PROTECTING ASIAN ELEPHANTS FROM LINEAR TRANSPORT INFRASTRUCTURE

The Asian Elephant Transport Working Group's Introduction to the Challenges and Solutions

IUCN
WCPA WORLD COMMISSION ON PROTECTED AREAS
CONNECTIVITY CONSERVATION Specialist Group
SSC Species Survival Commission
Asian Elephant Specialist Group

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By Rob Ament (co-chair), Sandeep Kumar Tiwari (co-chair),
Melissa Butynski, Becky Shu Chen, Norris Dodd,
Aditya Gangadharan, Nilanga Jayasinghe, Aaron Laur,
Gabriel Oppler, Wong Ee Phin, Rodney van der Ree, Yun Wang

This publication is made possible through support of the International Connectivity Program at the Center for Large Landscape Conservation and by funding from the New York Community Trust, Woodcock Foundation and friends.

Published by: Asian Elephant Transport Working Group

Citation: Ament, R., Tiwari, S.K., Butynksi, M., Chen, B.S., Dodd, N., Gangadharan, A., Jayasinghe, N., Laur, A., Oppler. G., Wong, E.P., van der Ree, R., Wang, Y. (2021). *Protecting Asian Elephants from Linear Transport Infrastructure: The Asian Elephant Transport Working Group's Introduction to the Challenges and Solutions.* AsETWG (Asian Elephant Transport Working Group; IUCN WCPA Connectivity Conservation Specialist Group/IUCN SSC Asian Elephant Specialist Group).

DOI: https://doi.org/10.53847/VYWN4174

Cover photo: Elephant on National Highway 209 near Sathyamangalam Tiger Reserve in India. | T. MURUGANANDAM

Layout by: David Harmon editorial + creative

Available online from: Asian Elephant Transport Working Group (AsETWG)
Secretariat of the IUCN WCPA Connectivity Conservation Specialist Group
c/o Center for Large Landscape Conservation (CLLC)
P.O. Box 1587
Bozeman, MT 59771
USA
connectivity@largelandscapes.org

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Foreword

As one of the last remaining mega-herbivores on earth, Asian elephants are endangered across their remaining home ranges in South and Southeast Asia especially due to the ongoing loss and fragmentation of habitat. It is estimated that the overall population has declined by at least 50% since 1945 to fewer than 52,000 individuals, and those that remain are nearly completely isolated within the 13 range states of Bangladesh, Bhutan, Cambodia, China, India, Indonesia, Laos, Malaysia, Myanmar, Nepal, Sri Lanka, Thailand and Vietnam. Living for up to 60-70 years, Asian elephants survive by moving significant distances seasonally to find safety, food, water, mates, and comfortable climates. Increasingly, traditional movement areas are being severed by linear transport infrastructure – such as roads, railways, and canals.

Human-elephant conflict is being exacerbated as more native habitat is converted for agriculture, plantation, natural resource extraction, community expansion and infrastructure development. Combined, these land use changes are compressing wild elephant populations into even closer proximity with humans. The most recent IUCN Red List Assessment of Asian elephants reports stark numbers: as of 2020 more than 600 humans and 450 elephants per year lose their lives in conflicts, and the number of elephants dying is likely an underestimate due to lack of reporting.

Only in recent decades has the impact of rapidly increasing linear transport infrastructure become a serious concern as habitats and ecological corridors are sliced up, and elephants seek resources in, or near, human settlements. Now, even more transport development is slated or underway in elephant range states, resulting in additional losses to the physical connectivity of habits and the functional connectivity of populations. This steady erosion of connectivity will further imperil the ability of elephant populations to recover from their historical losses. The 2nd Asian Elephant Range States Meeting in 2017 brought more attention to the need to stem declining population numbers by adopting the Jakarta Declaration for Asian Elephant Conservation to tackle critical issues facing the species, including habit loss and fragmentation and human-elephant conflict. These are issues that can be attributed to both the direct and indirect impacts of linear transport infrastructure development and its expansion.

Fortunately, a joint effort of IUCN's SSC Asian Elephant Specialist Group and the WCPA Connectivity Conservation Specialist Group has created the Asian Elephant Transport Working Group as a network of diverse experts devoted to advancing solutions for avoiding and mitigating the threats of linear transport infrastructure to Asian elephants. This publication represents the first effort to, present compelling evidence, offer effective solutions, and make recommendations for reducing Asian elephant-transport conflicts. We are proud of this exemplary collaboration across two of IUCN's volunteer commissions and acknowledge this publication is just the first achievement resulting from the coordinated efforts of the Asian Elephant Transport Working Group. We look forward to future successes from their endeavors.

Vivek Menon
Chair, IUCN SSC Asian Elephant Specialist Group
Founder, Trustee and Executive Director, Wildlife Trust of India

Dr. Gary Tabor
Chair, IUCN WCPA Connectivity Conservation Specialist Group
Founder and President, Center for Large Landscape Conservation

Acknowledgements

The Asian Elephant Transport Working Group (AsETWG) is a cross-commission collaboration of the IUCN World Commission on Protected Areas' Connectivity Conservation Specialist Group (CCSG) and the IUCN Species Survival Commission's Asian Elephant Specialist Group (AsESG). The authors thank the many contributors of photos and figures, and the following people that were invaluable supporting research, review, editing and layout: Alison Adam-Buskey, Christine Gianas Weinheimer, Dave Harmon, and Kendra Hoff.

Compliments are also made to the following specific case study contributors:

- Dr. Anupam Sarmah at WWF-India regarding the case study 'India: Upgrading National Highway 54E through the Lumding Reserve Forest in Assam'; and
- Prof. Reuben Clements and officers from the Department of Wildlife and National Parks Peninsular Malaysia concerning the case study 'Malaysia: Ecological viaducts on the Aring-Kenyir Road', as well as to Rimba, Malaysian Nature Society, Forest Research Institute Malaysia (FRIM), Sunway University, the University of Malaysia Terengganu and others for their efforts in research, awareness and protection of biodiversity in the Kenyir landscape.

Elephant family in Belum-Temengor Forest Complex in northern Peninsular Malaysia.
ALICIA SOLANA-MENA / MANAGEMENT & ECOLOGY OF MALAYSIAN ELEPHANTS

ADOBE STOCK

1. Introduction

The Asian elephant (*Elephas maximus*) is a wide-ranging keystone species in the biologically rich ecosystems of South and Southeast Asia (Williams *et al.*, 2020). Unfortunately, the spread of human settlements, plantations, industry, farming, mining and linear transport infrastructure (LTI), such as roads, railways, canals, power lines, pipelines, and fences, has squeezed extant elephant populations into ever-decreasing remnants of forest and blocked ancient movement routes attributing to the escalation of human–elephant conflicts (Leimgruber *et al.*, 2003; Sukumar, 2003; Dublin *et al.*, 2006; Aguirre and Sukumar, 2016; Menon *et al.*, 2017, Williams *et al.*, 2020). In such altered landscapes, the survival of Asian elephants depends on finding a balance between the retention of protected areas (PAs) and other key elephant habitats with community needs, such as lands needed for agricultural production and transport systems needed for the movement of goods and people. This requires both restoring habitats outside of PAs while maintaining and conserving enduring ecological corridors, connecting them within home ranges and across jurisdictional boundaries (Menon *et al.*, 2017; Menon *et al.*, 2020; Goswami *et al.*, 2014a; Hilty *et al.*, 2020, Sukumar *et al.*, 2016).

The emphasis of this report is on exploring innovations that can result in more equitable outcomes by better balancing the needs of society for improved transport systems – roads and railways – to spur social and economic development and the impacts they have on Asian elephants and their habitats. While there are many adverse impacts that roads and railways may cause, the focus will be on the ecological effects and their potential solutions.

Elephant in the Fasiakhali Wildlife Sanctuary near the Chittagong-Cox's Bazar Railway Project in Bangladesh. | NORRIS DODD

1.1. Background

Current estimates reveal that there are fewer than 52,000 Asian elephants still living in the wild across 13 Asian countries, while approximately 15,000 are held in captivity (Menon and Tiwari, 2019). Each range state's population size was estimated by experts of the IUCN Species Survival Commission's (SSC) Asian Elephant Specialist Group (AsESG) (Table 1) and a map of their current distribution (Figure 1) developed in 2008 (Hedges *et al.*, 2008; Williams *et al.*, 2020).

Three subspecies are currently recognized taxonomically: mainland Asia is home to *Elephas maximus indicus,* while Sri Lanka has *Elephas maximus maximus* and Sumatra hosts *Elephas maximus sumatranus* (Shoshani and Eisenberg, 1982). Expert opinion has not reached consensus on whether the island of Borneo – shared by Indonesia, Malaysia and Brunei – holds a fourth subspecies, *Elephas maximus borneensis.* A definitive subspecific classification awaits a detailed, range-wide morphometric and genetic study (Williams, *et al.*, 2020).

Country	Wild population (min–max)	Country	Wild population (min–max)
Bangladesh	289–437	Malaysia	3,263–3,717
Bhutan	605–761	Myanmar	2,000–4,000
Cambodia	400–600	Nepal	109–145
China	300	Sri Lanka	5,879
India	29,964	Thailand	3,126–3,341
Indonesia	1,784–1,804	Vietnam	104–132
Lao PDR	500–600	**Total**	**48,323–51,680**

Table 1. Wild Asian elephant population estimates for each range state. | IUCN/SSC ASIAN ELEPHANT SPECIALIST GROUP

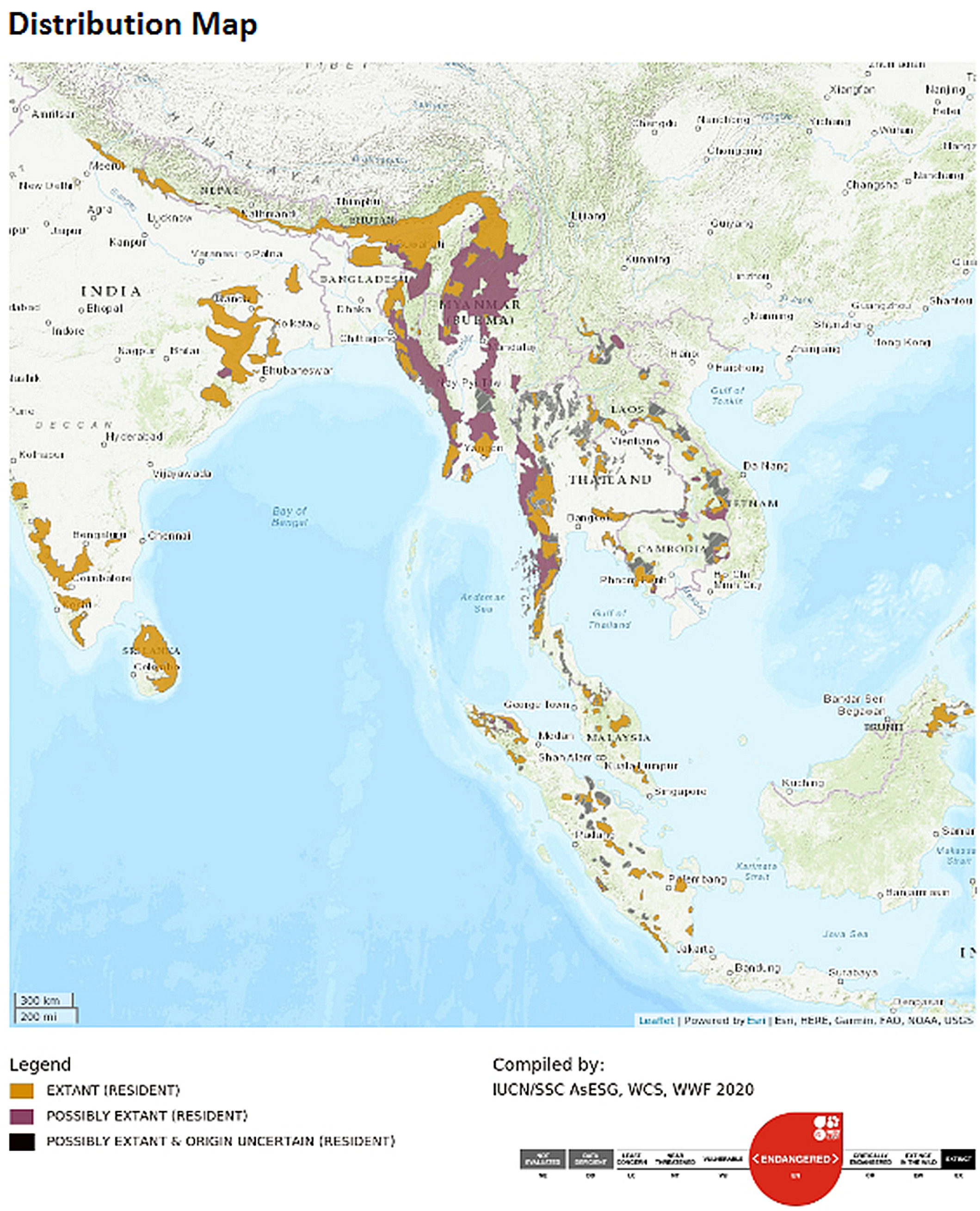


Figure 1. Map of historic and current wild Asian elephant population distribution.
| IUCN/SSC ASIAN ELEPHANT SPECIALIST GROUP, WILDLIFE CONSERVATION SOCIETY, WWF
(SOURCE: IUCN RED LIST OF THREATENED SPECIES, VERSION 2020-3)

1.2. Conservation Status

The Asian elephant is currently listed as "endangered" on the IUCN Red List (Williams, *et al.*, 2020) and has been recognized as an endangered species since 1975 under the Convention on Trade in Endangered Species of Wild Animals (CITES). As a result of the continued decline in its numbers, the 2nd Asian Elephant Range States Meeting (Asian Elephant Range States, 2017a) adopted the *Jakarta Declaration for Asian Elephant Conservation* in April 2017 to tackle four main issues: human-elephant conflict, habitat loss and fragmentation, transboundary issues and illegal trade (Asian Elephant Range States, 2017b). More recently, in 2020, the Government of India was successful in its proposal to classify the "Mainland Asian Elephant/Indian Elephant (*Elephas maximus indicus*)" under the Convention on Migratory Species (CMS) as a migratory species in danger of extinction throughout all or a significant portion of its range. In turn, it is now listed under CMS Appendix 1, and its related Concerted Action Plan was adopted in 2020 (CMS, 2020a).

1.3. Importance of Ecological Connectivity

Ecological connectivity, defined as the unimpeded movement of species and flow of natural processes that sustain live on Earth (CMS, 2020b), is highly important for wide-ranging species like the Asian elephant. In this regard, ecological connectivity considers structural connectivity as the measure of habitat permeability based on the physical features and arrangements of habitat patches, disturbances, and other elements presumed to be important for organisms to move through their environment (Hilty *et al.*, 2019; de la Torre *et al.*, 2019). Furthermore, while the ability to disperse across a landscape can reduce the chance of local extinction, functional connectivity is a critical determinant of how well individuals or genes move through the environment (Rudnick *et al.*, 2012). For many species, the lack of ecological connectivity – both structural and functional – can lead to a decrease in species movement and loss of access to resources such as food, water and breeding partners to maintain genetic diversity. This can, in turn, cause individual mortality, create isolated populations more vulnerable to stochastic events and even lead to local or species extinction.

Elephants crossing a road in Peninsular Malaysia. | ALICIA SOLANA-MENA/MANAGEMENT & ECOLOGY OF MALAYSIAN ELEPHANTS

Elephants need access to entire landscapes and cannot rely on just a few patches of habitat to thrive (Leimgruber *et al.*, 2003). Although many elephant populations exist in fragmented landscapes, enhanced conservation efforts are necessary to identify and protect corridors connecting the many patches of habitat needed by this wide-ranging species (Menon *et al.*, 2017; de la Torre *et al.*, 2019). All range states recognize that establishing ecological corridors is essential for the species to survive in the region (Ahmed *et al.*, 2016; Liu *et al.*, 2017; Menon *et al.*, 2017; Rangarajan *et al.*, 2010). At a larger scale, functional landscape connectivity must be achieved between protected areas and major habitats to overcome the deleterious effects of isolating small populations of elephants (Puyravaud *et al.*, 2016).

1.4. Impacts of Habitat Disturbance

The habitats of Asian elephants are composed of grassland, tropical evergreen forest, semi-evergreen forest, moist deciduous forest, dry deciduous forest and dry thorn forest in addition to cultivated and secondary forests or scrublands. (WWF, 2020; Williams *et al.*, 2020). They live in matriarchal societies where females form cohesive groups with strong yet flexible social bonds (Moss and Poole, 1983; Vidya and Sukumar, 2005; Desai, 1995; Williams *et al.*, 2020) and adult males are largely solitary but interact with other males and females within their home range. A population could consist of several herds and males, have well-defined home ranges and specific movement areas, and a population with several herds can have multiple paths or migration routes (Rangaranjan *et al.*, 2010). These paths facilitate elephants' need for large home ranges to meet their ecological needs, sometimes ranging in size from 180 km^2 to up to 600 km^2 for female herds (Baskaran *et al.*, 1995). Furthermore, these home ranges and matrilineal social hierarchies govern the movement and habitat use by herds. However, encroaching human development is disturbing paths that some herds have used for centuries, either for daily movements or for seasonal migration to feeding and watering areas (IEF, 2020; Menon *et al.*, 2017). Remaining home ranges are increasingly being converted, degraded or fragmented causing elephant populations to become divided into subpopulations (Leimgruber *et al.*, 2003).

2. Impacts of Linear Transport Infrastructure

Infrastructure development is shrinking and degrading habitat while also creating barriers to movement, either because movement paths are being bisected, or because construction is happening on the same trails that the elephants themselves opened. By 2050, it is estimated that 25 million kilometers (km) of new road-lanes will crisscross the globe to connect countries, communities, and people (Dulac, 2013). Further, by 2050, it is estimated that more than 300,000 km of new railway track will be constructed, adding to the existing stock of 1 million km (Dulac, 2013). This prognosis for expansive transport networks, much of it in Asia, will be accompanied by their increasing potential to enter many of the last remaining strongholds of biodiversity, disconnect habitats, cause untold lethality for animals large and small, further restrict wildlife movement, and ultimately contribute to an even steeper decline in species richness and population numbers.

This rapid expansion of LTI and its associated activities will have significant direct, indirect, and cumulative ecological effects on elephants and other species as well (Figure 2). Such impacts may include:

- **Mortality:** Wildlife-vehicle collisions or train strikes result in the death or injury of wildlife, as well as human fatalities and injuries.
- **Aversion:** Traffic, noise, fumes, and lights can create unnatural disturbance that turns wildlife away from even attempting to cross LTI.
- **Movement barriers:** Transport infrastructure can create either complete or partial impediments to wildlife crossings.
- **Sensory disturbance:** Noise, vibration, fumes or lights can result in the loss of habitat quality in adjacent habitats.
- **Chemical effects:** Air, water and soil pollution from trains and vehicles can often keep wildlife from approaching transport infrastructure.
- **Habitat loss and fragmentation:** Natural, intact habitats are lost or degraded through destruction and/or isolation, leading to increased human-elephant conflict.
- **Attractants:** Garbage as well as natural foods, such as palatable grasses, are often available in road verges, drawing elephants onto railways and roads.

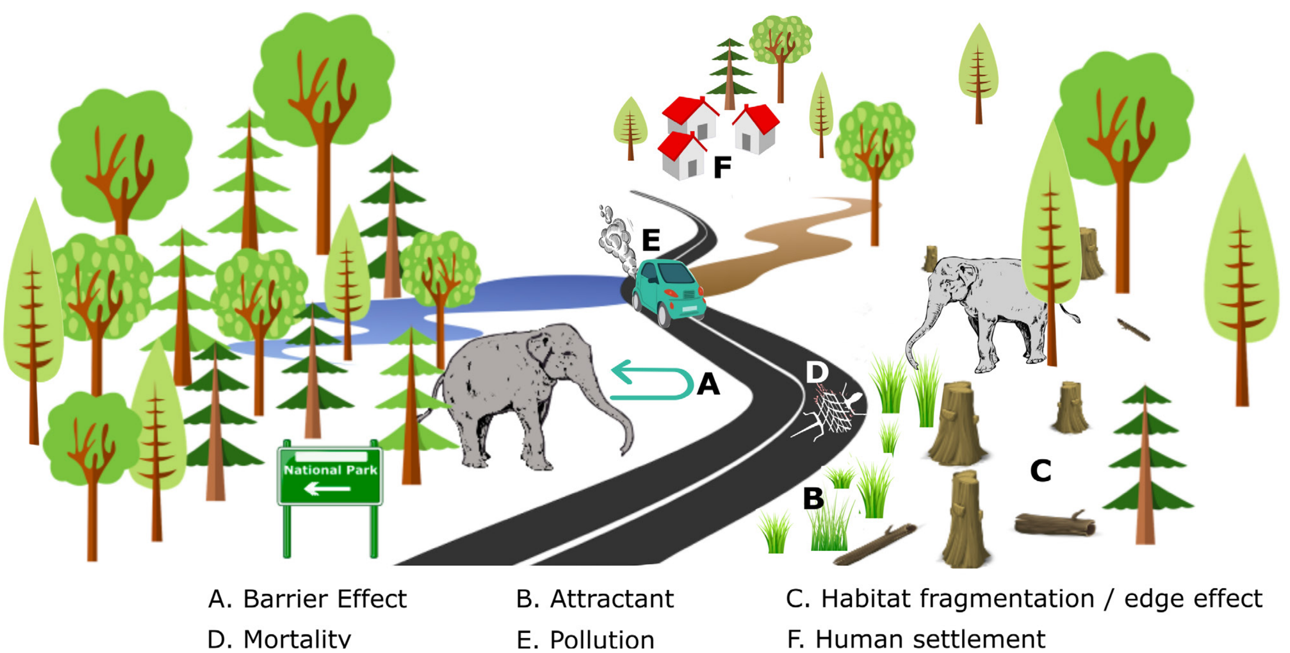


Figure 2. Schematic of ecological impacts from linear transport infrastructure.
| MELISSA BUTYNSKI / CENTER FOR LARGE LANDSCAPE CONSERVATION

Speeding vehicles along roads bisecting forests may sometimes collide with elephant herds. This baby elephant was killed by a car as it tried to cross the East-West Highway in northern Peninsular Malaysia. | ALICIA SOLANA-MENA / MANAGEMENT & ECOLOGY OF MALAYSIAN ELEPHANTS

Furthermore, LTI development can lead to significant social changes that impact elephants and other wildlife, such as increases in a) legal and illegal human settlement; b) natural resource extraction; c) poaching and illegal wildlife trade; and d) deforestation (Laurance and Arrea, 2017). Unless action is taken now to decrease the impacts of rapidly expanding LTI development in Asian elephant landscapes across its 13 range states, the decline of this iconic species will only be exacerbated.

2.1. Projected Expansion of LTI in Asia

Asian elephants need to move, but they face the challenge of crossing a vast and rapidly expanding network of LTI in the landscapes where they live. Most notably, Asian governments have been coordinating the development of regional roads and railways since at least 1992 with the launch of the Asian Land Transport Infrastructure Development (ALTID) project under the auspices of the United Nations Economic and Social Commission for Asia and the Pacific (ESCAP) (Chartier, 2007). ALTID's major foci were to coordinate the regional development of the Asian Highway Network and the Trans-Asia Railway (Figure 3) (Chartier, 2007). The Asian Highway Network was initiated in 2005 as a coordinated effort to develop highways across the continent via an Intergovernmental Agreement for approximately 140,000 km of roads linking to Europe (Madhur *et al.*, 2009; UN/ESCAP, 2014). Similarly, 24 Asian countries signed an intergovernmental agreement in 2006 to coordinate the development of the Trans-Asian Railway (TAR) network. According to ESCAP, TAR now involves 28 countries and 117,500 km of track (UN/ESCAP, 2014).

The Asian highway (Figure 3) and railway networks (Figure 4) are projected to rapidly expand across Asian elephant range states. According to the Asian Development Bank (ADB), over USD $880 billion is invested annually in developing infrastructure. The ADB has projected that the region will need to invest USD $26 trillion, or USD $1.7 trillion per year, in infrastructure between

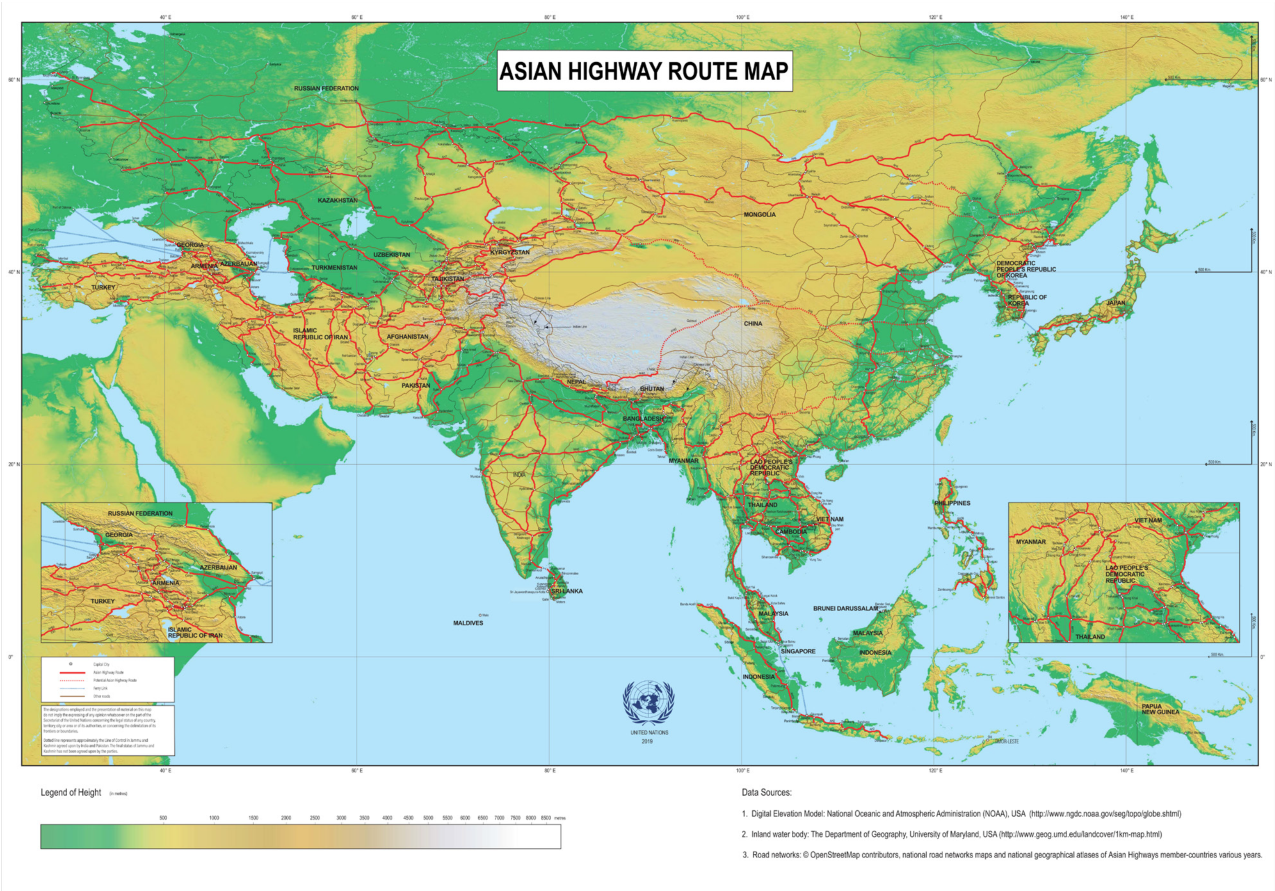


Figure 3. Map of the Asian Highway Network. | SECRETARIAT OF THE UN ECONOMIC AND SOCIAL COMMISSION FOR ASIA AND THE PACIFIC

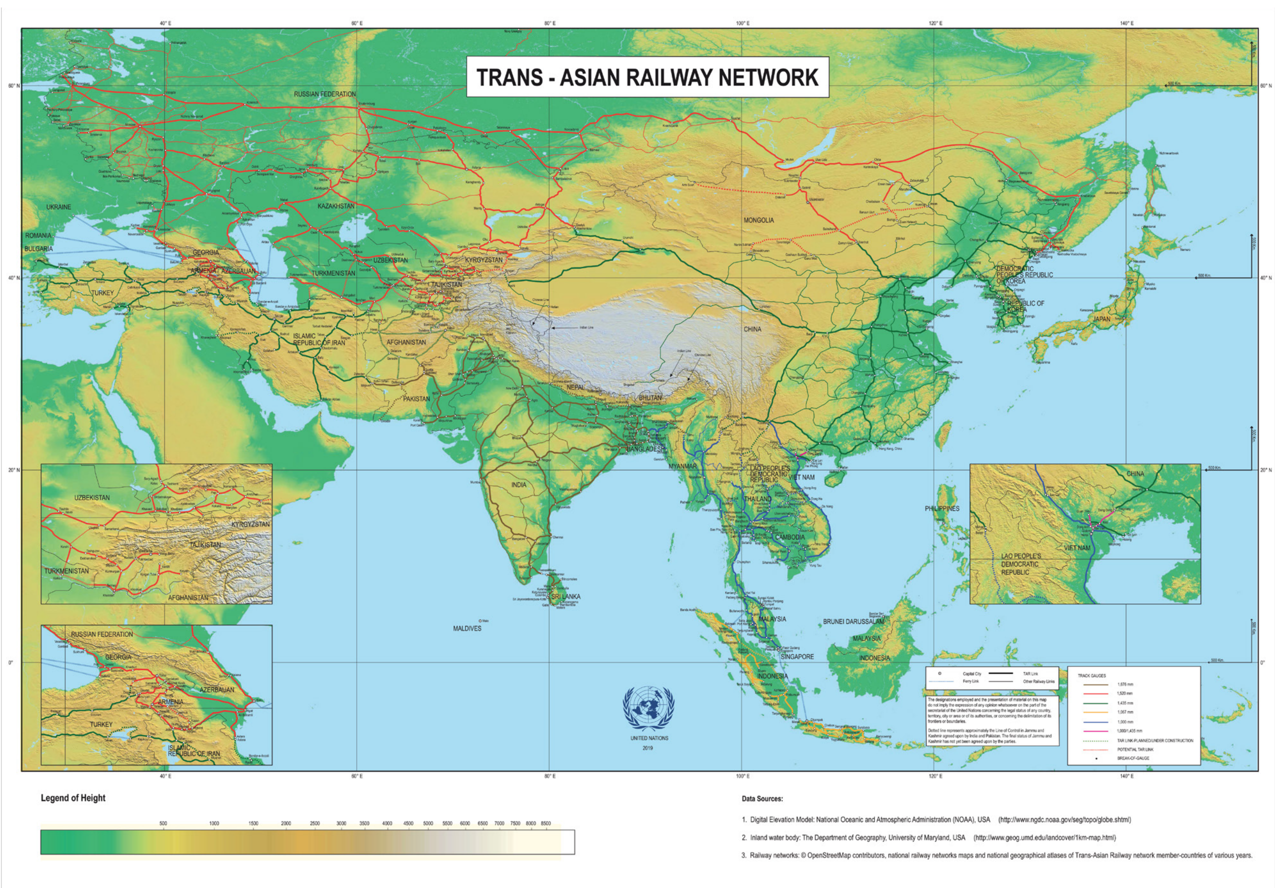


Figure 4. Map of the Trans-Asian Railway Network. | SECRETARIAT OF THE UN ECONOMIC AND SOCIAL COMMISSION FOR ASIA AND THE PACIFIC

2016–2030 to maintain current rates of growth and respond to climate change (ADB, 2017). Of this total, USD $8.4 trillion, or nearly one-third, will be for transport.

Excluding China and India, multilateral development banks are estimated to have financed over 10 percent of infrastructure investments to further develop Asia (ADB, 2017). A greater commitment is considered necessary in the future to support the doubling of needed infrastructure investment funding. Part of this will be filled by the Asian Infrastructure Investment Bank (AIIB), which was created in 2013 by China as a multilateral development bank to focus on Asia's infrastructure needs (The Economist, 2014). Thus, much more capital from both the East and West is now available for infrastructure development in the region.

Another driver of rapid LTI expansion in Asian elephant landscapes is China's Belt and Road Initiative (BRI) (Figure 5) that was launched by President Xi Jinping in 2013 (Cai, 2017). It is estimated that the BRI will invest over USD $5 trillion and connect 65 countries by land and sea, with much of the focus on Asia. Scientists are increasingly concerned about the BRI's environmental consequences and impacts to biodiversity (Liu *et al.*, 2017; Laurance and Arrea, 2017; Lechner *et al.*, 2018; Ascensão *et al.*, 2018; Hughes, 2019). Like many other species impacted by LTI, it is expected that Asian elephant populations, especially in southeast Asia, will be adversely impacted, although no specific analysis has yet been undertaken as was recently completed for tiger landscapes (Carter *et al.*, 2020).

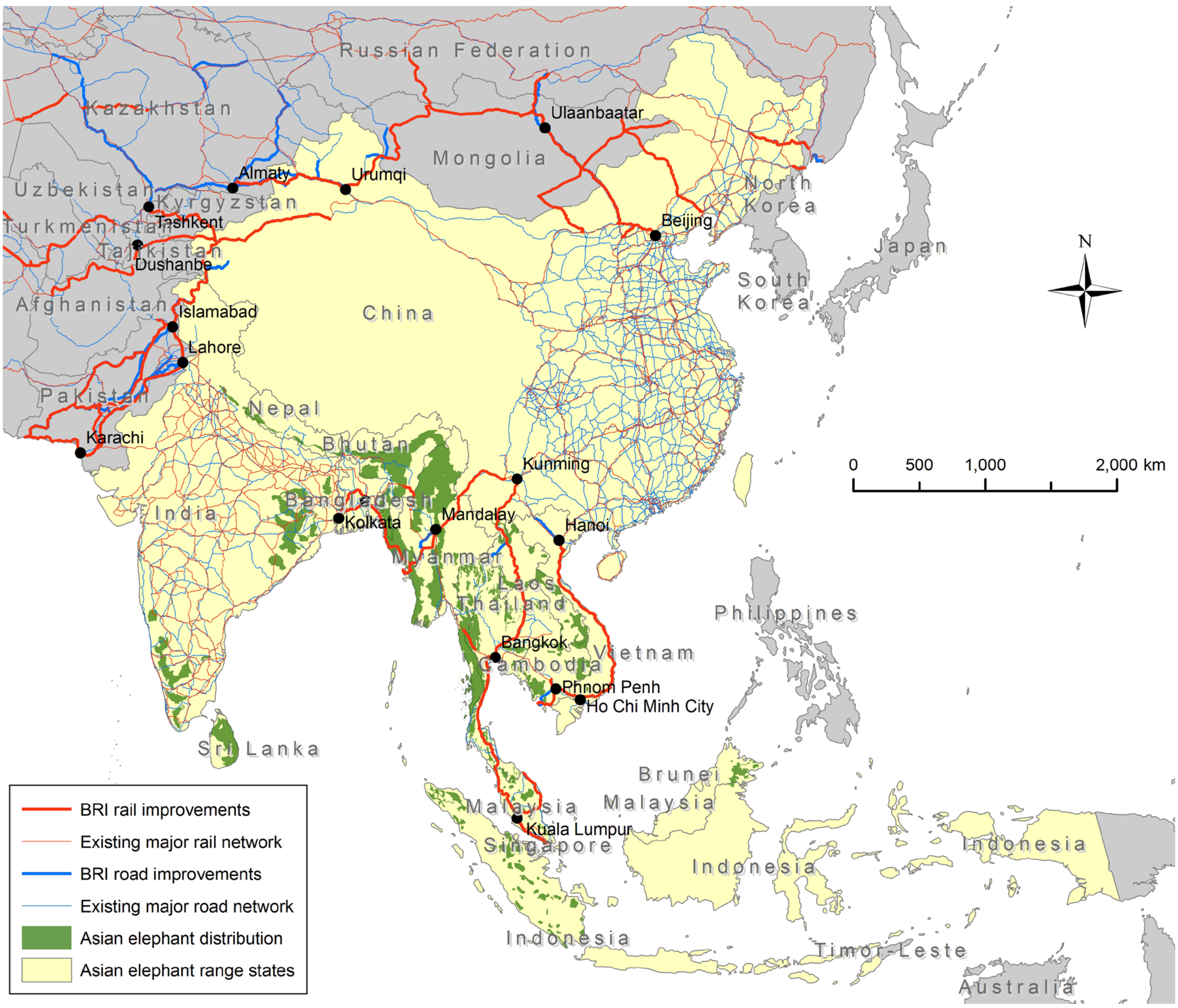


Figure 5. Map of Asian elephant distribution and the larger regional context of China's Belt and Road Initiative based on best available data in 2021. | TYLER CREECH / CENTER FOR LARGE LANDSCAPE CONSERVATION

2.2. Increasing Impacts of LTI on Asian Elephants

Despite all the threats to the Asian elephants' well-being, and necessary actions being clearly understood, human-caused fragmentation and barriers to movement are increasing at alarming rates across the 13 range states. This is due, in large part, to forest clearing, agricultural monoculture planting (i.e., palm oil plantations), human settlement and infrastructure development (Naha *et al.*, 2019). In particular, LTI is fragmenting habitats and leading to human-elephant conflicts (Saif *et al.*, 2019). The expansion of LTI is increasingly limiting movement by interrupting habitats or corridors used for generations and disturbing contiguous habitats (Alamgir *et al.*, 2019). Indeed, mega-herbivores like elephants, with such large home ranges and food requirements, have been among the species most affected by habitat alteration, fragmentation and the loss of ecological connectivity (Leimgruber *et al.*, 2003; Menon *et al.*, 2017; Suksavate *et al.*, 2019; Neupane *et al.*, 2019). For example, elephant deaths along certain stretches of railway tracks are a serious concern for elephant conservation in India (Singh and Sharma, 2001; Sarma *et al.*, 2006; Rangarajan *et al.*, 2010) and Sri Lanka. In India, about 329 elephants have died as a result of train collisions between 1987 and January 2021, of which more than two-thirds of the deaths have been reported in the states of Assam and West Bengal (Singh and Sharma, 2001; Sarma *et al.*, 2006; Roy *et al.*, 2009; Joshi and Singh, 2011). In Sri Lanka, approximately 15 elephants were killed in train collisions during 2018 and seven train-related elephant deaths were reported in 2017. In total, between 2005 and 2018, about 122 elephant deaths resulting from train collisions were reported in Sri Lanka. Similarly, elephant deaths from vehicular collisions are a concern in Peninsular Malaysia, Thailand and other range states. The proposed railway lines in Myanmar, Lao PDR, Vietnam, etc. could also majorly impact elephant habitats in South East Asia. The expansion of railway lines in India and new railway lines in the Cox-bazar region of Bangladesh are also anticipated to affect elephant habitats.

2.3. Existing Research: Evaluating Impacts of LTI on Asian Elephants

There have been a handful of studies evaluating the impacts of LTI on Asian elephants across their range. Nearly two decades ago, Indian scientists identified three forms of LTI – roads, rails and canals – as key habitat-fragmenting forces and inhibitors of Asian elephant movement along the Ganges River in Rajaji National Park (Singh and Sharma, 2001). Similarly, in Yunnan Province, China, the newly constructed Kunming-Bangkok Highway reduced the number of crossing sites used by elephants from 28 to 23, and their passages across the highway by 44 percent (Pan *et al.*, 2009). In Peninsular Malaysia, the major East-West Highway built in the 1970s through the Belum-Temengor Landscape has been found to be a significant barrier to elephant movement, which continues to increase the risk of elephant mortality (Wadey *et al.*, 2018).

Train strikes that cause Asian elephant mortality are another impact of LTI that is well documented. Various contributing factors, although not mutually exclusive, often operate in tandem contributing to increased potential for elephant and train collisions (Singh and Sharma, 2001; Sarma *et al.*, 2006, Joshi and Singh 2011; WTI, 2017)

Elephant mortality from train strikes in India has been assessed, accident "hotspots" identified, causes of accidents described and mitigation measures for specific sites selected. Various factors contribute to elephant mortality by train hits. These include ecological (food, water, shelter, vegetation and movement of elephants), physical factors (steep embankments and turning), technical (speed of train, frequency and time, unmanaged disposal of the edible waste and garbage) and lack of awareness of among drivers, passengers and planners (Singh and Sharma, 2001; Sarma *et al.*, 2006). The factors are not mutually exclusive and operate in tandem to increase the potential for elephant and

Elephant crossing National Highway 209 in Biligiriranganatha Swamy Temple (BRT) Wildlife Sanctuary in southern India.
| SANDEEP KUMAR TIWARI

train collisions. In one case study, a railway line in Northern West Bengal, India was investigated and mortalities were found to be higher near curves and areas where forested cover is adjacent to rails. Additionally, increased elephant-train collisions were due to increases in train traffic and speed, as well as low visibility and the lack of warning systems for train operators (Dasgupta and Ghosh, 2015). This same rail line was the subject of evaluation where data from the 1980s to 2015 was reviewed to describe both locations of high rates of elephant-train collisions, as well as to identify locations where elephants were susceptible to future accidents (Roy and Sukumar, 2017).

Each year, more studies report and journal articles describe new information regarding the causes and the amount of elephant mortality on roads and railways. However, few range states have standardized road and railway wildlife mortality data collection and reporting systems.

[Insert photo: Elephant crossing National Highway 209 in Biligiriranganatha Swamy Temple (BRT) Wildlife Sanctuary in southern India. Courtesy: Sandeep Kumar Tiwari]

2.4. Asian Elephant–Transport Conflict

Some examples of current and planned LTI projects that might threaten existing Asian elephant populations and their habitats include:

- The Pan Borneo Highway is to be constructed to link the Malaysian states of Sabah and Sarawak with more than 2,000 km of new and upgraded road. Under construction at this time, a stretch of the highway is planned to cut through the Tawai Forest Reserve with a large population of elephants moving in the same area as the planned road alignment (Mongabay, 2019).
- The Trans-Sumatra Toll Road runs 2,800 km between several cities and provinces on Sumatra. While a number of road segments are complete, several are under construction or are in the planning stages to connect Lampung on the southern tip with Aceh in the north. Specifically, the road will run through Balai Raja and Siak Kecil Nature Reserves,which are both movement corridors for a vulnerable population of Sumatran elephants (Jakarta Globe, 2019).
- The China-Laos Railway, running approximately 410 km, is being constructed between the Lao capital city of Vientiane and the town of Boten on the border with China. The track is reportedly

90% complete and projected to open in December 2021 at an estimated cost of $6 billion USD (SCMP, 2020; NPR, 2019).

- A quarter of the new 103 km Chittagong-Cox's Bazar Railway Project (see also more details in Chapter 4) alignment in southern Bangladesh crosses through three protected areas harboring Asian elephants. This project has been under construction since 2018. In addition to minimizing impacts with avoidance of core zone habitats in two areas, structural mitigation measures (two wildlife underpasses and an overpass, linked with fencing) are sought to lessen impacts to connectivity in the protected area where the railway disrupts corridors.
- In Nepal, the Simara-Tamsariya section of the East-West Electric Railway mega project was put on hold due to a 7 km stretch that passed through the center of the Chitwan National Park. After a thorough, detailed project report, the route was realigned to avoid this core area.

Currently there are relatively few published, scientific papers or a standardized reporting system that enumerates the breadth and depth of elephant mortality caused by roads and railways across the 13 range states. However, media continues to report each year on the human costs and wildlife carnage that proceed unabated, except for the rare mitigated TLI sites. A small sampling of print articles in English language newspapers around the region includes these headlines:

- India: 'Wild tusker hit by container truck near Hosur succumbs' (January 2021)
- Malaysia: 'Elephant calf found dead in East-West Highway hit-and-run' (January 2021)
- Thailand: 'Baby elephant hit by motorcycle survives after receiving CPR in Thailand' (December 2020)
- India: 'Female elephant dies after being hit by train in Odisha's Sundargarh' (September 2020)
- Malaysia: 'Elephant calf crossing Kota Tinggi-Mersing road killed by car' (September 2020)
- Malaysia: 'Endangered Malaysian elephant killed on highway' (July 2019)
- India: 'Guwahati-Ledo Intercity Express mows down elephant in Lumding' (April 2019)
- Sri Lanka: 'Elephants slaughtered by Sri Lankan trains a disturbing new trend' (January 2019)

ADOBE STOCK

3. Reducing Asian Elephant–Transport Conflicts

3.1. Guidelines, Policies, and Laws

Guidelines, policies, and laws have been developed in Asia to assist ministries, agencies, planners, engineers, consultants and others in the transport sector to better consider the needs of elephants and other wildlife when developing LTI plans and projects. They deal with the needs of wildlife, including elephants, at a variety of levels and from different perspectives. Efforts to provide published guidance have been made in various geographies and by different institutions or organizations operating at the international, national and project levels. While some include various specifications for understanding and monitoring impacts, and planning and designing avoidance and mitigation measures, they all generally seek to encourage the consideration of wildlife's needs and the development of wildlife-friendly LTI.

Elephants crossing a highway near Corbett Tiger Reserve in northern India.
| A.G. ANSARI

Guidelines produced over the last decade include:

- The Asian Development Bank's *Green Infrastructure Design for Transport Projects: A Road Map to Protecting Asia's Wildlife Biodiversity* published in 2019 to highlight the impacts of transport projects on wildlife and biodiversity in Asia, and the diversity of measures available for balancing construction with conservation (ADB, 2019);
- *Eco-Friendly Measures to Mitigate Impacts of Linear Infrastructure on Wildlife* released by Wildlife Institute of India in 2016 to provide detailed guidance for planning, locating, designing, implementing and operating infrastructure roads, railways and powerlines in wildlife habitats (WII, 2016);
- The World Bank's Global Tiger Initiative produced the technical report in 2010 titled *Smart Green Infrastructure in Tiger Range Countries: A Multi-Level Approach* that examines the challenges and opportunities for improvements – including in India, Bhutan, and Nepal – for conservation, planning and policy efforts that can be applied to landscapes where elephants and other wildlife co-occur with tigers (Quintero, *et al.*, 2010);
- *Guidance on Promoting Green Belt and Road* released by Ministry of Ecology and Environment, Ministry of Foreign Affairs, National Development and Reform Commission, Ministry of Commerce of the People's Republic of China in 2017 to highlight significance, overall requirements, main tasks and organizational guarantee of green road construction along BRI corridor (The state council of China, 2017); and
- China National Forestry and Grassland Administration's *Technical Regulation for Terrestrial Wildlife Corridor Design* in 2012 to highlight the principle, design basis, survey technology and design method of animal passages, including Asian elephants and others endangered species in China (National Forestry and Grassland Administration, 2012).

Some recent notable and applicable international and regional policies include:

- Resolution 071, 'Wildlife-friendly linear infrastructure', adopted by the 2020 IUCN World Conservation Congress, requests increased global collaboration to deliver more effective mitigation of LI impacts, including avoidance, on wildlife and ecosystems based on specific targets and indicators (IUCN, 2020);

- The 2nd Asian Elephant Range States Meeting adopted the 'Jakarta Declaration for Asian Elephant Conservation' in April 2017 with the number one priority to "Maintain large Asian elephant conservation landscapes where no unregulated, economic or commercial infrastructure development or other adverse activities are permitted, and create connectivity between such landscapes where all permitted developmental activities are elephant- and biodiversity-appropriate" (Asian Elephant Range States, 2017b);
- The 2017 'Hanoi Principles' for planning, designing and financing ecologically sound LTI adopted by the International Forum on Sustainable Infrastructure, including advocating for multi-stakeholder approaches from the onset of projects that include government, private sector and sustainability experts working in close collaboration (IFSI, 2017);
- India's Animal Passage Plan: The National Board of Wildlife (NBWL), India mandates that all LTI projects passing through PA, buffer zones or Eco Sensitive Zones of PAs seeking clearance should have Animal Passage plan; and
- Ministry of Transport of China issued a policy entitled 'Regulation of Green Road Construction in China' in July 2016 to strengthen wildlife preservation, research novel technology for wildlife crossing structures and deepen international cooperation to help develop green roads in China.

Examples of laws passed in Asian elephant range states to address the needs of wildlife movement in the case of LTI development include:

- The 2018 'Law of the People's Republic of China on The Protection of Wildlife' stating that "New construction of linear infrastructure (highways, railways, etc.) should avoid nature reserves and wildlife migratory corridors. If impossible to avoid, wildlife crossing structures should be constructed to mitigate the negative impacts". (Law of The People's Republic of China on The Protection of Wildlife, 2018);

Elephant in Peninsular Malaysia. | WONG EE PHIN / MANAGEMENT & ECOLOGY OF MALAYSIAN ELEPHANTS

- The Malaysian Federal Government approving the 'Central Forest Spine Master Plan for Ecological Linkages' (CFS) as part of the National Physical Plan in 2010, and subsequently the 'National Elephant Conservation Action Plan' (NECAP) released in 2013 setting a five-year target for "Corridors between priority sites and landscapes [to be] maintained or recreated" (Department of Wildlife and National Parks Peninsular Malaysia, 2013); and
- India's 'Wildlife (Protection) Amendment Act, 2006' requiring the state governments to ensure
  "…ecologically compatible land uses in the tiger reserves and areas linking one protected area or tiger reserve with another for addressing the livelihood concerns of local people, so as to provide dispersal habitats and corridors for spillover populations of wild animals from the designated core areas of tiger reserves or from tiger breeding habitats within other protected areas" (The Wildlife (Protection) Amendment Act, 2006).

3.2. Mitigation Hierarchy

In efforts to improve conservation outcomes in areas where LTI development is taking place, the mitigation hierarchy – avoid, and if not possible, followed by minimize, mitigate, restore, offset and compensate for residual impacts – is a fundamental approach to reduce the undesirable effects that even the most well-planned, designed and constructed LTI projects might have on Asian elephants. This simple framework allows for assessing and addressing the impacts of infrastructure in a step-by-step process of foremost considering avoidance as the first option, then followed by minimization, mitigation, onsite restoration and lastly, off-site compensation.

When applied in this specified order, the hierarchy can facilitate cost-effective and timely project implementation with measurable outcomes. The mitigation hierarchy is central to the International Finance Corporation's *Performance Standard 6: Biodiversity Conservation and Sustainable Management of Living Natural Resources* (IFC, 2012) and has been adopted as a best-practice guideline by some multilateral development banks and other financial institutions, governments and NGOs to enhance biodiversity conservation throughout the planning and construction processes, including through formalization within environment and social impact assessments. The mitigation hierarchy can be applied as follows:

- **Avoid** impacts on species and their habitats by considering potential risks prior to project design and choosing to not develop new or upgrade existing LTI, or selecting alternative routes in sensitive or critical areas;
- **Minimize** impacts when development cannot be completely avoided by taking proactive measures that can include undertaking an environmental management plan during and after construction to reduce the project footprint, such as reducing disturbance to the environment adjacent to the infrastructure;
- **Mitigate** impacts, after all other efforts to avoid and minimize have been taken, including technological and construction strategies such as noise and light barriers, and wildlife underpasses and overpasses – with associated fencing – that can provide for ecological connectivity and reduce wildlife-vehicle collisions;
- **Restore** (or rehabilitate) areas within or adjacent to the construction footprint that achieve no net loss of biodiversity values and ecosystem services, repair ecosystem structures and functions that can reverse degradation at or nearby the site, and follow well-established and practical techniques for maintenance and monitoring; and
- **Compensate** (or offset) for impacts at the site that cannot be avoided, minimized, mitigated or restored by pursuing actions that rehabilitate other habitats, ecosystems or ecosystem functions outside of the development footprint of a project such as funding and implementing management plans for protected areas, supporting research or enhancing enforcement activities.

3.3. Identifying Elephant Corridors

Knowing where to apply the mitigation hierarchy is informed by locating and mapping elephant movement areas and corridors. This is an important and proactive tool being pursued in a number of Asian elephant range states, as has been done in India (Menon *et al.*, 2017), Malaysia (de la Torre *et al.*, 2019) and Bangladesh (Motaleb *et al.*, 2016). Such efforts serve to identify priority areas and strategies to maintain and promote connectivity between core areas or habitat blocks, providing for wildlife movement and dispersal (Beier *et al.*, 2008). Where available, elephant corridor and landscape connectivity plans support the pursuit of LTI avoidance and other mitigation strategies. Conservation Action Plans informed by such work, although often varying in the level of detail, include:

- *Bangladesh Elephant Conservation Action Plan* (2018–2027)
- *Asian Elephant Conservation Action Plan for Cambodia* (2020–2029)
- *Right of Passage: Elephant Corridors of India* (2017)
- *Gajah – Securing the Future for Elephants in India* (2010)
- *National Elephant Conservation Plan (NECAP) – Peninsular Malaysia* (2013–2022)
- *Borneo Elephant Action Plan for Sabah, Malaysia* (2020–2029)
- *Myanmar Elephant Conservation Plan (MECAP)* (2018–2027)
- *Elephant Action Plan for Nepal* (2009–2018)

4. Recent Examples of Highway and Railway Measures to Protect Elephants

With the mitigation hierarchy in mind, and as the fragmentation and barrier impacts of LTI on Asian elephant movement become increasingly common, proven mitigation measures are now being designed and promoted to minimize elephant-vehicle collisions and increase ecological connectivity.

Structural solutions – overpasses and underpasses (infrastructure similar to bridges specifically designed for elephants to pass safely under or over the road or railway) – or flyovers (the entire highway/railway is elevated on pillars to allow animals safe passage underneath) are currently being deployed in various Asian elephant range states. Reviewed here are seven exemplary projects from five range states.

4.1. Bhutan: "Oversizing" Drainage Culverts for Asian Elephants Under the Southern Highway Corridor – Raidak-Lhamoizingkha Road

As one of five highway segments constructed as part of the new 183 km East-West National Highway, the 18 km Raidak-Lhamoizingkha Road is a two-lane highway that passes through Asian elephant habitat outside of designated protected areas along the India-Bhutan border. To avoid habitat degradation, fragmentation and barrier effects to the free movement of elephants, drainage culverts at three of four perennial stream crossings were "oversized" to increase the height and widths to better accommodate elephant passage. Prefabricated, corrugated metal plate arches were constructed to better accommodate passage of elephants as they use the stream corridors especially for seasonal movement. The projects are the first elephant underpasses constructed in Bhutan and range in height from 5.6 to 7.6 meters. During two years of monitoring in 2015–2017, 70 groups of elephants encompassing 145 individuals were recorded with 76% passing through the structures (Chogyel *et al.*, 2017). This monitoring has been expanded by ADB to include a wider range of underpass sizes; elephant use of structures with heights <5 meters have been documented.

(clockwise from upper left) Varying underpasses in Bhutan that are monitored with cameras; elephant using underpass. | NORRIS DODD / ASIAN DEVELOPMENT BANK

Camera trap photo near an underpass on National Highway 54E in Assam, India. | WWF-INDIA / ASSAM FOREST DEPARTMENT

4.2. India: Upgrading National Highway 54E through the Lumding Reserve Forest in Assam

The Lumding Reserve Forest in India is part of the Dhansiri-Lungding Elephant Reserve and connects the elephant habitats of central Karbi Anglong to the western Karbi Anglong, Dima Hasao, Hojai, Nagaon and Morigaon Districts. More than 100 elephants use this area for long-distance movement, and approximately 25 km of road passes through the reserve. From 2009-2019, the single-lane road was upgraded to a four-lane highway as part of the Government of India's East-West Corridor Programme. In response to the expected increases in vehicle numbers and speed, underpasses and additional mitigation measures were constructed throughout the road stretch. Structural mitigation includes two large "flyover" underpasses, four smaller underpasses for elephants, and 36 minor underpasses and culverts for reptiles and other wildlife. Non-structural measures include warning signs and speed bumps in critical movement areas, barricades and barbed wire fencing to funnel animal movement to underpasses, and 1.5-meter opaque fencing on the flyovers to decrease light and noise disturbance.

A wildlife underpass for elephants on National Highway 54E in Assam, India. | ROB AMENT

4.3. Malaysia: Ecological viaducts on the Aring-Kenyir Road

The four-lane stretch of the Aring-Kenyir Road (Federal Route 185) is located in the north-eastern state of Terengganu in Peninsular Malaysia. Three elevated viaducts were specifically built as animal crossing structures in 2008, in addition to seven bridges spanning rivers and ravines that also allow for animal movement in the landscape. For approximately 60 km, the road traverses four forest reserves: Tembat, Petuang, Hulu Telemong and Hulu Nerus. According to varying sources, it is estimated that there are between 120 and140 individual Asian elephants in the state and this complex of contiguous forest often serves as a translocation site for elephants from other areas with human-elephant conflict. A designated ecological corridor (T-PL1, previously known as CFS I: PL7) measuring approximately 150 square km surrounds the three viaducts and helps to link the reserves to Taman Negara National Park, which covers over 4,300 km^2 and supports approximately 600 elephants. To increase effectiveness, 20 km of electric fence are used to funnel wildlife to the underpasses, artificial saltlicks have been installed near or under them, and standard road signs have been installed to warn motorists of the potential for elephants crossing the road. The Department of Wildlife and National Parks recorded roadkill of elephants, melanistic leopard (*Panthera pardus*) and other wildlife. A research project assessing the effectiveness of the crossing structures found elephants and a few other herbivores utilize the underpasses, while other species, including carnivores, may prefer to cross directly on the road (Clements, 2010).

The three viaducts in the ecological corridor around the Aring-Kenyir Road in Terengganu, Malaysia. | S. ELAGUPILLAY

A view from below one of underpasses on the Sixiao Expressway in Yunnan, China. | YUN WANG

4.4. China: Sixiao Expressway through the Xishuangbanna Nature Reserve

The Sixiao Expressway forms part of the Trans-Asian Highway running from Kunming (the capital city of China's Yunnan Province) to Bangkok (Thailand). Completed in 2006 and totaling 97.75 km, the road extends for 18 km through the more than 990 km^2 Menyang Nature Reserve within the larger Xishuangbanna National Nature Reserve network on the banks of the Mekong River. The area contains the largest Asian elephant population in China – approximately 150–180 individuals – and the species is known to use habitat on both sides of the road. As the result of the environmental impact statement found that the highway would cause habitat degradation and fragmentation and act as a barrier to elephant movement, 25 crossing structures were constructed, including 23 bridges and two tunnels. Metal fencing at a height of 1.9 meters runs between the structures on both sides to direct animals to the crossings, and warning signs are placed on both sides of the expressway to warn drivers not to speed or honk their horns. Two different phases of monitoring in 2006–2008 and 2018–2019 indicate that elephants may be adapting to the expressway over time: the utilization rate increased from 32% (eight crossings) in 2006 to 40% (ten crossings) in 2008, and to 72% (18 crossings) in 2019. It has also been found that elephants preferred crossings that are aligned with original and/or historical movement corridors.

A warning sign along the Sixiao Expressway in Yunnan, China. | YUN WANG

4.5. India: National Highway 37 along the Boundaries of Kaziranga National Park in Assam

Kaziranga National Park (KNP) is a UNESCO World Heritage Site in the flood plain of the Brahmaputra River in northeastern India. The park covers a total area of over 884 km^2 and is part of the larger Kaziranga-Karbi Anglong Landscape. The park and surrounding areas are critical habitat for many threatened species, including Asian elephants, tigers, and the largest population of greater one-horned, or Indian rhinoceros in the world. However, the landscape is increasingly fragmented and animal-vehicle collisions are a common occurrence along a 60-kilometer stretch of National Highway 37 (NH 37) running along the river and cutting through the south flank of the park. Four major wildlife movement corridors are bisected by the road through which wildlife regularly move, especially during the monsoons when two-thirds of the park floods. As part of a plan approved in 2010, expansion of the road from two to four lanes has been a contentious issue that reached India's National Green Tribunal on multiple occasions. Now, through cooperation of the Wildlife Institute of India, wildlife management authorities, and the State of Assam, multiple sections of the new road will be elevated on pylons for a combined length of over 35 km in an effort to maintain wildlife movement and decrease collisions. These anticipated "flyovers" will be the longest purpose-built wildlife mitigation measures ever built in the country (Hindustan Times, 2019).

Elephant herd crossing the National Highway 37 running through Kaziranga National Park in Assam, India. | NILANGA JAYASINGHE / WWF-US

4.6. Bangladesh: Chittagong-Cox's Bazar Railway – Mitigating Impacts in Three Protected Areas

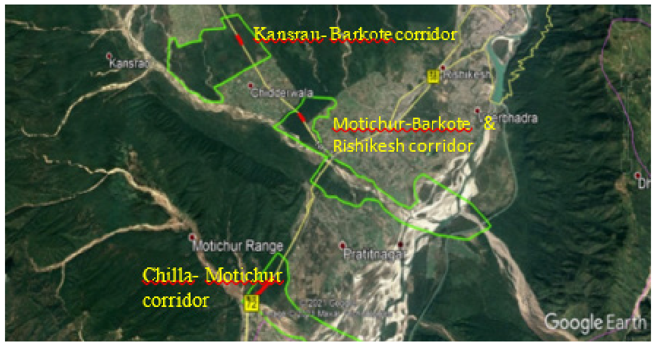
Approximately half of Bangladesh's total Asian elephant population is found in three legally protected areas in the southeastern part of the country: Chunati and Fasiakhali wildlife sanctuaries and Medhkachapia National Park. Construction of an ADB-funded LTI project began in 2018 to build a new 103 km section of a railway, of which 27 km (or 26% of the total project alignment) cut through the protected areas (ADB, 2017b). This railway will ultimately be part of the Trans-Asia Railway Network to boost regional trade and will eventually extend to Myanmar and establish rail-freight connectivity among India, Bangladesh, Myanmar and China. A comprehensive strategy is now being implemented to mitigate impacts in the three protected areas. In Chunati Wildlife Sanctuary with several identified elephant corridors, three crossing structures are being constructed: one overpass measuring 50 meters wide and 70 meters long, and two underpasses. These will be accompanied by stout elephant fencing constructed from retired, welded train tracks to be erected along 1.9 km of the alignment to funnel animals to the passage structures and limit access to deep cut slope stretches to prevent collisions with trains. In the other two areas where the railway avoids core zone habitats and elephant corridors, fencing will be erected along cut-slope sections with at-grade (level) crossings to prevent collisions. A study is underway to develop train- and ground-based electronic elephant detection systems, which ideally will be placed at the termini of fencing with train signaling to slow approaching trains when elephants are nearby. Over 300 ha of habitat improvements like forage enhancement, water tank improvements and artificial salt licks are being implemented.

(top) Elephant moving through Chunati Wildlife Sanctuary in Bangladesh.
NORRIS DODD / ASIAN DEVELOPMENT BANK

(bottom) Rendering of one of the crossing structures being constructed over the Chittagong-Cox's Bazar Railway in Bangladesh.
NORRIS DODD / ASIAN DEVELOPMENT BANK

4.7. India: Upgrading of NH72 (Haridwar-Dehradun highway) passing through Rajaji National Park and Dehradun Forest Division

The Rajaji National Park in northern India is part of the Shiwali Elephant Reserve and is also a Tiger Reserve with the landscape supporting about 400+ elephants and 37+ tigers. To cater to the increasing vehicular traffic, the National Highway was expanded to four lanes. The region has four corridors, two joining the Western and Eastern part of the Rajaji National Park and two corridors joining the Rajaji Tiger Reserve and Dehradun Forest Division (Menon *et al.*, 2017). To facilitate the movement of elephants and other wildlife, three “flyovers for vehicles” are being constructed. Two of the underpasses below the flyover have been completed – Chilla-Motichur corridor (0.9 km) and Motichur-Barkote & Rishikesh (0.5 mts) and a third is being constructed in Kansrau-Barkote corridor (0.5 mts). Fences are being constructed on either side to channel the wildlife through the underpasses. The corridors are being extensively used by elephants, tigers, leopards and many other wild animals. Signage is also being utilized to inform the local community of the importance of safe wildlife passage.



Detail of National Highway 72 in northern India running through elephant corridors outlined in green, with location and lengths of “flyovers” marked in red where elephants can utilize underpasses to avoid the four-lane highway. | WILDLIFE TRUST OF INDIA

A view of the National Highway 72 underpass for the Chilla-Motichur corridor in northern India. | WILDLIFE TRUST OF INDIA

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5. Emerging Technologies

Technological interventions are increasingly used to prevent collisions between wildlife and vehicles on transport networks, particularly railways. While such measures are still in their early stages of application for elephants, it is likely that they will become more widespread over the coming years. This is particularly so because they are also useful in addressing human-elephant conflict, such as providing an early warning of elephants entering crop fields.

Here follows a brief overview of conservation technologies that are commonly applied to transport networks.

Asian elephant herd crossing train tracks near Palakkad, Kerala in southwestern India. | RATHNA KUMAR / WILDLIFE TRUST OF INDIA

Technology-based mitigation may involve devices that are set up at specific locations where there is a high risk of collision, or they may be borne on the vehicles themselves, typically on trains. Location-based technological solutions are more prevalent at the present time. These systems consist of at least two parts: a component that detects the presence of an animal, and another that transmits this information to a manager or driver for further action, such as slowing down a train or sending out a patrol to move the animal away from the tracks. In some systems, a third component – a device meant to deter the animal from nearing or staying on the tracks – is also triggered by the detection. For example, a device developed by a startup company and implemented in Bhutan consists of a passive infrared sensor that detects animal movement and triggers a series of sound and light alarms to deter elephants (WWF-India, 2017). Another company has implemented a solution in North Bengal, India, that is customized for elephant detection via four sensors and triggers an alert in the nearest wildlife management office (SNAP Foundation, 2020). While both devices are designed for wildlife-conflict situations in agricultural fields or villages, they have strong potential for application along transport networks. Seismic sensors are also being piloted along the railway track in Rajaji National Park, India to detect elephants and alert train drivers.

An alternative approach concentrates on the detection of approaching trains and alerts or deters animals from the tracks without any human involvement. A device implemented along railway tracks in Poland sets off a set of sounds consisting of natural alarm calls of wildlife or calls of predators at a fixed amount of time (e.g., 30 seconds) before a train arrives at the location. This approach resulted in roe deer escaping from the tracks 20 seconds sooner than in the absence of the device (Babińska-Werka *et al.*, 2015). While this implementation aims to actively deter animals from tracks when trains are close by, a different option involves simply making the animal more vigilant (e.g., by looking up) with the goal of aversive conditioning. A system was also developed where a standard light and a bell are set off by approaching trains; animals associate these stimuli with the train and move away up to 6.5 seconds earlier (Backs *et al.*, 2020).

The key requirements for greater applicability of technology in mitigating elephant-train collisions include accurate detection and clear management response. False positives (triggering a response when an elephant is not present) would waste resources, while missing an elephant present on the tracks could lead to a collision. Further, the management response to detection of an elephant – alerting the animal, aversive conditioning or modification of human behavior – needs to be clear and customized for local conditions. As pilot implementations of technology-based interventions continue to rise, detailed quantitative evaluation of these new technologies and their publication in public fora is needed.

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6. General Recommendations for Future Policy, Practices and Research

The AsETWG offers its professional opinion to better inform adequate protections for Asian elephants from existing roads and railways, as well as future LTI projects. The field of transport ecology, particularly for Asian elephants, is in its infancy. While so little is understood, new LTI projects are currently being developed throughout the landscapes that the iconic species calls home. Much more information and cooperation is needed quickly to address issues across the range states. For example, the AsETWG is actively developing comprehensive guidelines, based on available information, science, and members' expertise to specifically address passage structure dimensions, spacing, approach slopes and the role of fencing and design. The following recommendations are provided at this juncture to inspire and enhance action now.

Elephant with radio tracking collar walking the road verge of the East-West Highway in northern Peninsular Malaysia.
| ALICIA SOLANA-MENA / MANAGEMENT & ECOLOGY OF MALAYSIAN ELEPHANTS

Recommendation 1. Mitigation hierarchy
Avoidance should be the first and foremost strategy to protect Asian elephants from LTI development across range states. Only after all options to avoid key elephant habitats and corridors are exhausted should project proponents advance to other mitigation options in the hierarchy: avoid, minimize, mitigate, restore and compensate.

Recommendation 2. Nomenclature
Adopt consistent nomenclature for Asian elephant (and other terrestrial wildlife) passage structures that are key to mitigating LTI impacts and may take many forms. Suggested terminology includes:

Underpasses to accommodate below-grade passage encompassing four broad subcategories:

- **Bridged underpasses** are girder bridges and arch structures up to 50 meters wide and designed specifically for wildlife passage. They are most effective when constructed along established travel corridors within drainages (Pan *et al.*, 2009);

- **Expanded bridges** span rivers, streams and wetland areas and exceed 40 meters in width under which elephants can pass (minimum 5 meters clearance, preferably higher);
- **Viaducts** are elevated roadways spanning valleys, gorges and wetlands, but are higher and longer than expanded bridges as viaducts preserve natural habitats and are very suitable for passage; and
- **Flyovers** are extended (up to 10 km or longer), elevated roadways passing over a variety of habitats. They have been designed for elephant and tiger passage in protected areas of India, with a recommended minimum height of 6-8 meters, span of 50 meters and width of 10-12 meters (WII 2016).

Overpasses to accommodate above-grade passage encompass two subcategories:

- **Bridged overpasses** are girder or arch structures designed specifically for wildlife passage and exceed 50 meters wide (Singh and Sharma, 2001; Rajvanshi *et al.*, 2001), or wider for longer spans (European "eco-bridges" and/or "ecoducts" are as wide as 100 meters); and
- **Natural overpasses/tunnels,** such as in China, are tunnels for traffic (some up to 765 meters long) that have "created" (maintained) natural overpass corridors above highways, which elephants prefer to underpasses.

Recommendation 3: Structural design guidelines
Even with the paucity of data and evaluation of the effectiveness of existing passage structures in range states, as well as lack of comprehensive structural design guidelines (height, length, width), there is a critical need for integrating elephant passage structures into LTI project planning. Until additional insights are gained (e.g., from ongoing underpass monitoring in Bhutan funded by the Asian Development Bank), design guidelines should adhere to the precautionary principal and consider larger and wider structures.

Recommendation 4. Siting of crossing locations
The location of elephant crossing structures should be aligned with their historical and current movement routes. Crossing sites must be identified based on high-quality, pre-construction data collection and evaluation. Locations and investments in mitigation measures must be substantiated and validated by high-quality wildlife data.

Recommendation 5. New technologies for mitigation
Support the development and evaluation of promising technologies to mitigate roads and railways, including animal detection-driver/manager warning systems and animal detection-adverse conditioning devices (e.g., noise, lights).

Recommendation 6. Address the barrier effect
Increase general knowledge about how traffic, both vehicular and train, adversely affects elephants as they approach or seek to cross LTI. Take a more systematized approach to monitor the impacts of traffic and roadkill across range states, which is important information both for retrofitting existing LTI and informing future projects.

Recommendation 7. Monitor effectiveness
Improve consistent monitoring and data collection, both pre- and post-construction, for LTI projects, including before-after-control-impact (BACI) studies conducted to evaluate the design effectiveness of mitigation measures implemented for elephants. Future LTI projects should incorporate and fund the development of adequate pre- and post-construction monitoring programs to better understand the effectiveness of their mitigation plans and designs.

Recommendation 8. Technical information
Collect and disseminate the best available scientific information on the design and deployment of mitigation measures for elephants, including methodologies for pre- and post-construction wildlife monitoring and mitigation measure evaluation, design specifications that can ensure better environmental performance and cost-benefit analysis information.

Recommendation 9. Economic and cost-benefit studies
Undertake studies of the environmental, social and economic value that Asian elephants generate for their communities in the range states to inform decisions that balance the costs of deploying mitigation measures with the benefits received through conservation.

Recommendation 10. Foster a professional network
Governments, financiers, engineering and construction firms, consultants and the conservation community can increase collaboration to share the best available information for safeguarding elephants from LTI development. A network of professionals with representation across the range states, joined with global experts and actors in transport ecology, can provide the necessary support to address the diverse facets of Asia's rapidly expanding LTI in elephant habitats.

Male elephant crossing National Highway 209 in Biligiriranganatha Swamy Temple (BRT) Wildlife Sanctuary in southern India. | SANDEEP KUMAR TIWARI

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MANAGEMENT & ECOLOGY OF MALAYSIAN ELEPHANTS

Asian Elephant Transport Working Group (AsETWG) — Building a Network of Experts to Address Elephant-LTI Conflicts

The Asian Elephant Transport Working Group (AsETWG) was formed in 2018 as a collaboration between the IUCN World Commission on Protected Area's Connectivity Conservation Specialist Group (CCSG) and the IUCN Species Survival Commission's Asian Elephant Specialist Group (AsESG). AsETWG currently has a growing membership of 25+ volunteers working to deliver practical, flexible, and science-based solutions that avoid and mitigate threats of LTI to Asian elephants across all 13 range states. Interested participants are encouraged to volunteer their time and contribute their energy and knowledge to ongoing activities.

To learn more about AsETWG, visit: http://conservationcorridor.org/ccsg/working-groups/asetwg/
To apply for membership, visit: https://conservationcorridor.org/ccsg/membership/
For more information, contact: connectivity@largelandscapes.org