife crossing structures—overpasses and underpasses
- Review design and construction considerations for fencing that directs animals to crossing structures

### PART 1. MITIGATING WILDLIFE-VEHICLE COLLISIONS (WVC)

#### WILDLIFE FENCING DESIGN

There are a number of design considerations for wildlife fences along highway and railway linear infrastructure. These designs can differ with respect to installation, costs, and their overall effectiveness in reducing WVCs.

#### KEY LESSONS LEARNED AND ADVICE

Previous linear infrastructure mitigation projects have resulted in lessons that can inform future wildlife fencing design.

### PART 2. WILDLIFE CROSSING STRUCTURE DESIGN

#### WILDLIFE UNDERPASS DESIGN

The construction of wildlife underpasses is one example of a mitigation strategy to lessen the impact of linear infrastructure on wildlife. There are many different types of wildlife underpasses, each with its own design considerations and advantages and disadvantages.

### WILDLIFE OVERPASS DESIGN

Wildlife overpasses are another type of mitigation structure. Depending on the targeted wildlife, overpasses require specific design considerations, each with its own particular advantages and disadvantages.

### BURIED BRIDGE (ARCH) STYLE WILDLIFE OVERPASSES DESIGN

One of the most frequently used wildlife overpass designs throughout the world is the arch-style overpass. This type of overpass has specific design considerations, including various geometric configurations, end treatments, material composition, and techniques for fabrication and construction.

### KEY LESSONS LEARNED AND ADVICE

The construction of wildlife crossing structures around the world can provide lessons and advice for future wildlife infrastructure with respect to the design, construction, and maintenance of wildlife underpasses and overpasses.

## QUIZ QUESTIONS

*Answers on page 38*

1. What is the most important consideration in fence design?
    a. Degree of exclusion being sought
    b. Alignment
    c. Maintainability
    d. Choice of fence material

2. True or False: Fencing alone is an appropriate LI wildlife-vehicle collision mitigation strategy.

3. True or False: Wildlife crossings are all relatively generic and can be duplicated based on designs used elsewhere in the world.

4. In the design of wildlife underpasses, which of the following is not likely a consideration?
    a. Soil conditions
    b. Dead load
    c. Heigh and width of structure
    d. Live load

5. Which of the following is considered essential in the implementation of an effective wildlife crossing?
    a. Large budget
    b. Good location
    c. Good data
    d. Diverse design team

# FURTHER READING

The following list contains recommendations for further reading provided by the module presenters. Use the hyperlinks below to access the resources.

## MODULE 1: LINEAR INFRASTRUCTURE AND BIODIVERSITY IN ASIA

### GLOBAL PERSPECTIVES

Global Land Transport Infrastructure Requirements: Estimating road and railway infrastructure capacity and costs to 2050 (2013)

Roads to riches or ruin? (2017)

### BIODIVERSITY AND LI IN ASIA

Central Asian Mammals Migration and Linear Infrastructure Atlas (2019)

Eco-friendly Measures to Mitigate Impacts of Linear Infrastructure on Wildlife (2016)

Guidelines on Mitigating the Impact of Linear Infrastructure and Related Disturbance on Mammals in Central Asia (2014)

### ECOLOGICAL CONNECTIVITY

Guidelines for conserving connectivity through ecological networks and corridors (2020)

Quantification of habitat fragmentation reveals extinction risk in terrestrial mammals (2017)

Moving in the Anthropocene: Global reductions in terrestrial mammalian movements (2018)

Biodiversity management in the face of climate change: A review of 22 years of recommendations (2009)

New concepts, models, and assessments of climate-wise connectivity (2018)

### ROADS

Handbook of Road Ecology (2015)

Fragmentation impacts caused by roads through rainforests (2007)

High-risk infrastructure projects pose imminent threats to forests in Indonesian Borneo (2019)

Assessing compliance with the wildlife crossing guideline in South Korea (2018)

Impact of vehicular traffic on the use of highway edges by large mammals in a South Indian wildlife reserve (2012)

### RAILWAYS

Railway Ecology (2017)

The environmental history of Chatthin Wildlife Sanctuary, a protected area in Myanmar (Burma) (2004)

Fragmentation of the habitat of wild ungulates by anthropogenic barriers in Mongolia (2013)

Railway underpass location affects migration distance in Tibetan antelope (*Pantholops hodgsonii*) 2019)

### POWER LINES

Avian-power line interactions in the Gobi Desert of Mongolia: are mitigation actions effective? (2021)

First use of artificial canopy bridge by the world's most critically endangered primate the Hainan gibbon *Nomascus hainanus* (2020)

Do birds respond to spiral markers on overhead wires of a high-voltage power line? Insights from a dedicated avian radar (2020)

Ecology Guidelines for Transmission Projects: A Standard Approach to Ecological Assessment of High Voltage Transmission Projects (2020)

## MODULE 2: ECONOMIC TOOLS FOR EVALUATION

### COST-BENEFIT ANALYSIS AND VALUATION

Cost-Benefit Analysis and the Environment (2015)

Cost-Benefit Analysis for Natural Resource Management in the Pacific: A Guide (2013)

Guide to Cost-Benefit Analysis of Investment Projects (2014)

Integrating Ecosystem Values into Cost-Benefit Analysis: Recommendations for USAID and Practitioners (2018)

Nature's Values: From Intrinsic to Instrumental. A review of values and valuation methodologies in the context of ecosystem services and natural capital (2017)

Pay – Establishing Payments for Watershed Services (2006)

Valuing Ecosystem Services: Toward Better Environmental Decision-Making (2005)

## ECONOMIC CASE STUDIES

*ASIA*

India: Making the hidden visible: Economic valuation of tiger reserves in India (2017)

Indonesia, Kyrgyzstan, and Sri Lanka: Real-Time Evaluation of ADB's Safeguard Implementation Experience Based on Selected Case Studies (2016)

Indonesia: Rerouting a major Indonesian mining road to spare nature and reduce development costs (2021)

Malaysia: CFS I: Master Plan for Ecological Linkages (2009)

Malaysia: Why did the elephant cross the road? The complex response of wild elephants to a major road in Peninsular Malaysia (2018)

Myanmar: The Economic Value of Forest Ecosystem Services in Myanmar and Options for Sustainable Financing (2013)

Sri Lanka: Changing abundance of elephants and willingness to pay for their conservation (2005)

*AFRICA*

Nigeria: Alternative routes for a proposed Nigerian superhighway to limit damage to rare ecosystems and wildlife (2017)

Uganda: Pave the impenetrable? An economic analysis of potential Ikumba - Ruhija road alternatives in and around Uganda's Bwindi Impenetrable National Park (2014)

*SOUTH AMERICA*

The Amazon: A better Amazon road network for people and the environment (2020)

The Amazon: Roads, deforestation, and the mitigating effect of protected areas in the Amazon (2014)

## ONLINE RESOURCES AND TOOLS

Conservation Strategy Fund Economic Video Lessons – *Animated video lessons that review key concepts of natural resource economics and detail the framework and steps for economic analysis tools such as valuation and cost-benefit analysis.*

- Valuation video lesson series
- Cost-benefit analysis video lesson series

MARXAN - *A suite of tools that aid conservation planning. This software is free and available for online download.*

Stanford Natural Capital Project - *A partnership between Stanford University and other institutions that uses valuation to guide more targeted natural capital investments. We recommend looking through their InVEST suite of tools.*

ValuES - *A global project providing training, discussion forums, and online tools related to ecosystem valuation. You can find examples of how valuation is applied by visiting their Case Studies page.*

WAVES Partnership - *A partnership through the World Bank that partners with countries to integrate natural resources into development planning. You can look at their blog posts and full reports for more information about valuation applications.*

## MODULE 3: CAPACITY BUILDING FOR WILDLIFE SAFEGUARDS IN ASIA

### CAPACITY ASSESSMENTS

UNDP Capacity Assessment Methodology (2015)

### MULTI-NATIONAL

Eco-friendly measures to mitigate impacts of linear infrastructure on wildlife (2017)

Guidelines on Mitigating the Impact of Linear infrastructure and Related Disturbance on Mammals in Central Asia (2015)


ROB AMENT

International Finance Corporation Performance Standard 6: Biodiversity Conservation and Sustainable Management of Living Natural Resources (2012)

Smart Green Infrastructure in Tiger Range Countries: A Multi-Level Approach (2010)

### BANGLADESH

*LI and Biodiversity*

Impacts of Railways on Elephants: Experience from Bangladesh (2019)

*LI Projects of Note*

BAN: SASEC Chittagong – Cox's Bazar Railway Project, Phase I (2016)

Dhaka and Western Zone Transmission Grid Expansion Project (2019)

EIA Report of Anowara-Matarbari Coal-fired Power Station 400kV Transmission Line Project (2013)

Environmental Management Framework (EMF) of Rural Transport Improvement Project (2012)

Environmental Impact Assessment Report: Padma Multipurpose Bridge Project (2010)

Southwest Transmission Grid Expansion Project (2018)

## INDIA

*Policy and Guidelines*

A Policy Framework for Connectivity Conservation and Smart Green Linear Infrastructure Development in the Central Indian and Eastern Ghats Tiger Landscape, Vol. 1 (2018)

Guidelines for linear infrastructure intrusions in natural areas: roads and powerlines (2011)

Urban and Regional Development Planning Formulation and Implementation Guidelines (2015)

*Finance*

Conservation and Infrastructure Finance

*LI Projects of Note*

India Under Construction

India Infra Monitor

Parivesh Portal

## MONGOLIA

*Environmental Laws*

Mongolian Red Book (2006)

Convention on the Conservation of Migratory Species of Wild Animals

Mongolian Law on Fauna

Mongolian Law on Special Protected Areas

*Policy and Guidelines*

Guidelines for Environmental Damage Assessment and Compensation Methodology

An introductory presentation of a new standard prepared by the specialists of the Ministry of Road and Transport Development of Mongolia on Infrastructure and migratory wildlife

## NEPAL

*Environmental Laws*

The Control of International Trade of Endangered Wild Fauna and Flora Act (2017)

The Environment Protection Act (2019)

The Forest Act (2019)

Environment Protection Regulations (2020)

*Wildlife-Friendly Linear Infrastructure*

Draft Guidelines for Construction of Eco-friendly Linear Infrastructures (2021)

Use and Effectiveness of Wildlife Crossings in Nepal (2019)

A Training Manual: Green Road Engineering (2019)

*Planning and Implementation*

Nepal's Sixth National Report to The Convention on Biological Diversity (2018)

Strategy and Action Plan 2015-2025 Terai Arc Landscape, Nepal

Connecting Corridors: Terai Arc Landscape (2021)

*LI Projects of Note*

National Pride Projects

# MODULE 4: WILDLIFE SAFEGUARDS FOR LINEAR INFRASTRUCTURE PRACTITIONERS

## LINEAR INFRASTRUCTURE IMPACTS AND WILDLIFE POPULATION CONSERVATION

Road development in Asia: Assessing the range-wide risks to tigers (2020)

Where and how are roads endangering mammals in Southeast Asia's forests? (2014)

Impacts of roads and linear clearings on tropical forests (2009)

## MITIGATION MEASURES

Understanding and minimizing environmental impacts of the Belt and Road Initiative (2019)

Innovative Strategies to Reduce the Costs of Effective Wildlife Overpasses (2020)

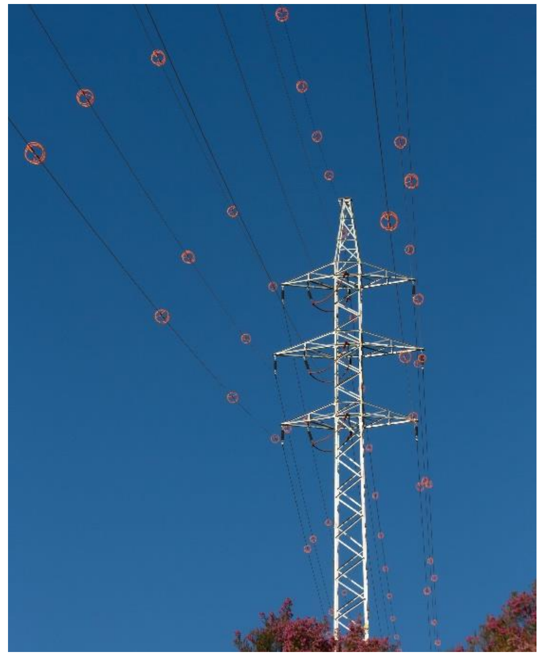
### PRE-CONSTRUCTION DATA COLLECTION FOR BIODIVERSITY ASSESSMENTS

ADB Webinar Hub: The modern road ecologist toolbox

### PLANNING CONSIDERATIONS AND POST-CONSTRUCTION DATA COLLECTION

Green Infrastructure Design for Transport Projects: A Road Map to Protecting Asia's Wildlife Biodiversity (2019)

Wildlife Crossing Structure Handbook: Design and Evaluation in North America (2011)



## MODULE 5: WILDLIFE CROSSING STRUCTURES – PLANNING, DESIGN, AND EVALUATION

### ECOLOGICAL EFFECTS OF ROADS AND ROAD ECOLOGY

Ecological effects of roads and traffic: A literature review (1998)

Effects of roads and traffic on wildlife populations and landscape function: road ecology is moving towards larger scales (2011)

Impacts of roads and linear clearings on tropical forests (2009)

### PLANNING AND DESIGN OF WILDLIFE-FRIENDLY ROADS

Green infrastructure design for transport projects: A road map to protecting Asia's wildlife biodiversity (2019)

Eco-friendly measures to mitigate impacts of linear infrastructure on wildlife (2016)

Final Report: Master Plan for Wildlife Linkages (Malaysia, 2009)

### MONITORING METHODS AND EVALUATIONS

Effectiveness of wildlife underpasses and culverts in connecting elephant habitats: a case study of new railway through Kenya's Tsavo National Parks (2021)

Assessing tiger corridor functionality with landscape genetics and modeling across the Terai-Arc landscape India (2020)

Monitoring of animal underpasses on National Highway 44 Passing through Pench Tiger Reserve, Maharashtra (2020)

### SAAS AND FOSS GIS TOOLS

ESRI 2021. ArcGIS Online. Redlands, CA: Environmental Systems Research Institute.

QGIS.org, 2021. QGIS Geographic Information System. QGIS Association.

### ANALYSIS TOOLS

Omniscape.jl: Software to compute omnidirectional landscape connectivity (2021)

Circuitscape user's guide (2009)

R: A language and environment for statistical computing (2010)

### METHODS AND EVALUATIONS

Road–wildlife mitigation planning can be improved by identifying the patterns and processes associated (2015)

Citizen, science, highways, and wildlife: using a web-based GIS to engage citizens in collecting wildlife information (2006)

Free and open source geographic information tools for landscape ecology (2009)

Spatial Analysis of Rural Road Network in Hilly Area of Chongqing Based on GIS (2010)

## MODULE 6: ENGINEERING CONSIDERATIONS IN THE DESIGN OF WILDLIFE CROSSINGS AND THEIR INFRASTRUCTURE

### MITIGATING WILDLIFE-VEHICLE COLLISIONS (WVC)

Managing and Enhancing Terrestrial Road Ecology (2020)

### WILDLIFE CROSSING STRUCTURE DESIGN

Innovative Strategies to Reduce the Costs of Effective Wildlife Overpasses (2021)

The use of fiber-reinforced polymers in wildlife crossing infrastructure (2020)

Wildlife Crossings Guidance Manual (2007)

Wildlife Crossing Structure Handbook: Design and Evaluation in North America (2011)

Technical Prescriptions for Wildlife Crossing and Fence Design (2016)

Design Considerations for Wildlife Crossings

## INTERNATIONAL CONFERENCES AND OTHER RESOURCES

Australasian Network for Ecology and Transportation (ANET)

African Conference for Linear Infrastructure and Ecology (ACLIE)

Infrastructure and Ecology Network Europe (IENE)

International Conference on Ecology and Transportation (ICOET)

Alliance of Leading Environmental Researchers & Thinkers (ALERT)

Mongabay series: Southeast Asian infrastructure

Transportecology.info

# QUIZ ANSWERS

## MODULE 1

1. b
2. c
3. d
4. a, b, and c
5. a, b, and c
6. d

## MODULE 2

1. e
2. d
3. c, d, and e
4. c
5. e, c, a, d, b

## MODULE 3

1. d
2. a
3. c
4. c, e, and f
5. False
6. a
7. d
8. d

## MODULE 4

1. False
2. True
3. c
4. d
5. c and e
6. False
7. c
8. False
9. True
10. b

## MODULE 5

1. True
2. True
3. a and d
4. e
5. c
6. e
7. True
8. False
9. a
10. a and b

**MODULE 6**

1. a

*While all four choices are design considerations, the most important factor is the degree of exclusion being sought as this influences the choice of fence composition, cost, and maintainability while reflecting the species to be prevented from accessing the highway or railway right-of-way.*

2. False

*While fencing is effective in preventing WVCs and resulting wildlife mortality, it prohibits wildlife from moving from one side to the other of the road or railway to access needed habitat, food, and water, and to ensure over the long term gene flow and genetic connectivity.*

3. False

*Each wildlife crossing is unique and must be undertaken in a contextually sensitive manner. Crossing structures must be built to reflect not only the requirements from a target species' perspective but also its budget and setting, location, and site nuances.*

4. b

*Wildlife underpasses direct animals to pass beneath a road or railway and have little or no vegetation. The dead load they carry is similar to any highway or railway bridge structure with the greatest loading being the live load to be carried. Height and width of structure as well as soil conditions are considerations in any structural underpass design.*

5. d

*While all the factors listed are good to have, they can be overcome to some degree save for the lack of a diverse team of not only design engineers, but also others knowledgeable about the species that the structure is being designed to serve. An ideal group of experts needed to consult with engineers includes biologists, road/railway ecologists, landscape architects, suppliers, and contractors. It is through early collaboration in the design process and the understanding and sharing of various perspectives and considerations that a truly effective crossing can be realized.*