AARON LAUR

BUILDING A FOUNDATION FOR LINEAR INFRASTRUCTURE SAFEGUARDS IN ASIA

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EXECUTIVE SUMMARY

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, increase wildlife mortality, reduce carbon sinks, and raise emissions.

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.

The LISA project conducted spatial assessments to identify Asia's highest biodiversity areas and digitized hundreds of proposed LI projects to locate areas of potential conflict. It also conducted spatial analyses to demonstrate where future LI may impact species such as tigers or saiga antelope, or impact important ecosystems such as the Terai Arc Landscape shared by India and Nepal.

The project also examined the availability of scientific information that developers draw upon to create WFLI by reviewing, synthesizing, and summarizing published literature regarding the direct and indirect effects of LI on Asian species and ecosystems. It examined peer-reviewed publications that evaluated potential solutions, such as the effectiveness of LI mitigation measures.

The LISA project then sought to better understand the current capacity of four constituent groups involved in the development of LI: government, industry, financing, and non-governmental organizations. It conducted interviews with LI leaders across Asia to gather their perspectives regarding existing WFLI capacity and future needs. The project conducted an electronic survey of constituents in five representative countries (Bangladesh, India, Mongolia, Nepal, and Thailand) regarding the capacity to provide wildlife safeguards and the key barriers to implementation.

Finally, the project evaluated and reported on eight case studies of exemplary LI projects, chosen either for their efficacy or for lessons learned from their shortcomings. Two of these case studies include economic analyses that demonstrate the benefits of providing WFLI safeguards. Training materials for future capacity building were also created based on the project's findings.

The LISA project found that there is a need to increase capacity to address WFLI safeguards in developing Asia. While Asia has many examples of successful LI plans and projects, systemic and standard practice is often lacking. LI practitioners across sectors are supportive of future workforce training to increase their expertise to better address the adverse effects of LI. They also expressed interest in opportunities to establish internet-based platforms to share data and information, as well as for networking to share wildlife-friendly policies and practices. With enhanced capacity, developing Asia will be well situated to address LI development through the application of effective safeguards.

The results presented in this Final Report are drawn from the following four annexes. Each annex contains an introduction, methods, results and discussion, key findings, and recommendations.

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 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 11 published studies from across Asia that conducted 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 AND THEIR COMPARATIVE ANALYSIS

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 WFLI safeguards from those that were not. 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.

GLOSSARY

Biodiversity: The variability of all life in its infinite forms and the ecological complexes that result from the interaction between the living and inanimate world.

Constituent Groups: The key categories of stakeholders that are involved in developing linear infrastructure and implementing wildlife safeguards. These include: government agencies, international financial institutions, industry, and non-governmental organizations.

Cost-Benefit Analysis: The process of comparing the estimated costs and benefits of a planned linear infrastructure project to determine whether to proceed, amend, or avoid.

Ecological Connectivity: The unimpeded movement of species and the flow of natural processes that sustain life on Earth.

Ecosystem Services: The benefits people derive from ecosystems, such as provisions (e.g., food, wood, water), regulatory services (e.g., pollination, disease control), supporting services (e.g., nutrient cycling), and cultural amenities (e.g., recreation, spiritual well-being).

Mitigation Hierarchy: A simple framework for linear infrastructure proponents to follow in an effort to achieve no net loss of environmental values: avoid, minimize, mitigate, and offset/compensate.

Net Present Value: An indicator used to assess the financial feasibility of a project. The indicator is calculated by subtracting the expected costs from the expected benefits in each period of analysis. The difference between the costs and benefits is discounted in each period so all values are comparable and translated into today's currency. If the Net Present Value is positive, then the project is financially feasible (i.e., the benefits are greater than the costs).

Project Development Process: A stepwise framework, consisting of seven phases, used for survey respondents to identify stages in a project's development during which potential barriers to WFLI safeguard implementation occur.

Safeguards: The sum total action(s) that can be taken to assure that environmental and social values are protected during linear infrastructure planning and project development. They provide policy makers, government agencies, financiers, engineers, and planners with the information and tools they need to apply the appropriate environmental and social protections for infrastructure development.

Spatial Analysis: A statistical analysis of data to discover patterns as they relate to geographic locations.

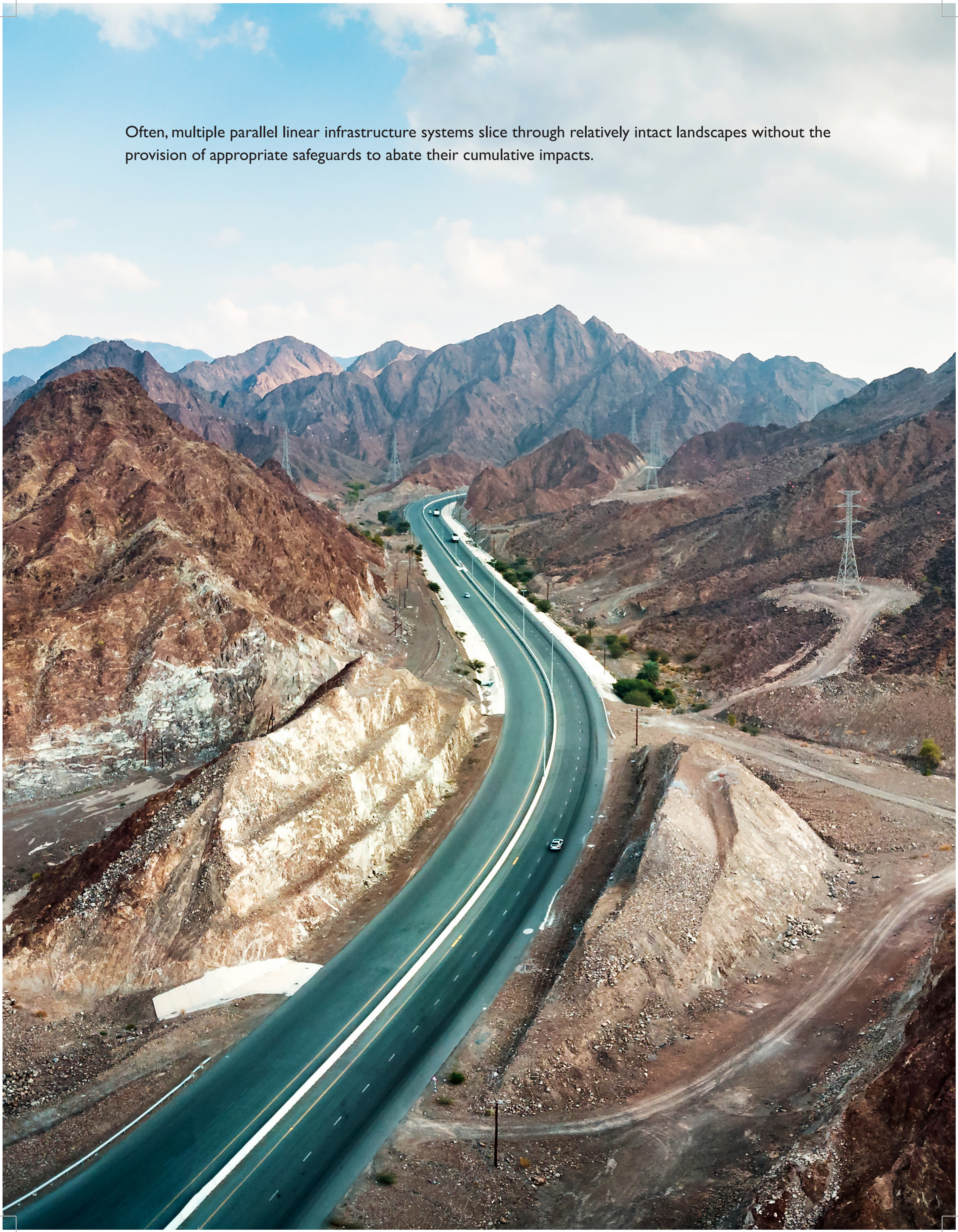
Wildlife: The native fauna of a region. This project focuses on terrestrial and arboreal species—mammals, birds, reptiles, and amphibians—since these are the most studied organisms in the emerging field of transport ecology in Asia. With time, linear infrastructure interactions with invertebrates, aquatic species, and other taxonomic groups will only increase.

Wildlife-Friendly Linear Infrastructure (WFLI): The result of policies and practices that take into consideration, evaluate, and implement measures that reduce the direct, indirect, and cumulative impacts of linear infrastructure on species, their habitats, and their ability to move and migrate.

Great Indian bustard.
Credit: Kesavamurthy N/Wikimedia Commons/CC BY-SA 4.0

ACRONYMS

ADB	Asian Development Bank
BRI	Belt and Road Initiative
CAREC	Central Asia Regional Economic Cooperation Program
CBA	Cost-Benefit Analysis
CMS	Convention on Migratory Species
EIA	Environmental Impact Assessment
IFI	International Financial Institution
IUCN	International Union for the Conservation of Nature
LI	Linear Infrastructure
LISA	Linear Infrastructure Safeguards in Asia
MEA	Multilateral Environmental Agreement
NGO	Non-governmental Organization
SASEC	South Asia Subregional Economic Cooperation Program
SDG	Sustainable Development Goal
TAL	Terai Arc Landscape
USD	United States Dollar
WFLI	Wildlife-Friendly Linear Infrastructure



Often, multiple parallel linear infrastructure systems slice through relatively intact landscapes without the provision of appropriate safeguards to abate their cumulative impacts.

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INTRODUCTION

Asian elephant

A HUB OF BIODIVERSITY

Asia is home to some of the world's richest biodiversity and most complex ecosystems. From Asian elephants and Mongolian gazelle to Bengal tigers and Sumatran orangutans, Asia's iconic wildlife species along with numerous birds, reptiles, amphibians, and many other species play essential roles in maintaining the balanced biological networks that sustain life.

Humans are also part of this biodiversity. Asia's ecosystems contribute to human wellbeing in numerous ways such as underpinning economic vitality, increasing communities' resilience to environmental change, and providing natural resources. Millions of people in the region depend directly on nature for their medicine, food, fuel, and other subsistence needs.

Yet, as Asia experiences unprecedented economic growth, much of the region's natural heritage is threatened by the rapid expansion of roads, rails, and other linear infrastructure (LI) development. Without proper safeguards, ongoing and anticipated expansion of LI will further fragment vital habitats, impact biodiversity, and increase wildlife mortality.

BUILDING A FOUNDATION FOR LINEAR INFRASTRUCTURE SAFEGUARDS IN ASIA

To address the impacts of this infrastructure growth on the natural world and Asian communities, USAID launched the Linear Infrastructure Safeguards in Asia (LISA) project. The project assessed how well-prepared developing Asian countries are to safeguard their ecosystems and rich biodiversity in the face of the continued, extensive expansion of infrastructure.

Three LI systems were the project's focus: roads, railways, and electric power lines. The project evaluated actions that may be taken while developing these three LI systems to protect wildlife, their habitats, and their ability to successfully move, migrate, and adapt to climate change.

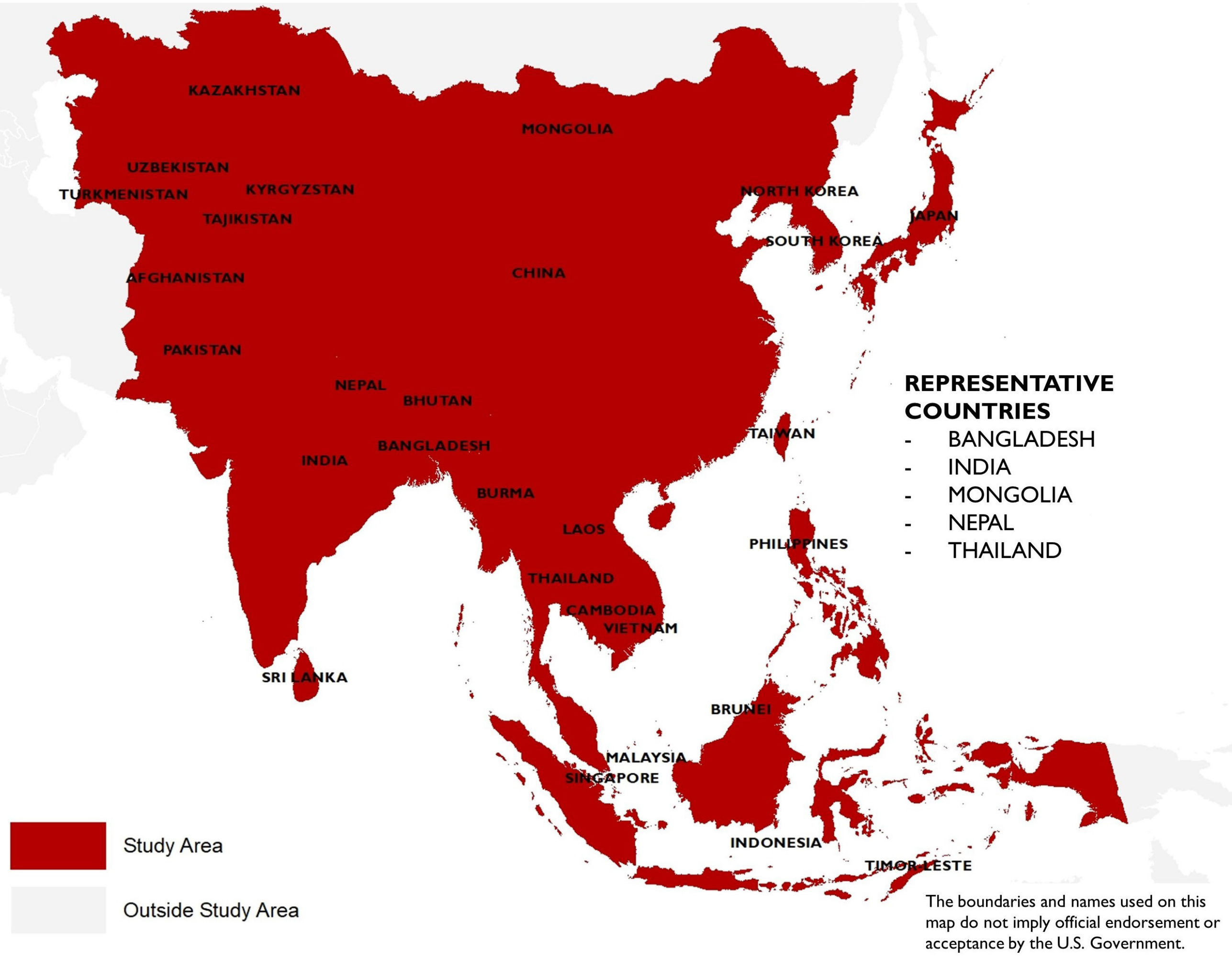
SPECIES

The LISA project focused mostly on terrestrial, arboreal, and aerial species, as these taxonomic groups are well represented in the scientific literature and other publications evaluating LI's impacts and potential solutions. Aquatic species and invertebrates are most likely impacted adversely as well, but are under-represented in LI studies and reports.

GEOGRAPHY

The LISA project assessed the capacity of 28 Asian countries to develop wildlife-friendly LI and selected five representative countries to evaluate capacity at a finer scale (Figure 1).

Figure 1: The 28 Countries in the Project Study Area



ROADS

Predictions indicate that 25 million kilometers of new roads will be built worldwide by 2050, with 90% of these in developing countries.[1]

POWER TRANSMISSION LINES

The world's network of power transmission lines is growing at a rate of about 5% annually.[2]

RAILS

It is estimated that, globally, more than 300,000 kilometers of new railway tracks will be built by 2050.[3]

A tunnel on the Sixiao Expressway, Yunnan Province, China. Credit: Rob Ament

WILDLIFE-FRIENDLY LINEAR INFRASTRUCTURE

LI, while providing many important benefits to human societies, has great potential to harm wildlife. The threats to wildlife include inducing mortality due to collisions with vehicles, trains, or power lines along with creating barriers to movement necessary for survival. In addition, the construction of new or expanded infrastructure drives habitat and biodiversity loss by opening previously remote areas to human development and exploitation. It can also cause increases to deforestation and greenhouse gas emissions.

WFLI can reduce the potential for harm to wildlife by avoiding, minimizing, or mitigating risks. While it is best to avoid building or expanding infrastructure in areas of importance for biodiversity, mitigation measures can be added to reduce the impacts of LI. Examples include underpasses or overpasses that allow animals to cross safely over or under highways, or early warning systems that alert train operators when large mammals are near, or on, the upcoming tracks.

METHODS

The project used four primary methods to better understand the challenges, barriers, resources, and opportunities related to implementing LI safeguards to protect wildlife:

Spatial Analysis: Spatial analyses were conducted to identify LI projects most likely to impact biodiversity and critical habitats in the study area.

Case Studies: Case studies of exemplary WFLI projects as well as cautionary examples were compiled to help inspire and guide future projects.

Policy Assessment: Capacities regarding policies, regulations, and resources for adopting LI safeguards were examined in the context of various representative countries and constituent groups.

Literature Review: Research was synthesized to understand the impacts of LI on wildlife and critical habitats throughout Asia, as well as potential solutions.

ASIA'S LINEAR INFRASTRUCTURE CHALLENGE

Snow leopard

SCALE OF LINEAR INFRASTRUCTURE DEVELOPMENT IN ASIA

BENEFITS OF LI TO PEOPLE AND DEVELOPMENT

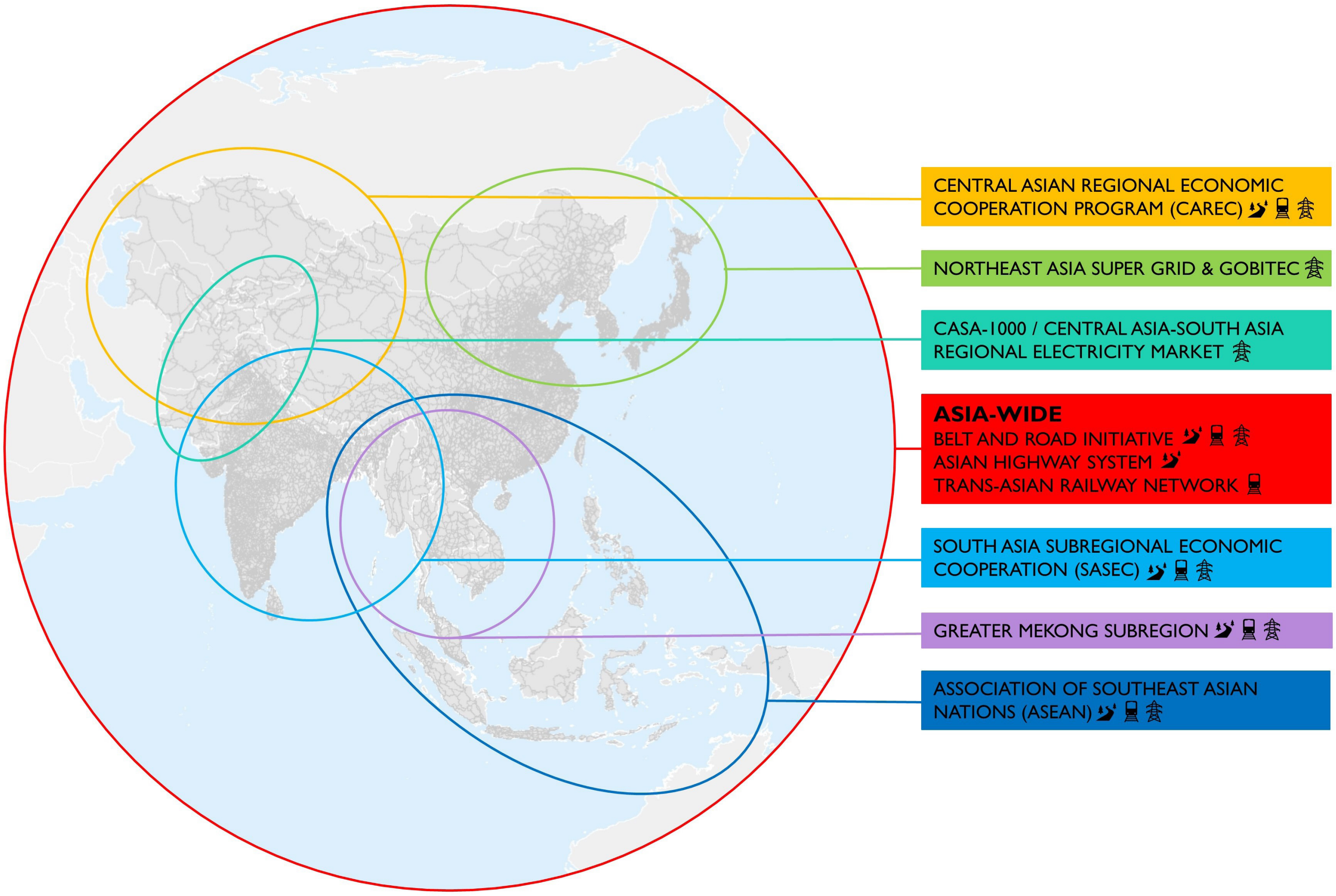
Infrastructure is a critical component for meeting the United Nations Sustainable Development Goals (SDGs). Globally, approximately 300 million rural dwellers lack access to adequate roads,[4] and roughly 13% of the world lacks access to electricity.[5] These challenges will be addressed through the installation of new infrastructure and the expansion of existing systems. Reliable transportation infrastructure allows access to markets, trade, health services, jobs, and countless other benefits. These fundamental societal needs will only continue to increase in importance as the world grows more populous alongside the demand for a higher standard of living. As Asia continues to further develop its infrastructure systems, it will be necessary to implement safeguards to ensure that biodiversity is protected for the benefit of all; the LISA project's term for this consideration is wildlife-friendly linear infrastructure (WFLI).

Long-tailed macaque

INTERNATIONAL LI INITIATIVES IN ASIA

Many international economic development initiatives in Asia promote the coordination and integration of infrastructure development across national borders (Figure 2). Some of these initiatives—the Asian Highway System, the Trans-Asian Railway Network, and the Belt and Road Initiative—are Asia-wide, while others are more regionally focused. Most initiatives include all three modes of LI studied by this project (roads, rails, and power lines) in addition to other infrastructure such as hydropower and ports. Most have also laid out future strategies that provide important insight into where LI will be developed over the next decade. While these initiatives do not encompass every LI project, especially those planned and funded at the national or sub-national level, they provide a key intervention point to consider WFLI safeguards before individual projects are developed.

Figure 2: International Linear Infrastructure Initiatives in Asia



DEVELOPMENT BY THE NUMBERS

- **$26 trillion USD**: the amount that Asia will need to invest in infrastructure from 2016 to 2030 to maintain economic momentum, including **$14.7 trillion USD** for power and **$8.4 trillion USD** for transport[6]
- **$3.4 trillion USD**: the cost of addressing climate change mitigation in infrastructure development from 2016 to 2030[7]
- **$770 billion USD**: the amount that China invested in Belt and Road Initiative (BRI) countries from 2013 to 2020, with 27 percent going to East Asia and 22 percent going to West Asia[8]
- **$120 billion USD**: the amount of investment required for more than 200 priority projects in the South Asia Subregional Economic Cooperation (SASEC) program's 2016-2025 operation[9]
- **$39.34 billion USD**: the amount that the Central Asia Regional Economic Cooperation (CAREC) program invested in development from 2001 to 2020[10]
- **145,000 km**: the length of roads that are currently part of the Asian Highway Network, passing through 32 countries[11]
- **117,500 km**: the length of railways that are currently part of the Trans-Asian Railway Network[12]
- **$44.1 billion USD**: the amount of financing needed to implement the transport sector of the Greater Mekong Subregion Regional Investment Framework from 2013 to 2022[13]

Dusky langur

FUTURE DEVELOPMENT OPTIONS: NEW OR UPGRADED INFRASTRUCTURE

LI development occurs in two primary ways: the construction of new roads, railways, and power lines; or the improvement and expansion of existing LI. New infrastructure creates an entirely original footprint and may involve clearing forests or removing other wildlife habitat. Upgrading infrastructure typically involves paving or widening roads to create more lanes or raise speed limits; improving railways to facilitate greater freight capacity and higher train speed; or increasing the voltage of power lines. Economic development initiatives tend to invest in both building new LI and upgrading existing infrastructure, both of which can impact wildlife and their habitat.

Mature male wild saiga antelope. Credit: Andrey Giljov/CC BY-SA 4.0

BIODIVERSITY IN ASIA

From the dense rainforests of Borneo to the montane grasslands of the Tibetan Plateau, Asia is home to a tremendous diversity of ecosystems that sustain thousands of endemic plant and animal species (Figure 3). However, this rich biodiversity has a downside: there is much to lose.

For instance, the Tibetan Plateau region of China forms roughly half of the elusive and vulnerable snow leopard's known range.[14] Borneo's peat swamp forests provide habitat for a globally important—and possibly the largest unprotected—population of orangutans.[15] The Leuser Ecosystem, a tropical rainforest in Sumatra, is thought to be home to the last remaining viable population of Sumatran rhinos.[16]

Several of the world's 36 recognized biodiversity hotspots—Earth's most biologically rich yet threatened terrestrial regions—are in Asia. For example, the Himalaya Hotspot, containing the world's highest mountains and habitat for important bird and mammal species like the endangered wild water buffalo, is experiencing human-caused biodiversity loss despite its remoteness. The Indo-Burma Hotspot, encompassing more than two million square kilometers of tropical Asia, is one of the most biologically important regions on the planet but also among the most threatened by habitat loss.[17] What societies choose to do—or not do—to protect these regions will have an enormous impact on global biodiversity.

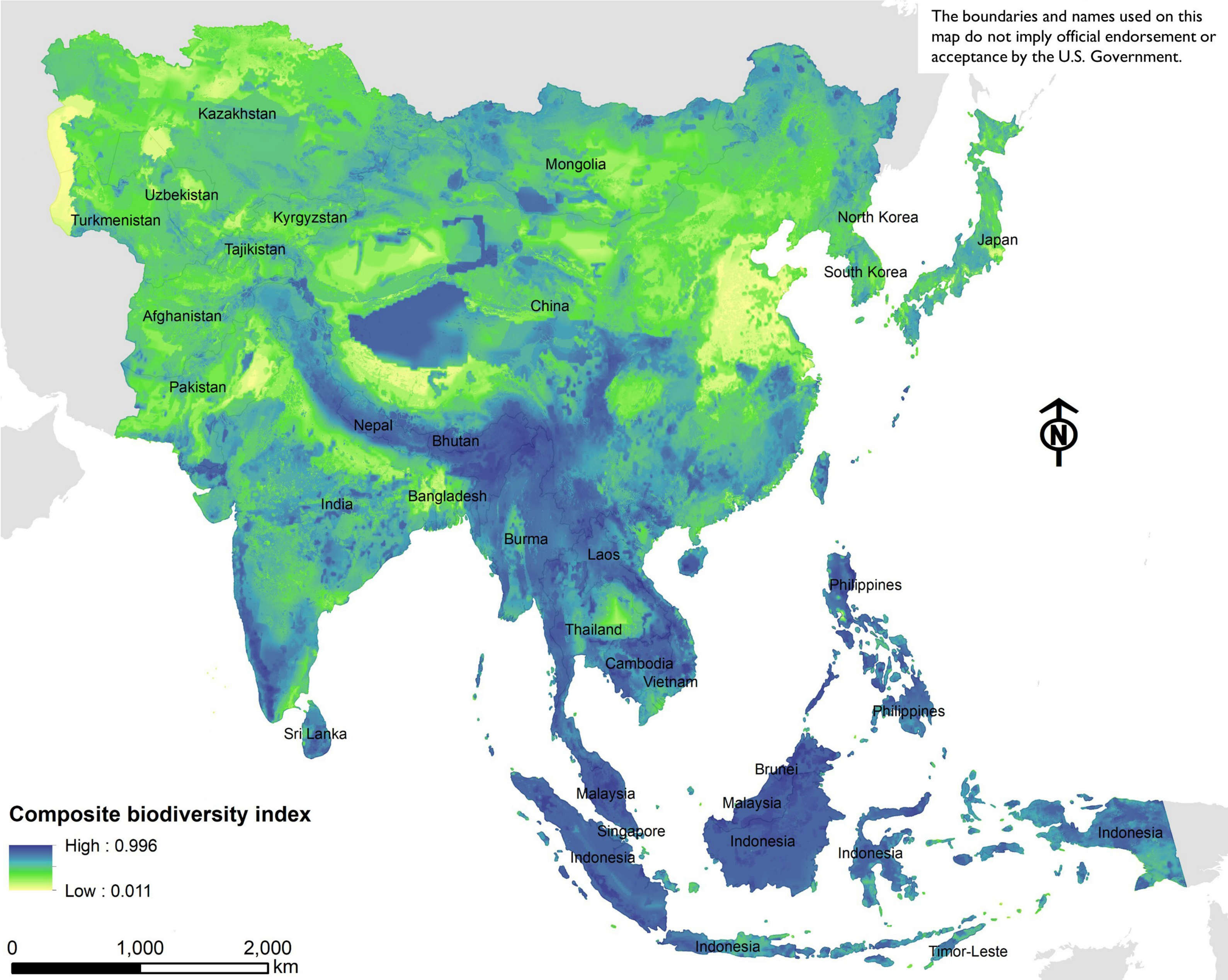


Figure 3: Biodiversity Hotspots in Asia

A myriad of endangered and at-risk species are present in Asia. Examples include Bengal tigers, snow leopards, Asian elephants, greater one-horned rhinos, and great Indian bustards—all of which appear on the IUCN Red List of Threatened Species with statuses ranging from Vulnerable to Critically Endangered (Figure 4).

All of the species in Figure 4 are experiencing declines in their populations with the exception of the greater one-horned rhino, due to excellent conservation efforts by India and Nepal.[18] Despite these heroic efforts, this rhino population remains at risk from, among other threats, severe fragmentation of its habitat and land use change spurred by rapid economic growth. This growth is often facilitated by LI development, which has generated significant pressure on the region's biodiversity and could have dire consequences for many species.[19]

Bornean orangutan

The Bornean orangutan population decreased by more than 60% between 1950 and 2010 and now, a decade later, is steadily declining.[20] The great Indian bustard, a large, long-legged bird, now numbers fewer than 250 individuals.[21] The Asian elephant, perhaps–along with the Bengal tiger–the most emblematic species of Asia, has disappeared from approximately 95% of its historical range.[22] These are just a few examples of Asian species at risk of being lost forever.

Figure 4: Species Decline in Asia[a]

	Bengal Tiger	Great Indian Bustard	Asian Elephant	Snow Leopard	Greater One-horned Rhino	Bornean Orangutan
Population Estimate	1,700[23, b]	50-249[24]	52,000[25]	2,710-3,386[26]	2,100-2,200[27]	55,000[28]
Current Population Trend	Decreasing	Decreasing	Decreasing	Decreasing	Increasing[c]	Decreasing
	Endangered	Critically Endangered	Endangered	Vulnerable	Vulnerable	Critically Endangered

[a] Species status and current population trends: International Union for the Conservation of Nature (IUCN) Red List of Threatened Species™

[b] Population estimate for India only, as population numbers and status for other countries are unclear.

[c] Though the greater one-horned rhino's population is increasing, their population is severely fragmented.

Male hoolock gibbon. Credit: Gregoire Dubois

WHY IS LINEAR INFRASTRUCTURE A PROBLEM FOR BIODIVERSITY?

LINEAR INFRASTRUCTURE'S IMPACTS ON WILDLIFE

Wild animals need to move for survival. From seeking food and fresh water, to finding mates, to completing seasonal migrations, barriers to natural movement can threaten the survival of animal populations in several ways. For instance, roads and railways directly affect wildlife in the form of animal-vehicle collisions and train strikes, resulting in injury or mortality. Although power lines do not carry vehicles, they too cause direct mortalities or injuries to wildlife through electrocution and when birds and other animals collide with the lines.

In addition to direct impacts, LI can have indirect effects on wildlife, such as the loss or degradation of habitat. LI can also trigger changes in habitat use, such as animals avoiding roadside verges that are different than the surrounding vegetation. The ecological impacts of LI may also expand far beyond the immediate area of its footprint due to artificial noise, light pollution, and poorer air quality caused by traffic. Known as the "effect zone," wildlife use of, or natural movement through, this area may be reduced. LI can also lead to increased human activity, like poaching or illegal logging, which may be detrimental to wildlife and its habitat.

The Human Factor: Impacts of Linear Infrastructure

Once roads, rails, and power lines make a natural area more accessible for travel, habitation, and recreation, wildlife becomes vulnerable to a range of human-caused disruptions:

- Habitat loss, fragmentation, and degradation
- Illegal logging or extraction activities such as mining
- Increase in hunting or poaching
- Introduction of exotic species
- Light, noise, air, or runoff pollution from vehicles and trains
- Increase in greenhouse gas emissions due to deforestation
- Other land-use changes such as legal or illegal settlement

Deforestation in Malaysia during the construction of a new road

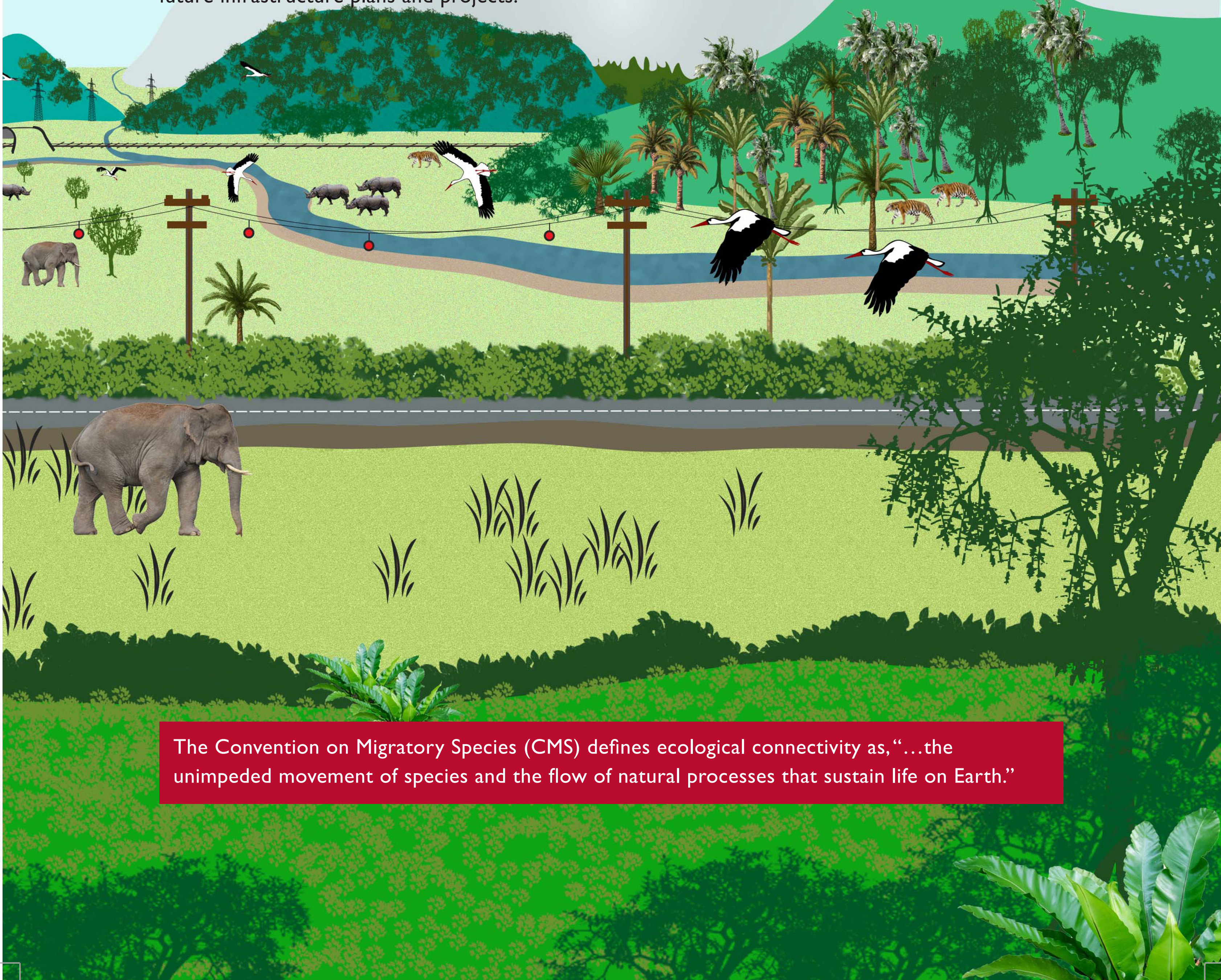
Figure 5: Ecological Connectivity and Linear Infrastructure

What is ecological connectivity and why is it important?

Earth's landscapes and seascapes are increasingly fragmented, resulting in detrimental effects to the maintenance of biodiversity and ecosystems.[29] Wildlife has less and less freedom to roam, free-flowing rivers are becoming rarer, protected and conserved areas are becoming isolated islands, and ecological processes essential to human well-being—such as pollination—are in jeopardy.[30] Biodiversity loss combined with the climate change crisis is now threatening the ecological health of our planet like never before. It is well documented that connected lands and waters strengthen resilience to climate change and provide crucial ecosystem services supporting human health and well-being.

Climate Change Adaptation and Mitigation

Mounting evidence demonstrates that connected landscapes, seascapes, and freshwater systems are critical for sustaining protected areas, maintaining ecological functions, saving species, and allowing them to adapt to climate change. It is now widely recognized that habitats and species function best as part of large, interconnected networks that are maintained and protected,[31] and that nature's persistence relies on the ability of plants and animals to move and adapt as conditions change.[32] Additionally, conservation science makes clear that protected areas, conserved areas, and other intact natural areas cannot thrive if they are isolated islands, especially as the impacts of climate change increase. Yet, the rate of species extinction and environmental degradation is accelerating. Alarmingly, the Intergovernmental Science-Policy Platform on Biodiversity reported in 2019 that up to one million species are currently at risk of extinction.[33] In the face of climate change, wildlife have limited options: move, migrate, adapt, or die. Roads, railways, and power lines act as barriers to animal movement, and thus it is critical that LI proponents are aware of potential negative impacts and increase efforts to maintain or improve landscape connectivity during the development of future infrastructure plans and projects.

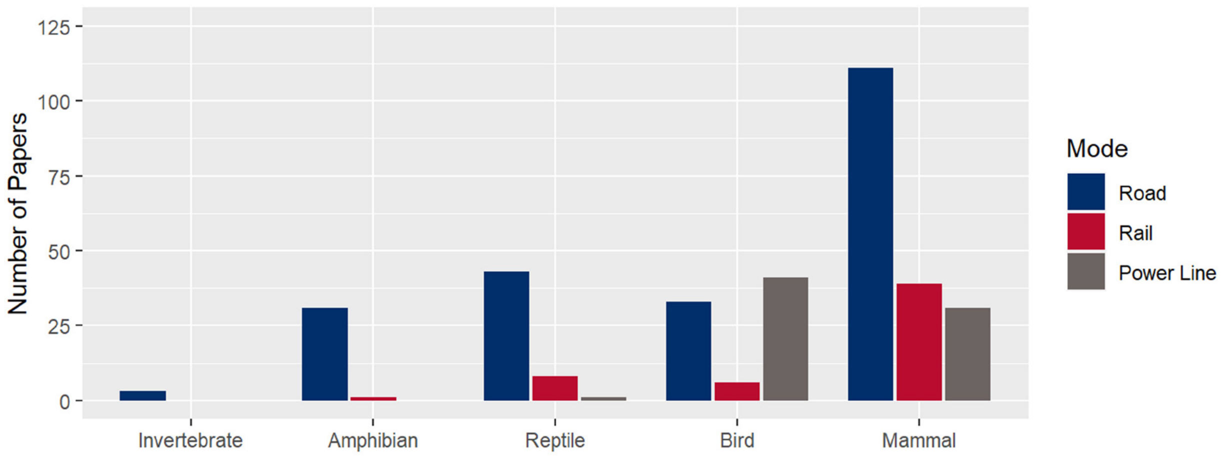


The Convention on Migratory Species (CMS) defines ecological connectivity as, "…the unimpeded movement of species and the flow of natural processes that sustain life on Earth."

WHAT IS KNOWN ABOUT IMPACTS ON WILDLIFE FROM ROADS, RAILS, AND POWER LINES IN ASIA?

A review of the literature by the LISA project revealed 289 peer-reviewed English language papers related to LI and wildlife in Asia, of which 56 percent were focused on roads, 17 percent on railways, and 27 percent on power lines. Mammals are the most commonly studied taxonomic group, followed by birds, reptiles, amphibians, and invertebrates (Figure 6).

Figure 6: The Number of Papers Covering Each Taxonomic Group Per Mode



Most papers focused on the direct effects of LI on wildlife, such as instances where animals were killed or injured. The documentation of LI-caused mortalities to wildlife is a crucial first step in the process of understanding the impacts of LI on wildlife populations in Asia. Summary statistics from such studies are easy to collect and report; they offer a rapid assessment of the scope and extent of species impacted.

This project found that road mortality (e.g., "roadkill") studies are the most extensive of the three modes in Asia, while scientific inquiry into the direct impacts of rails and power lines on wildlife is less robust. It is not yet known whether the low number of documented species directly impacted by rails, the lowest of the three modes in this report, is accurate or whether this number simply reflects a study bias for large, charismatic mammals, such as elephants. Similarly, there was only one peer-reviewed paper published in 20 years on the direct mortality of all three modes, combined, to invertebrates.

Therefore, increased documentation and evaluation of wildlife mortality are required to determine the extent and scope of LI impacts on a wide variety of taxonomic groups and individual species across Asia, particularly for railways but also for the other modes.

Camera trap photo of a tiger using a wildlife underpass under National Highway (NH) 44 in Maharashtra, India.
Credit: Bilal Habib, Wildlife Institute of India

ROADS

With the frequency and public visibility of wildlife-vehicle collisions on roads, comprehensive data on the direct impacts of roads on wildlife in Asia is surprisingly lacking. This project found that the direct impacts are typically studied in a fragmented and site-specific manner at small scales. Direct impact studies focused far more on documenting wildlife losses (i.e., producing lists of species that are killed on roads) rather than identifying the causes of these mortalities. In addition, the literature is lacking studies that evaluated evidence-based mitigation solutions. As a result, relatively few insights for population-scale conservation have been produced for Asia.

In contrast to the direct effects of LI to populations and their potential solutions, the barrier effects of roads are relatively well studied, particularly via models that help predict habitat or landscape connectivity. The genetic consequences of these barrier effects are being increasingly addressed, particularly for mammals.

Both the direct and indirect impacts of roads on wildlife demographics and parameters related to species fitness at the population level (such as reproduction and mortality rates) were rarely studied. This represents a major research gap in the literature.

Of the more than 30 mitigation measures evaluated in other parts of the world,[34] only 10 were found to have been addressed—even to a small extent—in Asia. Yet, other mitigation measures, particularly those related to modifying human or animal behavior, have been implemented on the ground in several Asian countries. The lack of documentation and evaluation of such measures makes it difficult to understand their efficacy in reducing the direct and indirect impacts of roads. It also prevents the development of a best practices manual for Asian safeguards.

Crossing structures that separate wildlife from roads but allow passage, such as overpasses and underpasses, are increasing in number across several Asian countries. At least 39 species in Asia have been documented using these wildlife crossings, whether they were designed for their use or serve that purpose "de facto." While the efficacy of structural separation measures is better documented than other mitigation measures, there appears to be a mismatch between the hundreds of such wildlife crossings constructed and the handful of studies that evaluate their effectiveness.

Potential Impacts of Proposed Roads and Railways on Ungulates in Mongolia

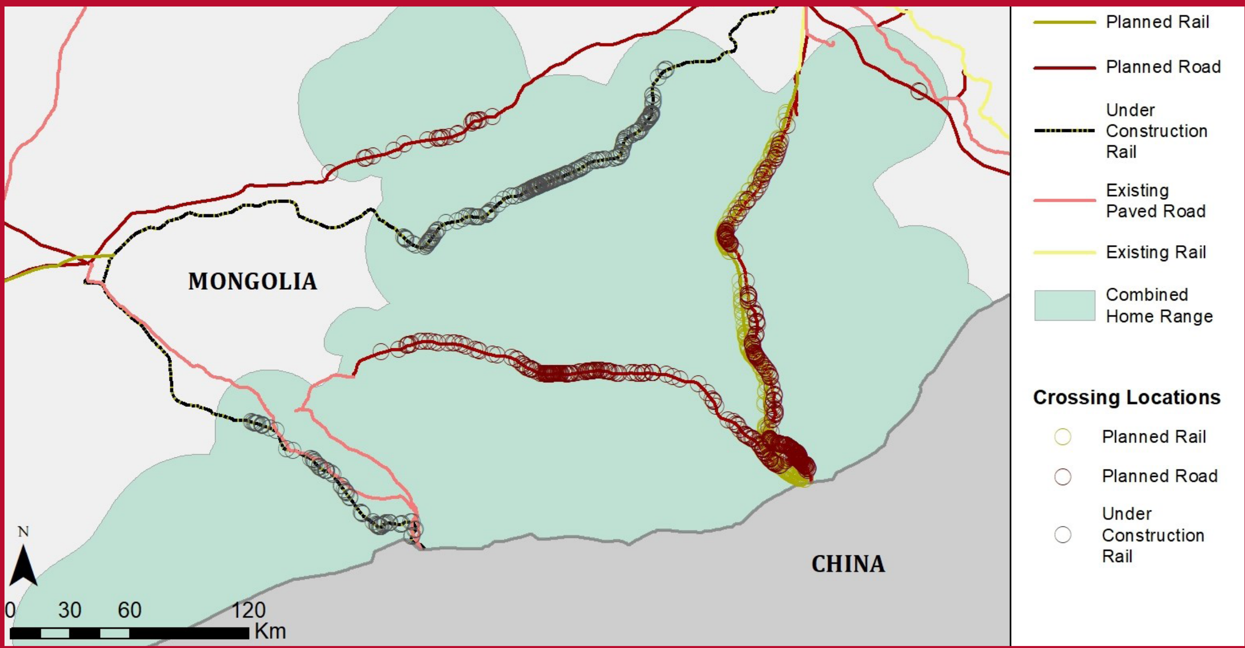


Figure 7: Circles Indicate the Locations Where 20 Collared Khulan Crossed Proposed Rail and Road Alignments

In Mongolia's Gobi-Steppe Ecosystem, ungulates such as khulan (wild ass) and goitered gazelle move throughout the landscape in search of quality forage. The construction of new roads and railways is carving up the landscape, fragmenting ungulate habitat and creating barriers to movement. A study of movement data from 20 khulan revealed that these animals cross the locations of proposed roads and railways many times per year (Figure 7). Previous studies have shown that ungulates in this area almost never cross existing railways or fences, meaning that the construction of LI in southeast Mongolia will likely impact animal movement. To ensure these species can continue to persist, mitigation measures will be needed for LI, such as building wildlife crossing structures and removing fences. *See Annex 1, Section 2.6.*

RAILWAYS

Studies of the indirect impacts on wildlife concentrate on the barrier effects of railways, particularly when the tracks are fenced or associated with human settlement. The consequences of the barrier effect caused by railways on gene flow continue to be explored. Railway corridors may be continuously fenced for extended distances—especially on high-speed routes—making them impassable to wildlife. This is a simple design flaw that can be corrected by retrofitting with wildlife crossings. Relatively few studies from Asia exist on wildlife use of crossing structures built specifically to facilitate safe passage across railway tracks. However, at least 14 species in Asia have been documented utilizing such structures to cross over or under railway tracks. Design and location are key determinants of effectiveness, and structures that are placed at the wrong locations may lead to increased and unnecessary energy expenditure by animals to access and cross them.

POWER LINES

Birds and mammals dominate the existing literature on the impacts of power lines. Birds alone accounted for 53 percent of the literature, while 40 percent of the literature focused on mammals. Scientific literature detailing the indirect and population effects of power lines is nearly nonexistent. Like the road and rail literature, most of the studies focused on documenting power line impacts themselves rather than evaluating the effectiveness of mitigation measures. The installation and assessment of mitigation measures is largely focused on reducing power line electrocution fatalities. However, information on the effectiveness of different types of power line mitigation measures that seek to reduce animal collision fatalities is lacking in the peer-reviewed literature.

For more in-depth information on all three modes, see Annex 4.

Potential Impacts of Road and Rail Development on Tigers in Nepal's Terai Arc Landscape

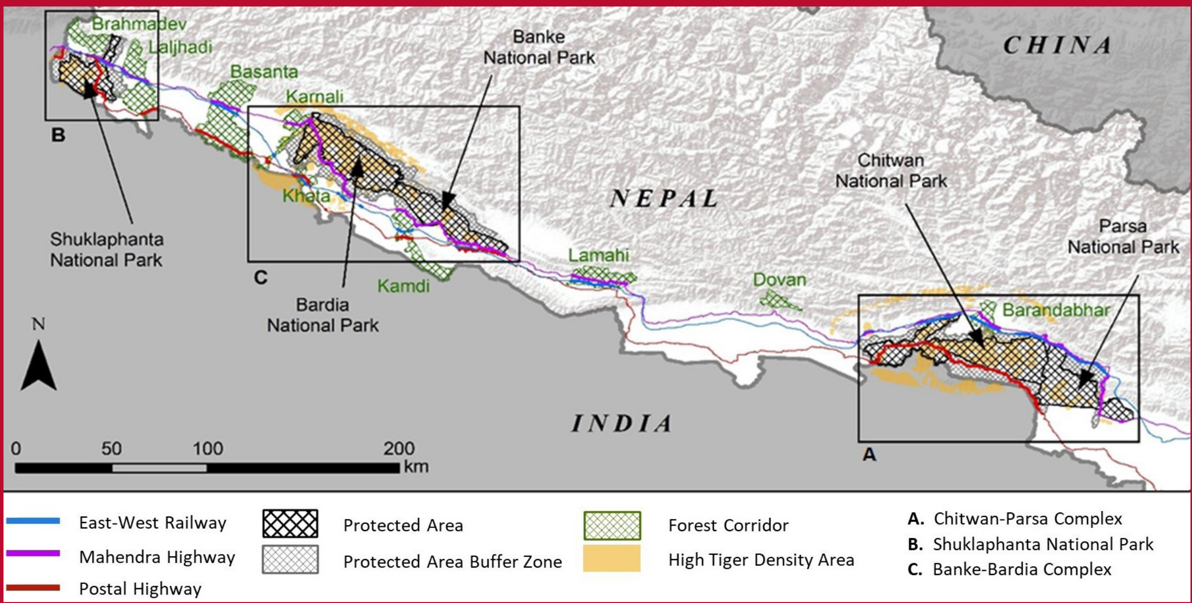


Figure 8: Intersections Between Proposed Linear Infrastructure Routes and Priority Areas for Tiger Conservation

The Terai Arc Landscape (TAL) is a ~50,000-kilometer(km)^2 area of forests, grasslands, and wetlands along the India-Nepal border, and an area of global conservation priority due to its high biodiversity and presence of charismatic and endangered megafauna such as elephant, rhinoceros, and tiger. The TAL is undergoing rapid development, including three major LI projects that run east-west across much of Nepal. More than 800 km of these proposed LI routes intersect priority areas for tiger conservation, which include protected areas, buffer zones, forest corridors, and high-density tiger areas (Figure 8). While the impacts inside protected areas are relatively minor, less protected lands serve as crucial habitat links between tiger subpopulations. Thus, tiger populations may be impacted if connectivity is severed by construction of new LI routes or by upgrades to existing LI routes that lead to a wider LI footprint, increased traffic volume, and a stronger barrier effect for tigers. Understanding tiger movement at local and regional scales will be needed to properly plan safeguards for ongoing and future LI developments. *See Annex 1, Section 2.2.*

Greater one-horned rhinoceros

ECONOMICS

Biodiversity, ecosystem services, and the intrinsic value of nature are all fundamental to human wellbeing and life on earth. There is no doubt that nature is essential for humankind, but often the task of quantifying the value of these goods and services is omitted during LI development. These services tend to be overlooked in decision-making or are frequently undervalued. This is often due to the lack of consensus on how to assign an economic value to many of the services and natural capital owing to their complexity. As a result, economic incentives to conserve biodiversity and sustainably utilize natural resources are infrequent and variable in LI development plans and projects.

Cost-benefit analysis (CBA) is an essential tool that allows developers and decision makers to quantify the value of nature and include it explicitly in the project development process. By assessing the potential impact of the project on the quality and quantity of other values of nature, project developers can better account for the true cost of a project with respect to the environmental values lost or gained.

Often, the expected costs and benefits are used to calculate the Net Present Value, an indicator of the financial feasibility of a project. The LISA project's case studies have demonstrated that, in some instances, the environmental costs of a project can far outweigh the economic benefits (a negative Net Present Value) and that alternative LI routes may better serve environmental and social values. CBA also offers a way to identify which mitigation strategies are more cost effective and will best reduce unavoidable impacts.

On roads, wildlife-vehicle collisions can be costly due to their environmental and societal consequences. The cost of wildlife-vehicle collisions can include:

- Vehicle repair or replacement
- Medical expenses (short and long term)
- Loss of human life
- Insurance payouts
- Towing, accident attendance and investigation
- Carcass removal and disposal
- Monetary value of animal

Once the costs of wildlife-vehicle collisions are better understood in Asia, these values can be incorporated into CBAs and other economic evaluations.

Java-Bali 500 Kilovolt Power Transmission Crossing Project (Indonesia)

The Java-Bali 500 kV Power Transmission Project was proposed in 2009 and aimed to construct 220 km of high voltage lines between Java and Bali.[36] Portions of the alignment were adjacent to two national parks with possible impacts to wildlife and thus required installation of safeguards. Two primary safeguards were considered: reduce air pollution and fund a conservation program for a critically endangered bird, the Bali starling. A cost-benefit analysis was conducted to assess the monetary costs and benefits resulting from the implementation of the environmental safeguards. The analysis was done in the four steps below (all calculations were done considering a time horizon of 10 years):

1. Calculation of the Net Present Value taking into account the financial costs and benefits of the project
2. Quantification of the negative externalities resulting from the project in monetary terms
3. Calculation of the benefits associated with two environmental safeguards
4. Combination of all values to calculate an adjusted Net Present Value of the project

Bali starling

The economic analysis showed that the selected safeguards in the Java-Bali 500 kV Project created a positive Net Present Value, meaning that the project was financially feasible when safeguards were implemented. This Indonesian case study used a rigorous CBA, one that was incorporated into the project's feasibility study. It determined that environmental safeguards not only protect environmental and wildlife values, but added to the infrastructure project's overall Net Present Value.

This project demonstrates that a more balanced accounting by a CBA, one that incorporates safeguard benefits, must be used in project economic analyses so that wildlife safeguards are not considered only as project costs. Equally important, the type of CBA conducted for this project is replicable, and can be used for LI projects, both in Indonesia and throughout Asia. *See Annex 2, Case Study 7.*

Examples of Ecosystem Services

Provisioning: Food, water, fiber, fuel, and other goods

Regulating: Climate, disease, and pollination

Supporting: Nutrient cycling and soil formation

Cultural: Recreation, tourism, and cultural heritage

Grey heron,
Tadoba National Park, India.
Credit: Gregoire Dubois

Federal Route 4, East-West Highway (Malaysia)

The 307-km Federal Route 4 connects Peninsular Malaysia's east and west coasts, traversing key elephant and tiger habitats.[37] This highway project, completed in 2005, was the subject of two economic analyses as part of a national Master Plan to create several ecological corridors. Many elephants and tigers utilized habitat bisected by this stretch of highway to move between a forest reserve and a state park, but the road fragmented their habitat and created a barrier. To address this problem, the Master Plan identified three mitigation measures:

1. Acquisition of lands surrounding both parks to expand connectivity between them and reduce human-wildlife conflict
2. Creation of wildlife crossings, wildlife warning signs, and speed limits
3. Establishment of guidelines for sustainable agriculture management in the area

The economic analysis showed that the benefits from the three safeguard measures were greater than their costs. This gave a strong economic signal that the implementation of such measures was cost effective, not just good for conservation.

Unfortunately, the wildlife safeguards were not completely implemented as the cost of their deployment was to be paid by local governments, not by the federal department that created the Master Plan and its CBA. As a result, an adjusted version of the plan is being developed and should be released at the end of 2021.

This case study demonstrates the importance of conducting a thorough cost-benefit analysis of environmental safeguards. By comparing the costs to the benefits of implementing safeguards and factoring in avoided costs—such as those associated with human-wildlife conflict—the authors were able to show that the proposed mitigation measures would result in positive gains to society.
See Annex 2, Case Study 8.

Road through a tiger reserve in the Terai Arc Landscape, India.
Credit: Shiv Marwaha

ASIA'S CAPACITY TO ADDRESS THE IMPACTS OF LINEAR INFRASTRUCTURE ON WILDLIFE

Throughout Asia, the expansion of LI coupled with increasing traffic volume is impeding species' movement, increasing direct wildlife mortality due to collisions with vehicles and trains, and degrading critical habitats by fragmenting ecosystems. Similarly, increases to power line networks heighten the risk to birds and forest- and canopy-dwelling species and their habitats.

As the LI construction boom continues, developing Asia will need to increase its capacity to safeguard wildlife from the effects of new and expanding infrastructure. LI proponents, builders, and other stakeholders will not be able to properly select, design, and apply effective wildlife safeguards in the absence of suitable WFLI laws, policies, technical information, and workforce training. To target capacity-building efforts where they are most needed, it is important to understand both the existing capacity and the current challenges for funding, planning, and implementing safeguards. By identifying opportunities for additional engagement in the project development process, and specific training needs both within and across constituent groups, a more robust capacity-building program can be developed.

Bornean elephant on the shores of the Kinabatangan River, Borneo, Malaysia. Credit: Gregoire Dubois

CONSTITUENT GROUPS INVOLVED IN LINEAR INFRASTRUCTURE DEVELOPMENT

Four primary constituent groups are engaged in LI development:

Government Agencies: Government agencies—specifically, transportation, energy, and environmental or conservation agencies—all play a role in the implementation of wildlife safeguards for LI. Governments set policy related to safeguard requirements, and typically make decisions regarding permitting and LI siting.

International Financial Institutions (IFIs): IFIs provide funding for LI projects, typically in the form of loans. IFIs often have environmental and social safeguards that borrowing countries must adhere to. While there are many other types of funders that provide aid or loans for infrastructure, this project focused on a suite of lenders that operate in multiple Asian countries and regions.

Industry: Industry includes infrastructure planners, engineers, and builders, or the people who are on the ground and responsible for constructing infrastructure and implementing safeguards. Industry may include environmental impact assessment (EIA) consultants, who are responsible for evaluating potential impacts and recommending appropriate mitigation measures.

Non-governmental Organizations (NGOs): NGOs that focus on wildlife conservation may have data on wildlife or habitat that can illuminate the potential impacts of LI projects in a given area. Community-focused NGOs deal with some of the more localized issues related to LI, such as impacts to community forests or sites of high cultural value. NGOs may also follow the development and construction of LI to ensure accountability regarding whether safeguards are implemented.

THE LI PROJECT DEVELOPMENT PROCESS

The LI Project Development Process consists of seven key phases (Figure 9). Opportunities to include wildlife safeguards arise in all seven phases (Table 1):

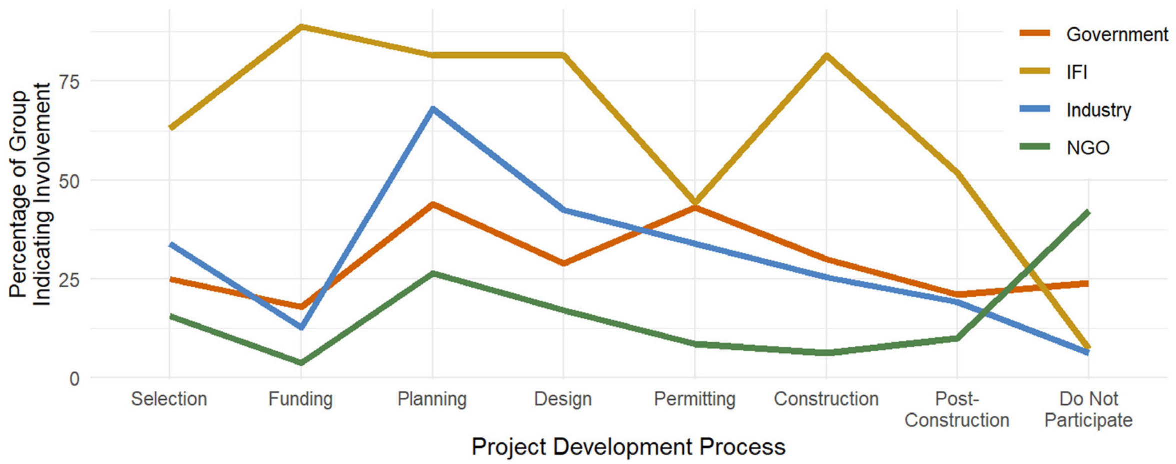
Figure 9: The Project Development Process

Table 1: Wildlife Safeguard Opportunities in the Project Development Process

Project Phase	Wildlife Safeguard Opportunities
1. Selection	Avoid selecting projects that pass through important wildlife areas.
2. Funding	Include funding for wildlife safeguards in the project budget and require safeguard standard compliance.
3. Planning	Conduct EIA and collect or review wildlife data to understand potential impacts to species.
4. Design	Evaluate mitigation options and choose designs that are effective for impacted species.
5. Permitting	Ensure that sufficient information is provided to acquire proper permits for wildlife impacts.
6. Construction	Utilize best practices to minimize construction impacts to wildlife, such as noise, pollution, and poaching.
7. Post-Construction	Monitor wildlife post-construction to evaluate mitigation effectiveness.

The four constituent groups vary in levels of involvement throughout the project development process (Figure 10). The project's survey of more than 300 respondents from five representative Asian countries found that IFIs have the most involvement through all phases, while NGOs have the least. Government agencies are more involved during the planning and permitting phases, while industry is most involved in planning. Given that industry should also be a key player in design and construction, the survey likely did not reach respondents from firms providing those services.

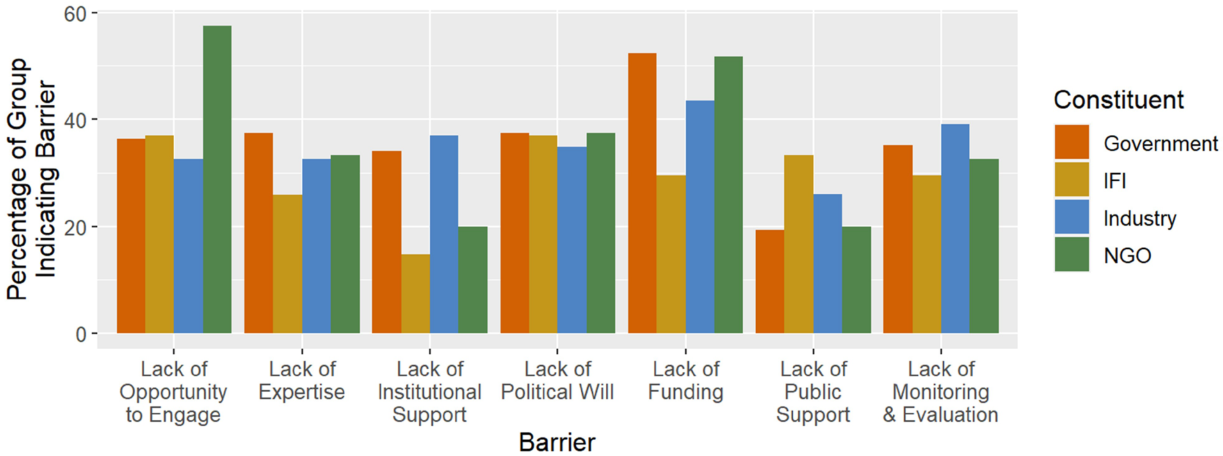
Figure 10: Constituent Group Involvement in the Project Development Process



BARRIERS TO IMPLEMENTING WILDLIFE SAFEGUARDS FOR LI

Results from the LISA project's survey found that all four constituent groups agreed that barriers to implementing wildlife safeguards for LI arise most often in the planning, construction, and design phases of the project development process. Specifically, the lack of knowledge regarding proper design and engineering techniques for mitigation options was selected as a key barrier (Figure 11). Two additional barriers include a lack of funding for wildlife safeguards, as well as a lack of political will and institutional support. The lack of political will for non-economic goals or institutional support for WFLI is commonplace in the developing world and is likely to continue to be a barrier unless countries encourage green infrastructure as the norm to meet both development and biodiversity commitments.

Figure 11: Barriers to Implementing Wildlife Safeguards for LI



POLICY FOR WILDLIFE SAFEGUARDS

National policy provides an important opportunity for countries to institutionalize best practices regarding wildlife safeguards for LI. One use of policy at the national level is the formalization of a country's commitment as a signatory to international multilateral environmental agreements (MEAs) that govern the conservation of terrestrial and freshwater environments. Generally, countries in Asia have a very high level of participation in key international MEAs such as the Convention on Biological Diversity and the World Heritage Convention. However, only 12 of the 28 countries are parties to the Convention on Migratory Species (CMS), which is the only global convention that specializes in the conservation of migratory species, their habitats, and migration routes. Given that LI can be especially impactful to these species, becoming a signatory to the CMS could create an opportunity to enhance national policy regarding landscape connectivity for wildlife.

Wildlife safeguards can also be institutionalized through their inclusion in national laws or guidelines regarding roads, railways, power lines, and EIAs (Table 2). Currently, either laws or guidelines regarding wildlife safeguards with respect to roads are prevalent in the most countries (21), followed by rails (17), and then power lines (14). Laws or guidelines that include provisions requiring wildlife safeguards are also prevalent within the majority of Asian countries (22), providing an important starting point for future provisions that focus specifically on safeguarding wildlife from the impacts of LI.

Table 2: National Laws and Guidelines Regarding Biodiversity Protection and Linear Infrastructure Modes or Environmental Impact Assessment

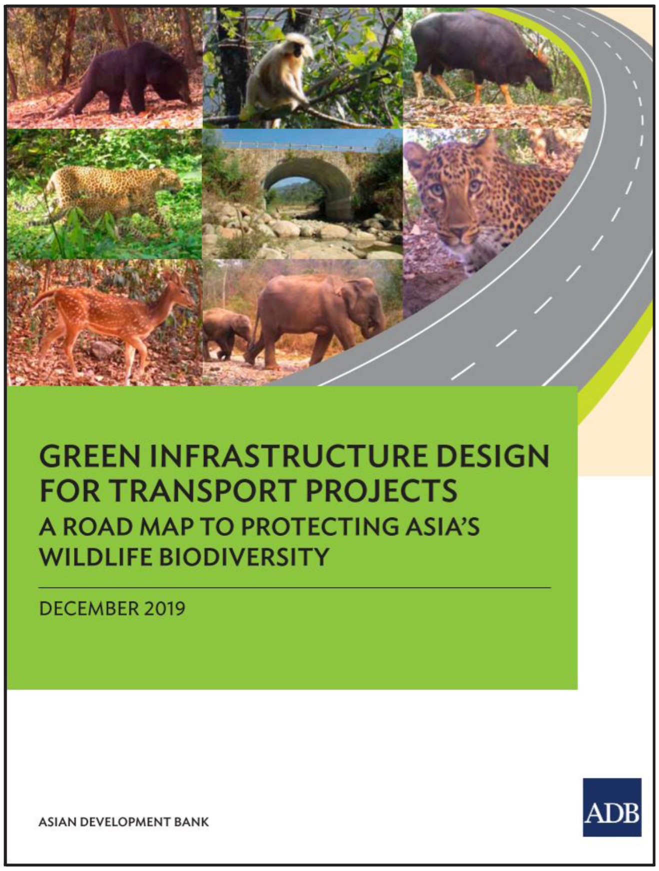
COUNTRY	EIA		ROAD		RAILWAY		POWER LINE		SCORE
	Laws	Guidelines	Laws	Guidelines	Laws	Guidelines	Laws	Guidelines	
India	Included	Included	Included	Included	Included	Included	Included	Included	8
Japan	Included	Included	Included	Included	Included	Included	Included	Included	8
Mongolia	Included	Included	Included	Included	Included	Included	Included	Included	8
South Korea	Included	Included	Included	Included	Included	Included	Included	Included	8
Tajikistan	Included	Included	Included	Included	Included	Included	Included	Included	8
Bangladesh	Included	Included	Included	Included	Included	Included	Included	Included	8
Malaysia	Included	Included	Included	Included	Included	Included	Included	Included	8
Timor-Leste	Included	Included	Included	Included	Included	Included	Included	Included	8
Turkmenistan	Not Included	Included	Included	Included	Included	Included	Included	Included	7
Nepal	Included	Included	Included	Included	Information Unavailable*	Included	Included	Included	7
China	Included	Included	Included	Included	Included	Included	Information Unavailable*	Information Unavailable*	6
Uzbekistan	Included	Included	Included	Included	Included	Included	Information Unavailable*	Not Included	6
Bhutan	Included	Included	Included	Included	Information Unavailable*	Information Unavailable*	Not Included	Included	5
Afghanistan	Included	Included	Information Unavailable*	Included	Included	Included	Information Unavailable*	Not Included	5
Kazakhstan	Included	Likely Included	Included	Likely Included	Included	Likely Included	Information Unavailable*	Likely Included	5
Brunei	Included	Included	Not Included	Included	Not Included	Not Included	Not Included	Included	4
Sri Lanka	Included	Included	Not Included	Included	Not Included	Included	Information Unavailable*	Information Unavailable*	4
Pakistan	Included	Information Unavailable*	Included	Information Unavailable*	Included	Information Unavailable*	Included	Information Unavailable*	4
Thailand	Included	Information Unavailable*	Included	Information Unavailable*	Included	Information Unavailable*	Included	Information Unavailable*	4
Cambodia	Not Included	Included	Included	Not Included	Not Included	Not Included	Information Unavailable*	Not Included	2
Indonesia	Not Included	Information Unavailable*	Included	Included	Not Included	Information Unavailable*	Information Unavailable*	Information Unavailable*	2
Vietnam	Included	Not Included	Not Included	Not Included	Information Unavailable*	Not Included	Not Included	Not Included	1
Singapore	Not Included	Included	Information Unavailable*	Information Unavailable*	Information Unavailable*	Information Unavailable*	Information Unavailable*	Information Unavailable*	1
Myanmar	Not Included	Not Included	Not Included	Not Included	Not Included	Not Included	Not Included	Not Included	0
Laos	Not Included	Information Unavailable*	Information Unavailable*	Information Unavailable*	Information Unavailable*	Information Unavailable*	Information Unavailable*	Information Unavailable*	0
Kyrgyzstan	Information Unavailable*	Information Unavailable*	Information Unavailable*	Information Unavailable*	Information Unavailable*	Information Unavailable*	Information Unavailable*	Information Unavailable*	0
North Korea	Information Unavailable*	Information Unavailable*	Information Unavailable*	Information Unavailable*	Information Unavailable*	Information Unavailable*	Information Unavailable*	Information Unavailable*	0
Philippines	Information Unavailable*	Information Unavailable*	Information Unavailable*	Information Unavailable*	Information Unavailable*	Information Unavailable*	Information Unavailable*	Information Unavailable*	0
Total	**19**	**18**	**18**	**17**	**15**	**14**	**12**	**12**	

KEY	Included	Likely Included	Not Included	Information Unavailable*

* Information regarding laws for all countries is not easily available online in English. Gray squares do NOT mean that a country does not have legal provisions.

THE ROLE OF FINANCIERS AND THEIR SAFEGUARD POLICIES

Much of developing Asia's infrastructure is funded through loans from IFIs or other regional economic bodies. IFIs tend to have environmental and social safeguards systems in place that are based on and aligned with the World Bank Group's Performance Standard 6. Currently, IFIs have not developed formal wildlife safeguards standards that are specific to roads, rails, or power lines, although some have developed voluntary guidance documents regarding infrastructure. For example, the Asian Development Bank published *Green Infrastructure Design for Transport Projects: A Road Map to Protecting Asia's Wildlife Biodiversity* in 2019,[38] and the World Bank supported the Wildlife Institute of India in developing a guidance manual, *Eco-friendly Measures to Mitigate Impacts of Linear Infrastructure on Wildlife*, in 2016.[39] Most IFIs also refer to the World Bank's Environmental, Health, and Safety Guidelines, which are a collection of voluntary guidelines that provide industry-specific examples of best practices across many sectors of development.



When providing a loan, IFIs typically require compliance with their own safeguard policy, or they default to the policy of the borrowing country. Some of the larger IFIs also reinforce safeguard compliance through additional support in the form of technical assistance or training and make efforts to ensure that the borrower's safeguard policies are aligned with their own. However, some of the newer IFIs are only just beginning to provide these additional tools; in the past, they relied on the borrowing country to provide the capacity to implement safeguards. For example, financing related to China's BRI encourages voluntary green development and provides some limited resources and guidance for implementing safeguards, but the burden of cost, training, follow-through, and monitoring falls to the borrowing country.

IFC PS 6 - Biodiversity Conservation and Sustainable Management of Living Natural Resources

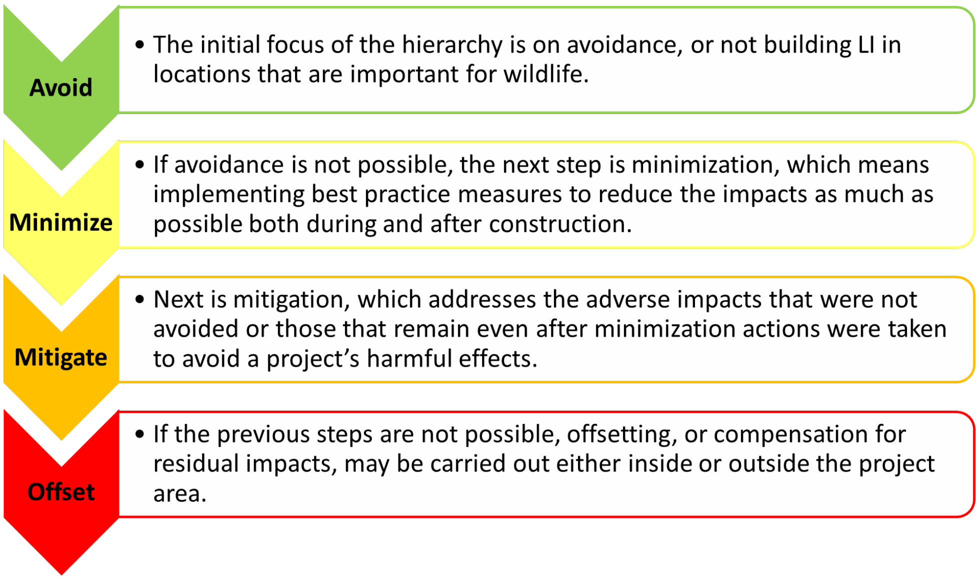
Performance Standard (PS) 6 recognizes the relevance of biodiversity, ecosystem services, and living natural resources in sustainable development. It is applicable in the environmental and social risks and impacts identification process. The requirements are applied to projects in modified, natural, and critical habitats; or with potential impact or dependence on ecosystem services under the client's management or influence; or that include living natural resource production (agriculture, animal husbandry, fisheries, forestry).

PLANNING AND DESIGNING WILDLIFE SAFEGUARDS

Asia has more than 30 professional associations that represent the road, railway, and energy-transmission sectors, as well as civil engineers. These professional associations engage in many different capacity-building activities, including workforce training, webinars, publications, conferences, and other technical resources. Currently, capacity building specifically related to WFLI safeguards is extremely rare among these institutions. However, industry respondents to the project's survey indicated a high level of willingness to incorporate wildlife safeguards into the design and construction of LI projects; they were also largely aware of the mitigation hierarchy (Figure 12). Industry respondents also indicated a high level of interest in receiving training regarding both the LI impacts to ecosystems and effective design principles for mitigation measures. Additionally, there is a lack of incentives such as awards or other public recognition systems for firms that do implement best management practices regarding wildlife safeguards. Since the implementation of such safeguards is governed by guidance and thus is mostly voluntary, additional incentives may be necessary for industry to be willing to incur any extra costs associated with implementing WFLI.

Figure 12: The Mitigation Hierarchy

The mitigation hierarchy is a simple framework for LI proponents to follow to achieve no net loss of environmental value during and after construction.



* Some versions of the hierarchy also include rehabilitation or restoration as a distinct step between mitigation and offsetting.

Globally, there are numerous resources regarding specific design principles for WFLI. Countries in other continents have technical handbooks for wildlife crossing designs, other types of technical design guidelines, engineering requirements for mitigation measures such as overpass or flyover structures, national transportation agency support for workforce training, and platforms for gathering and sharing data such as for wildlife-vehicle collisions. As developing Asia furthers its capacity, it too will need to develop such support and technical information for its unique species and ecosystems.

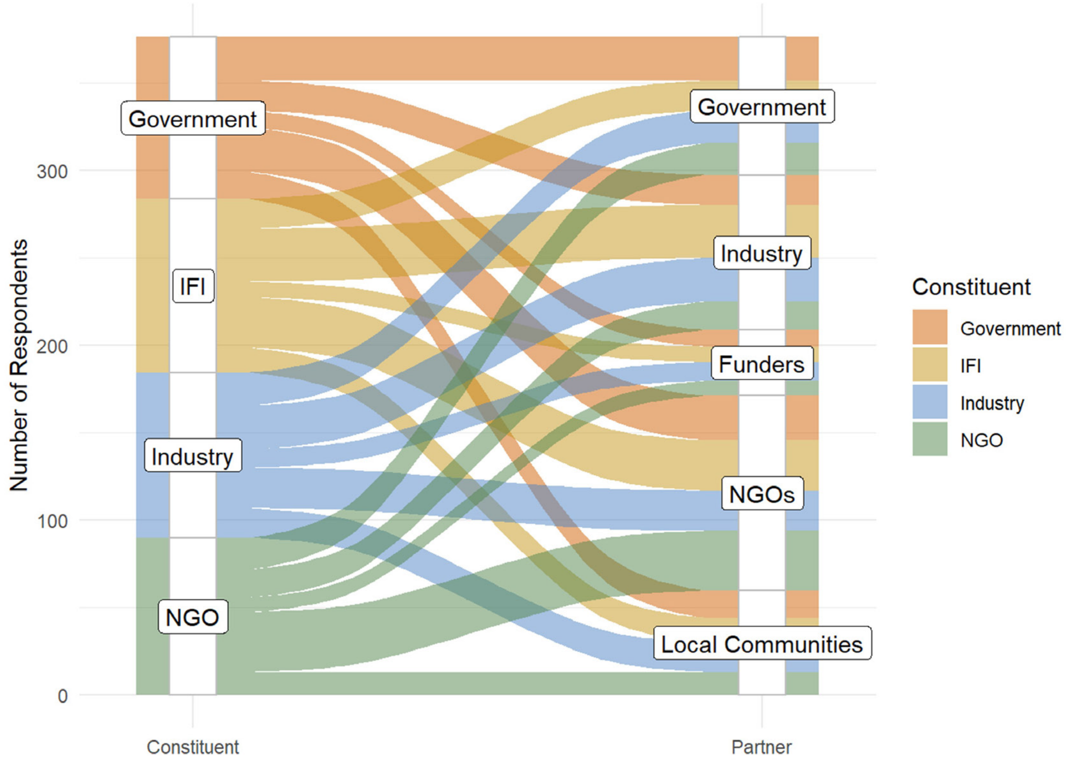
CONSERVATION NGOs AND LI

Conservation or wildlife-focused NGOs working at both the national and international level in Asia consider the impacts that LI can have on wildlife to be a high priority for their organizations, and many of them address LI in their work. However, addressing the impacts of LI is not commonly institutionalized; out of 11 of the largest international NGOs working in Asia who were interviewed for the LISA project, only two have programs dedicated to LI. Instead, NGOs tend to address LI within other programs, support current staff in learning more about LI on an as-needed basis, or work with external partners. Of the four constituent groups, NGO survey respondents reported being the least involved in the project development process; when they do engage, NGOs tend to participate most by conducting general advocacy for wildlife protection and collecting pre-construction data—tasks which many NGOs tend to do anyway. NGOs felt that the main barriers to participating in the project development process were funding and expertise, and thus indicated a high level of interest in training and opportunities to partner with other constituent groups.

COLLABORATION BETWEEN CONSTITUENT GROUPS

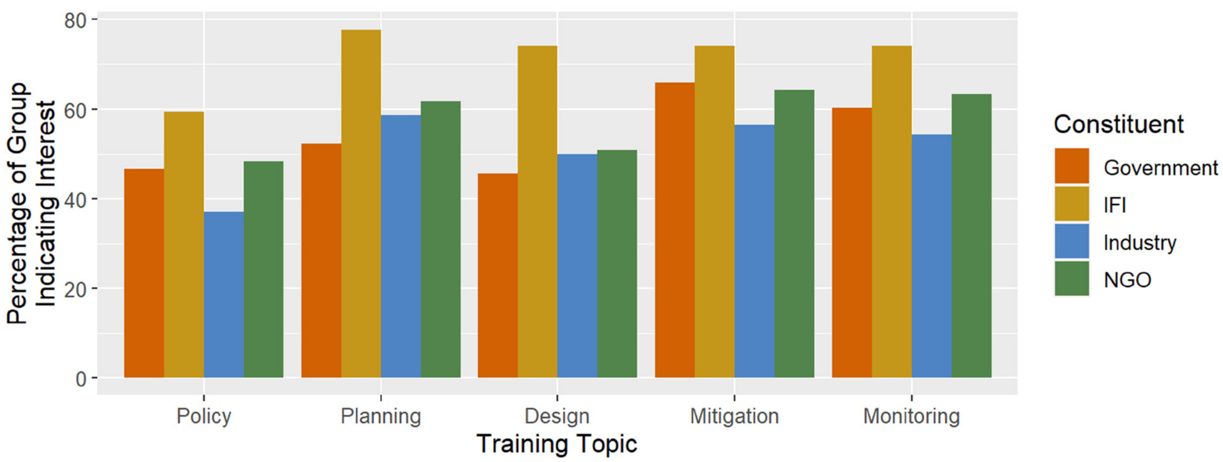
All four constituent groups are highly interactive with one another throughout the project development process (Figure 13). While survey respondents from all four groups indicated that they partner with their own constituent group with the highest frequency, partnerships with other constituent groups are also common. Respondents indicated that governments partner often with NGOs and sometimes industry, IFIs work heavily with both industry and NGOs, and industry works equally with government and NGOs. NGOs overwhelmingly partner with other NGOs, but also work some with industry and government. IFIs were partnered with the least often, despite reporting the highest level of involvement throughout the project development process, indicating that other constituent groups might not fully understand the role of IFIs.

Figure 13: The Number of Respondents From Each Constituent Group (left) that Report Working With Each Type of Partner (right)



While the constituent groups each have different roles and responsibilities during the project development process, a common understanding of safeguard requirements is important for the successful implementation and monitoring of WFLI mitigation measures. All constituent groups are interested in working with external partners and engaging in cooperative training opportunities. A high interest in future training was indicated across all groups, in topics such as policy, planning, design, mitigation, and monitoring (Figure 14). Trainings that bring all constituent groups into the same room not only provide an opportunity to break down the silos between groups, but also ensure that all constituent groups are building from the same general knowledge base, paving the way for easier collaboration in the future.

Figure 14: Interest in Training Topic by Constituent Group



Bengal tiger, Tadoba National Park, India.
Credit: Gregoire Dubois

A PATH FORWARD

As Asian nations advance their LI systems, it is imperative that they also foster their capacity to safeguard their richly biodiverse landscapes. These safeguards will take many forms, such as more protective laws and policies, better coordination among national and regional infrastructure and wildlife agencies, improved designs from planning consultants and construction firms, and enhanced collection and use of pre-construction and post-construction wildlife data. The region has many exemplary WFLI projects that use global best practices; unfortunately, these have not been institutionalized in many countries nor become standard practice throughout the region. This report has found there are many willing participants, LI proponents, developers, and stakeholders in Asia who want to learn more about the essentials in protecting wildlife, while at the same time providing for the safe and efficient movement of goods, energy, and people. Agencies, funders, private firms, consultants, conservationists, and community groups are all eager to gain access to workforce training, technical information, case studies, and smart policies that will help enhance their performance to successfully meet international standards and practices. What follows are key findings from this report, alongside actionable recommendations to build Asia's capacity to implement wildlife safeguards for linear infrastructure.

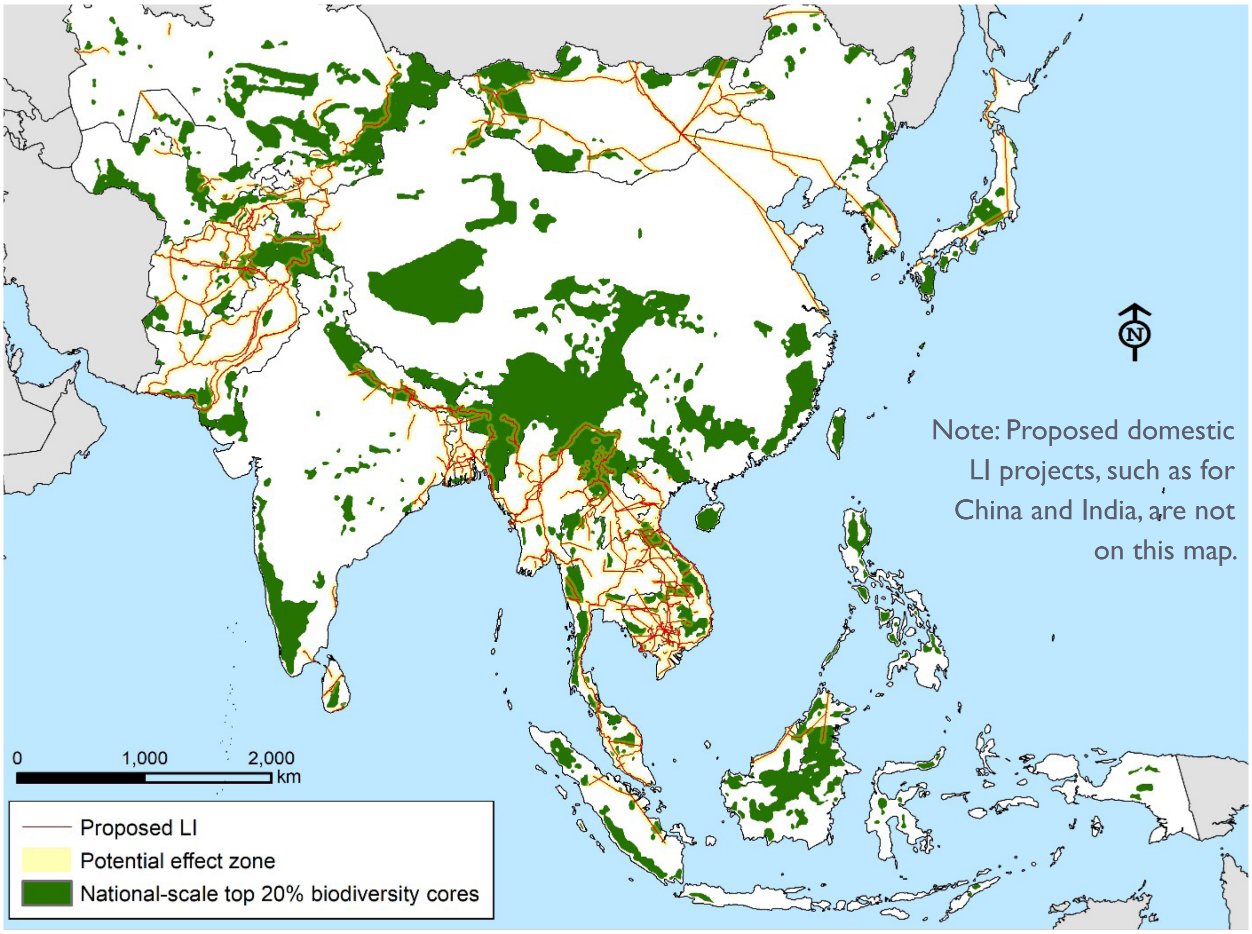
PROPOSED LINEAR INFRASTRUCTURE WILL PASS THROUGH SOME OF ASIA'S MOST BIODIVERSE LANDSCAPES

Asia contains some of the most biodiverse landscapes in the world, but this biodiversity faces a growing threat from rapidly expanding LI. Spatial analyses, or explorations of problems through a geographic lens, can characterize the location and severity of LI impacts to biodiversity. One component of this analysis used information from nine biodiversity datasets to map consensus areas of high biodiversity value ("cores") at the national, regional, and continental scales. Another component of the analysis compiled spatial data on proposed LI development projects associated with international development initiatives in Asia (but excluding national LI programs), including more than 81,000 km of future road, railway, and power line projects. The analysis revealed extensive overlap between proposed LI routes and biodiversity cores (Figure 15). Up to 20 percent of the total biodiversity core areas, as well as 363 protected areas, are located within 25 km of the proposed LI routes. *See Annex 1*.

RECOMMENDATION

Spatial analyses are often conducted after LI construction is completed, making them less useful for designing appropriate wildlife safeguards. Compiling high-quality spatial data on proposed LI and analyzing overlap with important biodiversity areas in advance of construction are crucial to understanding potential threats. Additionally, the mapping of the most biodiverse landscapes in Asia at the national, regional, or continental scale provides LI proponents, financiers, and planners with the information needed to apply the first option in the mitigation hierarchy: avoid areas of greatest LI-biodiversity conflict.

Figure 15: Overlap Between Proposed New Linear Infrastructure and Biodiversity Hotspots



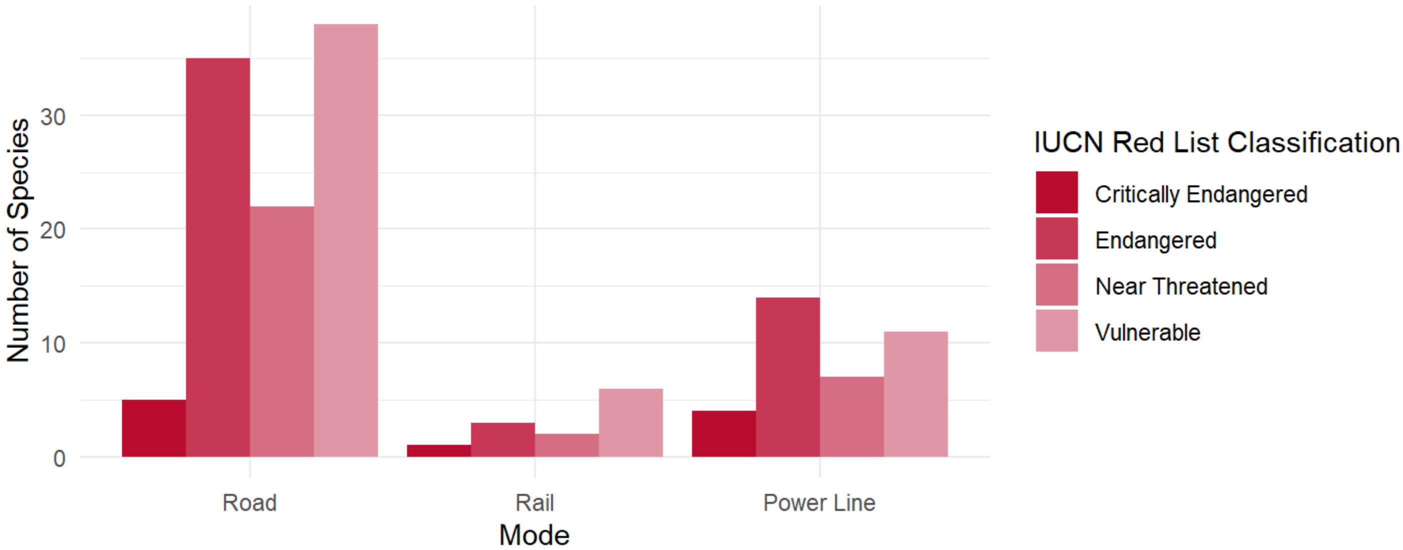
Wildlife underpass under construction on National Highway (NH) 44 in Maharashtra, India. Credit: Rob Ament

ROADS, RAILWAYS, AND POWER LINES ARE KILLING THREATENED SPECIES ACROSS ASIA

The most common direct effect of LI on wildlife studied in Asia is animal mortality caused by collisions (Figure 16). This type of direct effect not only has severe consequences for individual animals, but also for entire populations, jeopardizing species' survival. Many types of Asian species are impacted, including mammals, birds, amphibians, reptiles, and invertebrates.

To date, roads are the most studied of the three transportation modes evaluated in this project, and studies documented more than 100 species from the IUCN Red List of Threatened Species™ that have been killed as the result of animal-vehicle collisions on roads. Reports on Asian power line collisions that cause mortality indicated 36 different listed species affected (mostly birds) and studies of railway strikes of wildlife identified 12 species from the IUCN Red List. The low number of documented railway collisions is likely due to the lack of published papers on the subject. Thus, as more studies are conducted on all three modes, the number of species impacted could increase substantially.

Figure 16: The Number of IUCN Red List Species Documented as Killed by Collisions on Roads and Rails, or with Power Lines in Asia



Underpass for elephants, tigers, and other wildlife on the Jeli-Gerik Highway, Malaysia. Credit: Rob Ament

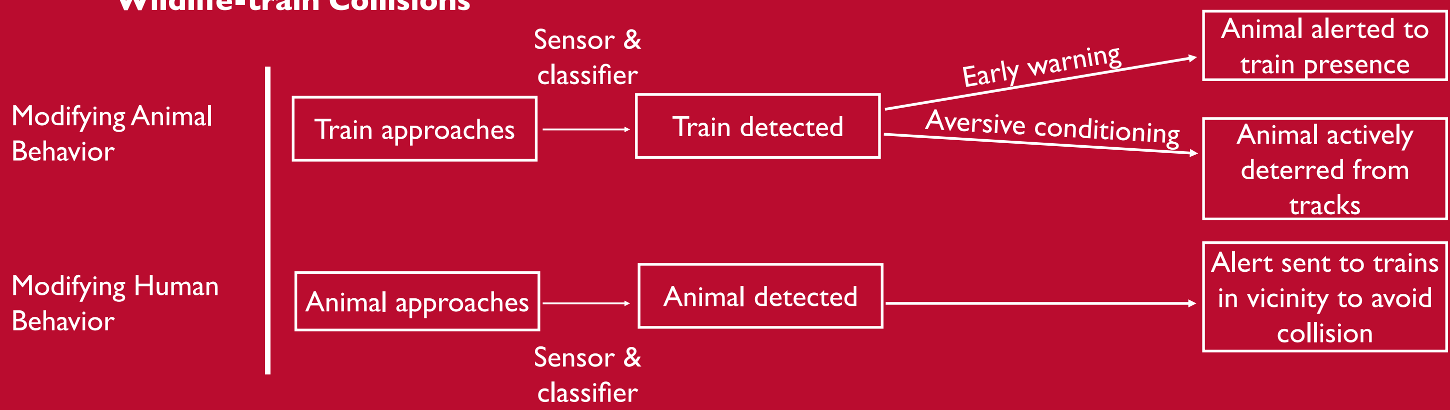
RECOMMENDATION

Well-known, effective measures exist that protect wildlife from collisions with vehicles and trains, while at the same time providing for habitat connectivity. Wildlife crossing structures are the most studied of the mitigation measures deployed in Asia and include physical structures such as underpasses or tunnels, and overpasses or bridges, that allow animals to cross safely below or above the road or railway. Additionally, Asia is home to multiple flyovers, where the entire highway or railway is elevated above the ground for distances from 1 km to 10 or more, which allow a variety of species to safely pass underneath. Further research is needed to understand what type of structure is most effective for threatened species across Asia, and to consider the role of emerging mitigation technologies.

Emerging Technologies

Technology-based animal-vehicle collision reduction measures (e.g., animal detection systems using lidar, radar, or microwaves) have been implemented in other parts of the world and are increasingly recommended for investigation in Asia (Figure 17). However, very few reports exist that have evaluated any of these techniques on the continent. More testing of potential technological solutions, under realistic field conditions, would help assess their effectiveness, costs, and benefits under conditions found in Asia.

Figure 17: The Conceptual Mechanism Underlying Technology-based Mitigation of Wildlife-train Collisions



COST-BENEFIT ANALYSES TYPICALLY ONLY CONSIDER THE COSTS OF MITIGATION, NOT THE BENEFITS

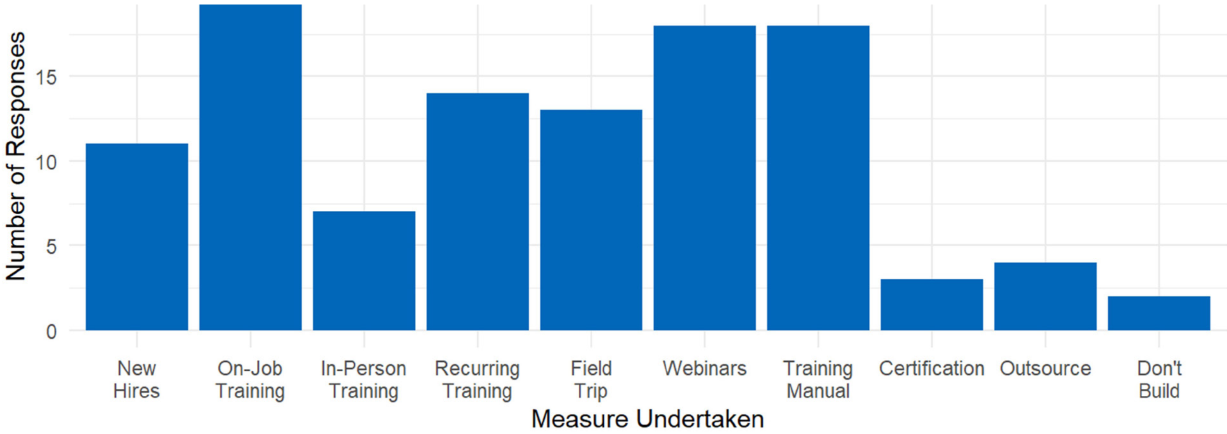
Mitigation is nearly always considered a cost in the economic analysis of infrastructure projects, while the valuation of wildlife and their habitat, and thus the benefit of protecting them, is rarely considered. To understand the full economic picture of potential projects, CBAs of the mitigation measures used for roads, rails, and power lines need to become standard practice. This type of analysis is predicated on the availability of passive use economic valuations—or measurements of intrinsic or indirect value—of Asia's wildlife, which have many gaps and shortcomings. However, it is often important that LI decision-makers more fully understand and articulate the economic benefits of mitigation measures—for example, building a wildlife overpass—not just the costs of their deployment and maintenance.

RECOMMENDATION

Economic analyses can show that wildlife safeguards for LI do not represent only costs, but also generate benefits to society in terms of species and habitat conserved, as well as avoided costs. CBAs should be included in any feasibility study of LI projects. Such economic analysis can demonstrate the importance of accounting for the indirect costs of LI development, especially to parties not directly related to the project such as local communities. A rigorous CBA—one that is incorporated into a project's evaluation—can demonstrate that wildlife safeguards for LI not only protect environmental and wildlife values, but also can add to an infrastructure project's overall Net Present Value, or the success of the investment.

The Wubei Underpass allows for Tibetan antelope to pass underneath the railway on the Tibetan Plateau, China.
Credit: Wenjing Xu

Figure 18: The Number of Respondents of the IFI Constituent Group that Identified the Various Measures Adopted by IFIs to Build Capacity Internally



INTERNATIONAL FINANCIAL INSTITUTIONS CAN PLAY AN IMPORTANT ROLE IN IMPLEMENTING WILDLIFE SAFEGUARDS

Most of the IFIs already have internal capacity to address wildlife safeguards through such means as providing workplace training, webinars, and manuals (Figure 18). They have supported some efforts to build capacity in other constituent groups, such as by funding workshops attended by government and industry personnel. However, such external capacity-building support is primarily conducted on a project-by-project basis. IFIs were found to be harmonizing their LI development to better incorporate conservation and community values, such as by developing larger landscape assessments (e.g., Strategic Environmental Assessments). China's multilateral banks and its BRI are just beginning to ramp up capacity building to address WFLI. Currently, China's development efforts tend to default to the safeguard laws of the recipient countries, and most often rely on these countries to pay for and implement their own wildlife safeguards and WFLI capacity-building efforts.

RECOMMENDATION

IFIs can play a key role in future WFLI capacity building in Asia. Concurrent with their harmonizing infrastructure development with the conservation of biodiversity, IFIs could provide long-term funding for regional advisory and stakeholder groups to engage with IFIs and other constituent groups responsible for LI development in Asia.

Currently, there are many gaps in knowledge regarding the impacts of LI projects on a variety of Asian species and ecosystems, as well as the effectiveness of potential solutions such as mitigation measures. Therefore, for future LI projects, IFIs should develop LI project budgets that include sufficient contingency funding provisions to meet unforeseen wildlife safeguard needs and monitor their effectiveness.

In the future, China's BRI and other international LI initiatives, in cooperation with their implementing IFIs, should provide adequate funding to build WFLI capacity internally, and for the various constituent groups' members in recipient countries of initiative projects.

BARRIERS TO IMPLEMENTING WILDLIFE SAFEGUARDS ARISE THROUGHOUT THE PROJECT DEVELOPMENT PROCESS

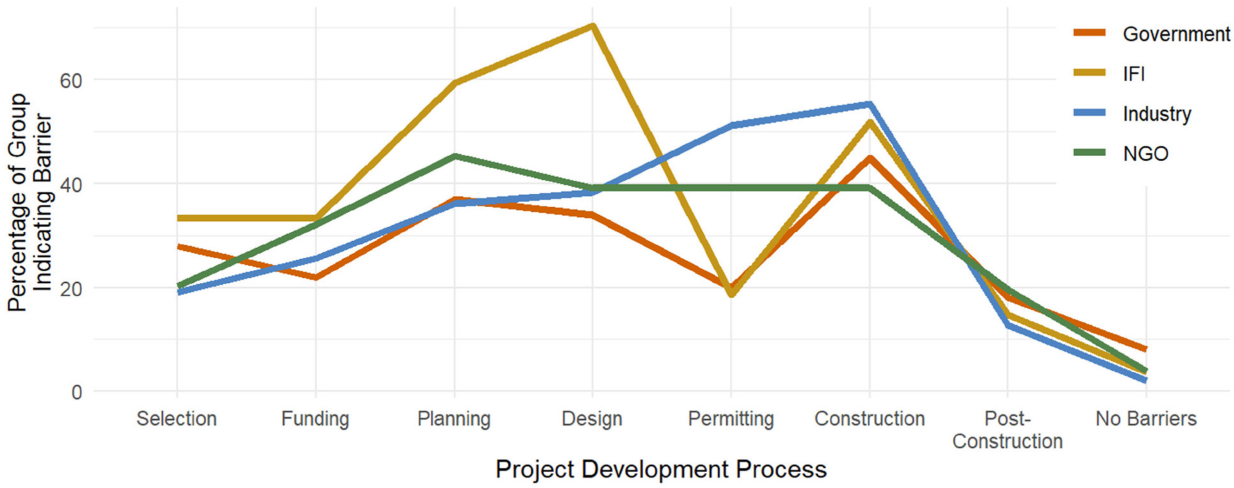
The project development process for LI projects typically consists of seven phases: Project Selection, Funding, Planning, Design, Permitting, Construction, and Post-Construction. Of these phases, survey respondents from the five representative countries identified three primary points where barriers to implementing WFLI typically arise: Planning, Design, and Construction (Figure 19). The four constituent groups identified funding, political will, institutional support, and the lack of expertise as the four greatest barriers to implementing wildlife safeguards.

RECOMMENDATION

Regardless of constituent group, 86 percent of the survey respondents are overwhelmingly interested in training opportunities for safeguarding wildlife from LI impacts. However, different constituent groups prefer different types of training to increase their expertise in providing WFLI safeguards:

- IFIs and NGOs have the highest preference for webinars (short, one-hour online training sessions) and workshops (multi-day trainings).
- Workshops combined with field trips are preferred more often by government agencies and NGOs.
- IFIs and NGOs see the most merit in the existence of a central clearinghouse of information (i.e., online library, case studies, design guidelines, etc.).
- All four constituent groups ranked online, university-level courses with continuing education credits or certificates as their least preferred option.

Figure 19: The Percentage of Respondents, by Constituent Group, Indicating Specific Phases of the Project Process that Contain Barriers to Implementing Wildlife Safeguards



Members of the IUCN Asian Elephant Transport Working Group visit an underpass on the Jeli-Gerik Highway, Malaysia. Credit: Aaron Laur

GOOD DATA IS CRUCIAL TO UNDERSTANDING THE POTENTIAL IMPACTS OF LINEAR INFRASTRUCTURE TO WILDLIFE

Spatial analyses of threats to biodiversity from proposed LI are currently constrained by limited availability and quality of data. Spatial data on LI project routes have generally not been systematically compiled in spatial databases, and this information often must be cobbled together opportunistically by project developers, consultants, researchers, and other interested parties using planning documents and media reports. While many different types of biological data can help assess risks to species and habitat from LI development, these data are often not collected until after LI route location and construction decisions have been made, thus forgoing the opportunity for avoiding or reducing LI impacts.

This project found that existing spatial analyses of future LI impacts to biodiversity have largely focused on South and Southeast Asia because of these regions' rapid LI development and high biodiversity value, but this narrow geographic focus limits understanding of potential LI impacts to biodiversity in other regions of Asia. Also, it found that while existing analyses on environmental impacts at the global or continental scales have focused largely on LI projects associated with China's BRI, proposed LI funded by other regional economic development initiatives is also extensive across Asia.

Elephant tracks observed near the construction site of a wildlife underpass in Bangladesh. Credit: Asif Imran

RECOMMENDATION

Limitations to existing spatial analyses should be addressed and improved through the following actions: (1) Financial institutions, regional infrastructure partnerships, and governments need to dedicate resources to create and maintain geospatial databases of proposed LI projects. (2) Biodiversity baseline assessments and related spatial analyses should be conducted as early as possible in the planning and design phase of LI projects to ensure that WFLI safeguards are informed by best practices. (3) LI planners, funders, and developers should partner with transport ecologists and other subject matter experts from academia, NGOs, and wildlife agencies more frequently to design studies, collect data, and conduct analyses to inform WFLI safeguard recommendations. (4) The geographic and taxonomic scope of spatial analyses could be expanded to include more Asian regions other than Southeast and South Asia and taxa other than large mammals. (5) All sources of LI projects—BRI, other international economic development initiatives, and national- and subnational-funded projects—should be combined in large-scale spatial analyses evaluating impacts to biodiversity. (6) Post-construction evaluations of WFLI safeguards could help future project designs by using an adaptive management approach, where lessons learned from the monitoring of past projects inform and improve future projects.

Wildlife underpass designed primarily for elephant passage on the NH2 road (Raidak-Lhamoizingkha) in Bhutan. Credit: Karma Chogyel

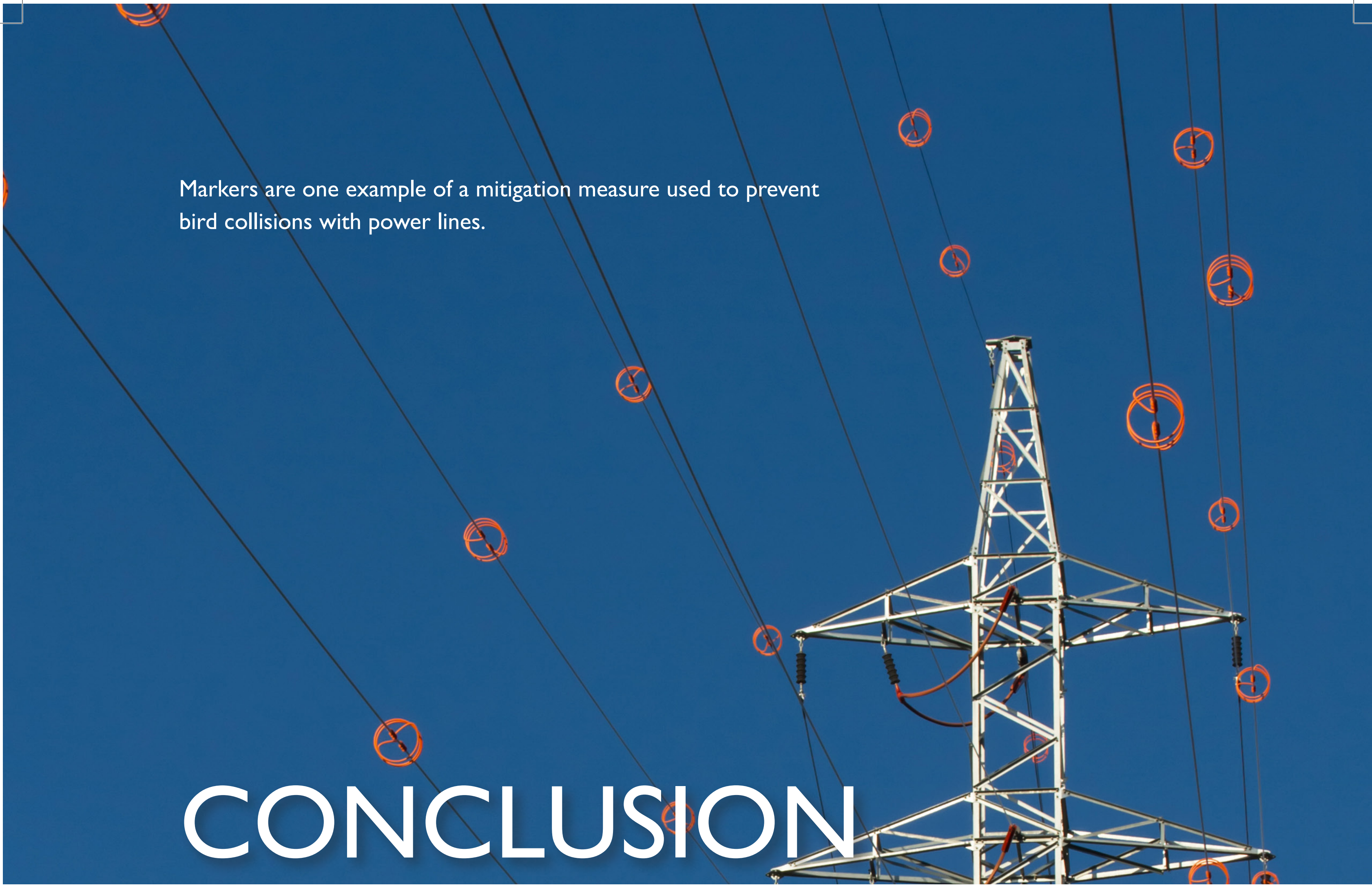
Top Right: Elephant using a wildlife underpass on NH2 road in Bhutan. Credit: Norris Dodd

ASIA ALREADY HAS MANY GREAT EXAMPLES OF WILDLIFE-FRIENDLY LINEAR INFRASTRUCTURE

Increasingly, LI projects in Asia are including transport ecology experts in the design of pre-construction biodiversity assessments, wildlife safeguard selection and design, and post-construction performance evaluations. Positive examples of expert involvement include: the southern segment of the East-West National Highway in Bhutan, Chittagong-Cox's Bazar Railway in Bangladesh, the Tonle Sap Power Line in Cambodia, and Nepal's East-West Railway. *See Annex 2*.

RECOMMENDATION

Different types of mitigation measures are prevalent in different Asian countries, offering potential opportunities for technical transfer and the exchange of ideas. An online platform that interactively shares successful WFLI projects from across Asia, including data collection techniques and mitigation measure designs, could serve as a useful planning tool for practitioners. Approaches that are successful should be institutionalized within planning firms and deployed widely across the continent.



CONCLUSION

PRIOR AND ONGOING CAPACITY-BUILDING EFFORTS IN ASIA

Asia has already begun the process of building capacity to implement WFLI. Capacity building has taken many forms, including workshops, field trips, workforce trainings, technical transfer webinars, delegation trips between Asian and North American or European nations, and the creation of WFLI-specific guidance. These activities have happened all over Asia, and have been led by many different groups, from financial institutions to NGOs to governments. These important efforts provide a promising foundation to build upon as LI development expands across the continent.

FUTURE ACTIONS TO BUILD ADDITIONAL CAPACITY WITHIN CONSTITUENT GROUPS

The following recommendations for capacity building are based on the results of an electronic survey completed by hundreds of Asian LI practitioners; interviews with LI experts, government leaders, financial specialists, and members of think tanks; and engagement and discussions with many others from the private sector, public sector, non-profit sector, and academia. Some were working on or were funding LI projects and others were conducting wildlife studies on the impacts of specific modes of transport or specific projects. Some were conducting, or had conducted, evaluations of LI at the regional level, while a few had provided continental perspectives. Combined, they offered a plethora of opinions on capacity needs for implementing WFLI safeguards in Asia. This short list seeks to capture and summarize those options that were most frequently expressed for each of the four constituent groups.

GOVERNMENT

- Support, along with other LI developers and proponents, the establishment and maintenance of a publicly accessible national and/or regional collaborative WFLI data and information-sharing platform.
- Identify existing provisions in national laws that provide direction to implement WFLI safeguards and suggest additional wildlife-friendly language for future legislative efforts, particularly for infrastructure bills.
- Follow the lead of Asian governments that have initiated coordinating bodies and other forms of multi-agency integration of international and national environmental provisions to better incorporate WFLI directives across infrastructure and conservation agencies.
- Promulgate nationwide laws and regulations specific to LI development so that directives for wildlife safeguard provisions are authorized and clearly defined.

INTERNATIONAL FINANCIAL INSTITUTIONS

- Concurrent to harmonizing infrastructure development with the conservation of biodiversity, provide long-term funding for regional advisory/stakeholder groups to engage with IFIs and other constituent groups responsible for LI development in Asia.
- Considering the gaps in knowledge regarding the impacts of LI projects and effectiveness of potential solutions for a variety of Asian species and ecosystems, build in contingency funding provisions for implementing wildlife safeguards and monitoring their effectiveness in LI project budgets.
- Provide adequate funding to build WFLI capacity, both internally and for the various constituent groups' members, for recipient countries of BRI projects and other international LI initiatives.

INDUSTRY

- Provide workforce training for LI planners and consultants to better identify and address the various needs of the diverse wildlife species and their habitats present in Asian landscapes.
- Offer capacity-building training for developing Asia's LI practitioners that describes international best practices for wildlife data collection and analysis.
- Institutionalize the inclusion of wildlife's needs in all project plans, designs, and operations within the infrastructure sector.
- Establish more public recognition and incentives, within professional associations and governments, for industry professionals who plan and construct LI and willingly provide voluntary wildlife safeguards.
- Capitalize on the considerable potential of industry associations to provide WFLI capacity building, education, and training opportunities to their members across Asia who plan, design, and construct roads, rails, and power lines.

NON-GOVERNMENTAL ORGANIZATIONS

- Offer increased capacity-building opportunities to members of the NGO community to help them better understand how to provide effective WFLI safeguards.
- Facilitate partnerships between NGOs and LI project proponents and funders to improve the use and incorporation of NGO's wildlife data collection and analysis expertise throughout the full project development process.

SUMMARY

All regions of Asia are facing rapid growth in their linear infrastructure systems and often this development can cause conflict with a nation's duty to protect biodiversity, ecological services, and community values. The need to increase the capacity to address these issues was expressed frequently by LI practitioners across the continent. Fortunately, the various constituent groups have overwhelmingly expressed interest in receiving training to increase their expertise to better align with international best practices. Many were supportive of creating additional opportunities for capacity building such as the establishment of internet-based platforms for information sharing, authoring technical handbooks or manuals, and developing new or improved policies. Combined, these efforts to increase Asia's capacity to address future LI development will greatly improve the planning and application of WFLI safeguards.

Cover Photo: Underpass on the Jeli-Gerik Highway, Malaysia.
Credit: Aaron Laur

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