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Comprehensive Guidelines for Elephant Crossing Structures: Insights from the Handbook to Mitigate the Impacts of Roads and Railways on Asian Elephants

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Introduction and context

The expansion of linear transportation infrastructure (LTI) across Asia continues to challenge the conservation of Asian elephants (*Elephas maximus*), an endangered keystone species. Roads, railways, and canals fragment habitats, impede movement, and increase human-elephant conflicts.

To address the impacts of LTI, the Asian Elephant Transport Working Group (AsETWG) was formed. The AsETWG is a collaboration between the IUCN World Commission on Protected Areas' Connectivity Conservation Specialist Group (CCSG) and the IUCN Species Survival Commission's Asian Elephant Specialist Group (AsESG). Its mission is to serve as the hub of expertise and technical support to deliver practical, science-based solutions that avoid and mitigate threats to Asian elephants posed by LTI across all 13 range states. In 2024, the AsETWG released the "Handbook to Mitigate the Impacts of Roads and Railways on Asian Elephants", a detailed guide focusing on specific mitigation strategies and best practices for elephant crossing structures (Fig. 1).

Building on the 2021 publication, "Protecting Asian Elephants from Linear Transport Infrastructure, the AsETWG's Introduction to the Challenges and Solutions" (Ament *et al*. 2021), the new handbook offers elephant-specific mitigation measures to address the negative impacts of LTI, including nuanced design and site selection criteria for wildlife crossing structures to ensure safe, effective passage for elephants.

With the projected expansion of LTI across Asia, even with concerted efforts to avoid high-biodiversity areas, effective mitigation measures will be critical to reduce project impacts and prevent further habitat degradation for Asian elephants. The handbook aims to foster the application of effective mitigation measures, specifically crossing structures.

Best practice guidelines for elephant crossing structures

The AsETWG aims to establish a consistent nomenclature for Asian elephant wildlife crossing structures, especially with the diversity of names used for structures (e.g., flyovers,

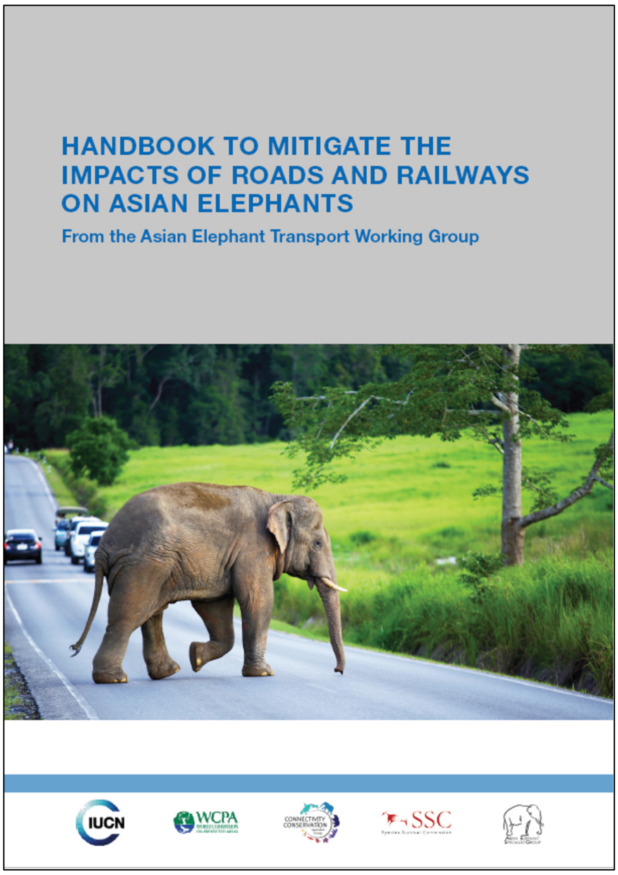
HANDBOOK TO MITIGATE THE IMPACTS OF ROADS AND RAILWAYS ON ASIAN ELEPHANTS
From the Asian Elephant Transport Working Group

Figure 1. The cover of the second publication by the IUCN's AsETWG.

ecoducts, wildlife bridges, etc.) design types and applications. Wildlife crossing structures are classified as underpasses providing below-LTI-grade passage or overpasses that provide above-LTI-grade passage (Clevenger & Huijser 2011; Smith *et al.* 2015). Each passage type has a range of applications, design variations, and preferences in use by various wildlife taxa (Clevenger & Huijser 2011; van der Ree *et al.* 2015).

Underpasses

Minor bridge underpasses are girder bridges, typically less than 30 m wide, and include arch structures and large reinforced concrete box culverts (RCBC). Though they are often designed for wildlife passage, they may also function as dual-use drainage structures. They are most effective when constructed along established travel corridors within drainages (Pan *et al.*, 2009).

Major bridge underpasses are wider, often multi-span bridges with spans exceeding 30 m but less than 120 m. They are often designed explicitly for elephant and other wildlife passage but may also span rivers, streams, and wetland areas. Their large size makes them especially effective as crossing structures for Asian elephants and other wildlife.

Long-span bridges are structures with spans exceeding 120 m that typically span rivers. Typically, they are not designed for wildlife passage. However, their size allows them to accommodate elephant use alongside river and stream areas, especially where dense vegetation exists and passage is not blocked by steep terrain or obstructions. In addition to creating 10–12 m wide flat, obstruction-free passage lanes adjacent to bridge abutments, minimum bridge heights should follow those in Table 2.

Table 1. AsETWG sliding-scale guidelines for minor bridge underpasses up to 30 m in width by underpass length across LTI.

Underpass	Minimum underpass dimensions		
Length (m)	Width (m)	Height (m)	Openness index
≤10	12.0	6.0	7.2
11 – 20	15.0	6.5	4.9 – 8.9
>20	20.0	7.0	4.7 – 6.7

Viaducts typically are not designed specifically for wildlife passage (Clevenger & Huijser 2011), but the sensitive habitats they protect allow for the maintenance of wildlife movement and adjacent habitats. As such, they are highly effective wildlife passages due to their large size, high clearance, and the degree of openness they afford for approaching and crossing animals. The AsETWG recommends a 10 m clearance height to ensure effectiveness for passing elephants.

Flyovers are extended (up to 10 km), elevated roadways passing over a variety of habitats. Increasingly used in India and now proposed in Nepal, these structures are specifically designed and constructed for elephant and tiger passage within protected areas. Both flyovers and viaducts provide animals with many crossing options and do not require costly wildlife funnel fencing to be effective. The AsETWG recommends a 10 m clearance height to ensure effectiveness for passing elephants.

Overpasses

Bridged (engineered) overpasses include girder, arch, and RCBC structures designed for wildlife passage and linking ridgeline travel corridors at cut slopes and embankment areas. Recognising that overpass widths should reflect the span length over which they cross LTI, the AsETWG guidelines provide a sliding scale of minimum overpass widths based on three classes of total overpass length, including landscaped approach slopes (Table 3). For narrow 2-lane highways or railways with total overpass lengths less than 60 m, a minimum 50 m width is acceptable; wider overpasses are recommended for longer lengths over LTI (Table 3).

Table 2. AsETWG sliding-scale guidelines for bridged underpasses up to 30 m in width by underpass length across LTI.

Underpass	Minimum underpass dimensions	
Length (m)	Width (m)	Height (m)
<20	30	6.5
>20	30	7.0

Table 3. Sliding-scale guidelines for engineered overpasses by total overpass length across LTI, including landscaped approach slopes.

Overpass length including approach slopes (m)	Minimum overpass width (m)	Width : length ratio
≤60	50	≥0.83
61 – 80	60	≥0.75
<80	70	≥0.88

The AsETWG feels that 1 m high side walls with durable fencing/barrier above are adequate to guide elephants across sufficiently wide overpasses. Other treatments, including earthen berms, trees or similar vegetation (e.g., bamboo) established along overpass edges, can provide more cost-effective and environmentally sensitive options to limit noise and light disturbance from LTI below. The full revegetation of overpasses with native vegetation is strongly recommended, and thus sufficient (1 m or deeper) soil depth is needed atop structures to establish vegetation effectively.

Natural overpasses are tunnels through mountainsides and ridges through which vehicles or trains pass. In China, natural overpasses (up to 765 m long) have been created by tunnelling, allowing elephants to pass over highways through undisturbed habitats. Though costly to excavate, natural overpasses can provide superior (Wang *et al*. 2015) passage for Asian elephants as they maintain natural ecological connectivity and vegetation without impact or disruption. Based on China's experience, natural overpasses should be constructed in areas not subject to human disturbances (homes and other buildings) that limit effective use.

Methodologies for Asian elephant crossing structure site selections

Identifying suitable sites for Asian elephant crossing structures is pivotal in ensuring their efficacy. The Handbook emphasises a multi-faceted approach integrating ecological data, field observations, and advanced technologies. One primary method involves aligning crossing structure placement with regional and national connectivity plans, which map key habitats and movement corridors based on ecological studies and stakeholder input. These plans provide a foundational framework to ensure that interventions support existing movement patterns and do not create new barriers.

Field-based sign surveys remain a crucial tool, particularly in remote or data-deficient areas. These surveys identify movement corridors through physical evidence, such as tracks, dung, and feeding marks, which indicate frequently used pathways. Camera traps further supplement these efforts by capturing real-time data on elephant activity, offering insights into the frequency and timing of crossings as well as herd composition. Advances in technology, particularly the use of GPS telemetry, have revolutionised site selection by enabling precise tracking of elephant movements across fragmented landscapes. These data help identify critical bottlenecks where infrastructure intersects established routes, providing a basis for evidence-driven mitigation.

Historical data on vehicle- and train-related elephant collisions offer another critical layer of information. Collision hotspots often align with high-use habitat corridors where barriers such as roads and railways present acute risks. Targeting these areas for crossing structures can significantly reduce mortality.

Role of fencing in promoting effective elephant crossing structures

The Handbook emphasises the importance of integrating fencing with wildlife crossings to ensure their functionality and reduce mortality rates. By physically preventing elephants from accessing dangerous roadways or railway tracks, fencing funnels animals toward safe crossing points, increasing the likelihood of their use. This approach not only safeguards elephants but also reduces the risk of vehicle collisions, protecting human lives and property.

The design and implementation of fencing require careful consideration of both ecological and engineering factors. Fencing must be robust enough to withstand elephant interactions, as their size and strength often make traditional fencing ineffective. Reinforced materials, such as welded tube metal or concrete barriers, are recommended, with designs tailored to specific landscapes and infrastructure types. Additionally, fencing should extend far enough along the LTI to prevent elephants from circumventing it, which could compromise its utility. Post-construction monitoring of fencing systems is essential to identify weaknesses, ensure maintenance, and adapt designs based on observed elephant behaviour.

Non-structural mitigation approaches

Non-structural mitigation approaches are complementary measures to structural interventions for reducing the impacts of LTI on Asian elephants. These approaches are designed to modify human behaviours and improve the safety of both elephants and humans. They are particularly useful in areas where structural mitigation may be infeasible or insufficient. Motorist alert systems, including signage and flashing lights, warn drivers of potential elephant crossings and are intended to modify driver behaviour through reduced vehicular speed and increased alertness. Traffic calming measures, such as speed bumps or rumble strips, are another effective strategy to reduce vehicle speed and improve driver reaction time in high-risk zones, decreasing the likelihood of a collision with animals on or approaching the road. When traffic calming measures are integrated with effective signage within designated (place-specific) high-incidence elephant crossing zones, they have the potential to be quite effective, but more studies are needed.

Technological innovations, such as thermal imaging cameras and real-time warning systems, represent another promising avenue for non-structural mitigation. These systems can detect elephants near railways or highways and relay alerts to train operators or motorists, providing critical time to prevent collisions. Additionally, scheduling train and traffic operations to avoid peak elephant activity periods, such as nighttime or crop harvesting seasons, has proven effective in reducing train-elephant collisions in some regions.

Citation

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