
LET US BREATHE
LET US BREATHE
Solutions for Wild Elephant & Human Conflict in Sri Lanka
Mobile Vet Hospital
AI Early Warning System
Solar-Lit Elephant Crossings
Designed and Operated by "Hellenic Lemurians (PVT) Ltd"

LET US BREATHE

By Hellenic lemuria Pvt Ltd

Let us breathe (Elephant-Friend) Mobile Veterinary & Emergency Response Unit

Implementing Organization:"Let Us Breathe" Project
Project Location:Sri Lanka, with a primary focus on regions with high Human-Elephant Conflict (HEC) such as the North Western, North Central, Eastern, and Uva Provinces.

1.0 Executive Summary

The "Let Us Breathe" project proposes the establishment of a state-of-the-art Mobile Veterinary Hospital Truck, named the "Aathi-Mithra" Unit, to provide rapid, advanced, and life-saving medical interventions for injured wild elephants across Sri Lanka. Sri Lanka has one of the highest rates of Human-Elephant Conflict (HEC) in the world, resulting in hundreds of elephant deaths and injuries annually from gunshots, hakka patas (explosive traps), electrocution, and train accidents.

Current wildlife veterinary services, though valiant, are hampered by a lack of mobile, fully-equipped facilities, often leading to critical delays and compromised treatment in the field. The Aathi-Mithra Unit is a custom-built, all-terrain truck that will function as a fully operational surgical and medical clinic on wheels. It will be equipped with advanced veterinary medical equipment, on-board power generation (including solar), and camping facilities for staff, enabling extended operations in remote, off-road locations.

This project will directly contribute to reducing elephant mortality, alleviating suffering, and supporting the conservation of this iconic and endangered species in Sri Lanka.

2.0 Background and Problem Statement

The Crisis:·

- High Mortality: Approximately 400-500 elephants and over 100 humans die each year due to HEC in Sri Lanka.
- Brutal Injuries: Elephants are frequently victims of:
- Hakka Patas: Crude explosive devices hidden in food, causing horrific facial and jaw injuries, leading to slow, painful death by starvation and infection.
- Gunshot Wounds: Leading to embedded pellets, deep tissue damage, and bone fractures.
- Electrocution: From illegal power lines, causing instant death or severe burns.
- Train Accidents: A persistent cause of mortality on certain railway tracks.
- Limitations of Current Response: The Department of Wildlife Conservation (DWC) veterinarians are highly dedicated but often must rely on transporting bulky equipment in separate vehicles or performing complex procedures in suboptimal field conditions. The lack of a mobile, integrated facility leads to:
  - Delayed response times.
  - Inability to perform complex surgeries on-site.
  - Risk of infection from non-sterile environments.
  - Logistical challenges for staff during multi-day rescue missions.

3.0 Project Goal and Objectives

Goal: To significantly improve the survival rate and welfare of injured wild elephants in Sri Lanka through the deployment of a rapid-response, advanced mobile veterinary unit.

Objectives:

1. To deploy a custom-built, all-terrain mobile hospital truck within 12 months.
2. To reduce the average response time to an injured elephant report in target zones by 40%.
3. To enable on-site advanced medical procedures (surgery, radiography, dental work) that are currently not feasible in the field.
4. To provide a self-sufficient base for veterinary teams, allowing for 72-hour continuous field operations without external support.
5. To collaborate with and augment the existing efforts of the Sri Lankan Department of Wildlife Conservation (DWC).

4.0 The "Aathi-Mithra" Mobile Hospital Truck: Technical Specifications

The vehicle will be a robust, multi-axle truck designed for extreme off-road conditions.

4.1 Chassis and Mobility:·

Base Vehicle: A heavy-duty 4x4 or 6x6 truck chassis (e.g., TATA, Ashok Leyland, or UD Trucks) with high ground clearance.
Tyres: All-terrain, run-flat tyres.
Suspension: Heavy-duty, reinforced suspension for rough terrain.
Winch: A front-mounted electric winch (e.g., 12,000 lbs capacity) for self-recovery.
Lighting: Roof-mounted, 360-degree LED floodlights for night operations.

4.2 Medical and Surgical Facilities:

The truck body will be a customized,shock-proof, and insulated container divided into sections:

- Sterile Surgical Bay:
- Portable veterinary anesthesia machine with ventilators.
- Portable multi-parameter patient monitor (ECG, SpO2, NIBP, EtCO2).
- Surgical instrument sets for major and minor surgery.
- Mobile high-frequency digital X-ray system.
- Ultrasound machine.
- Portable oxygen concentrator.
- Pharmacy and Medical Storage:
- Refrigerated compartment for vaccines and sensitive drugs.
- Comprehensive inventory of antibiotics, sedatives (e.g., Etorphine/Ketamine), analgesics, anti-inflammatories, and wound care supplies.
- Immobilization equipment: Dart guns (pneumatic and cartridge), darts, and protective gear.
- Diagnostic and Treatment Area:
- Dental kit for treating jaw injuries from hakka patas.
- Endoscopy system.
- Water-proof wound debridement and cleaning station.

4.3 Power and Utility Systems:

- Primary Power: A silent, diesel-powered generator (15-20 kVA) housed in a soundproof compartment.
- Secondary/Sustainable Power: Roof-mounted, high-efficiency solar panels (2-3 kW system) connected to a battery bank with an inverter. This ensures silent operation during sensitive procedures and provides backup power.
- Water System: On-board fresh water tank (200-300L) and a grey water tank.
- Climate Control: A robust air-conditioning and heating system to maintain a stable temperature for drugs, equipment, and patient care.

4.4 Staff and Camping Facilities:

- Cabin Area: Seating for the driver and 2-3 team members.
- Rear Living Quarters: A compact, convertible space with:
- Bunks for 2-3 staff to rest in shifts.
- A small galley with a refrigerator, microwave, and sink.
- Storage for personal gear and food supplies.

External Awnings: Side-deployable awnings to create shaded outdoor work and rest areas.

4.5 Communication and Navigation:·

VHF/HF Radio: For communication in areas with no cellular coverage, coordinating with DWC.
Satellite Phone: For emergency communication anywhere on the island.
GPS Navigation System.

5.0 Operational Protocol

1. Alert: Receive a call from DWC, police, or community informants about an injured elephant.
2. Mobilization: The Aathi-Mithra unit is dispatched from its base station, with the veterinary team alerted.
3. Assessment & Immobilization: On-site, the team assesses the elephant and, if safe, administers a sedative dart.
4. On-Site Treatment: The elephant is treated at the location using the mobile hospital's facilities. This could range from wound cleaning and medication to complex surgery and radiography.
5. Monitoring & Recovery: The elephant is monitored until it safely stands and rejoins its herd.
6. Post-Operation: The team de-briefs, restocks supplies, and prepares for the next call.

Note: Costs can vary significantly based on supplier choices, import taxes, and specific equipment models.

7.0 Stakeholders and Partnerships·

- Primary Partner: Sri Lanka Department of Wildlife Conservation (DWC) - for operational coordination, permits, and veterinary collaboration.
- Technical Advisors: Wildlife veterinarians from Sri Lanka and international experts.
- Funding Partners: Corporate sponsors, international conservation NGOs (e.g., IUCN, WWF), and public donations.
- Community: Local villagers who act as informants and first responders.

8.0 Sustainability and Monitoring·

- Sustainability: After the initial capital investment, the project will require annual funding for operational costs. A dedicated fund and ongoing fundraising will be established. Partnerships with corporate entities for "adopting" annual running costs are a key strategy.
- Monitoring & Evaluation (M&E): Success will be measured by:
- Number of elephants treated successfully.
- Response time metrics.
- Types of procedures performed.
- Survival rates post-treatment.
- Regular reports will be published for donors and the public.

9.0 Conclusion

The "Let us breath" Mobile Veterinary Hospital is not just a vehicle; it is a paradigm shift in wildlife emergency care in Sri Lanka. It represents a direct, practical, and powerful solution to a pressing conservation and animal welfare crisis. By bringing the hospital to the elephant, we can turn certain death into a second chance at life. The "Let Us Breathe" project is committed to making this vision a reality and invites partners to join this critical mission to safeguard Sri Lanka's national treasure for generations to come.

Part 1: Essential Equipment List

The mobile hospital must be equipped to handle the most common and critical injuries faced by wild elephants: gunshot wounds, hakka patas (jaw explosions), electrocution burns, and fractures. The equipment is categorized for clarity.

A. Immobilization & Anaesthesia

This is the most critical first step. The safety of the elephant and the team depends on this.

- Remote Drug Delivery System: Dart guns (pneumatic and cartridge-fired) for accurate dosing from a safe distance.
- Anaesthetic Drugs: Etorphine (M99) or Carfentanil (strictly controlled), Ketamine, Xylazine, and their antagonists like Naltrexone. A significant stock is needed as multiple elephants may need treatment in one trip.
- Portable Anaesthesia Machine: With a large-animal ventilator and vaporizer, capable of maintaining anaesthesia for hours during complex surgery.
- Oxygen Cylinders & Portable Oxygen Concentrator: Essential for life support during anaesthesia.

B. Surgical & Procedural Equipment

- Major Surgical Kit: Scalpels, forceps (various sizes), retractors, needle holders, scissors, all in large-animal sizes.
- Orthopaedic Kit: For fracture repair - bone plates, screws, drills, saws, and wire.
- Dental Kit: Specially designed extraction forceps, rasps, and picks for treating devastating hakka patas injuries to the jaw and teeth.
- Wound Debridement Kit: Scalpels, curettes, and pulsed lavage system (high-pressure irrigation) to clean contaminated wounds.
- Suturing Materials: Absorbable and non-absorbable sutures, staplers.

C. Diagnostic Equipment·

- Portable Digital X-Ray System: A must for diagnosing fractures, locating embedded shrapnel/bullets, and assessing jaw damage. The digital system allows for instant images.
- Ultrasound Machine: For assessing soft tissue damage, internal bleeding, and pregnancy checks. A portable, rugged model with a convex probe is ideal.
- Multi-Parameter Patient Monitor: To track the elephant's vital signs under anaesthesia, including:
- ECG (Electrocardiogram)
- SpO2 (Pulse Oximetry) - requires a specialised veterinary probe.
- NIBP (Non-Invasive Blood Pressure) - with large cuffs.
- EtCO2 (Capnography)
- Digital Thermometer with a large-animal probe.

D. Treatment & Support Equipment

- Electric Clippers: For shaving large areas of skin around wounds.
- Cold Laser Therapy Unit: For advanced wound healing and reducing inflammation.
- Infusion Pumps: For delivering IV fluids and drugs accurately over time.
- Large Animal Endoscopy Kit: For visual examination of internal injuries or retrieving foreign objects.

E. Pharmacy & Medical Consumables

- Refrigerator: A 12V/240V powered fridge for storing vaccines and sensitive drugs.
- Broad-Spectrum Antibiotics (Injectable and topical)·Anti-Inflammatory Drugs (e.g., Flunixin Meglumine, Phenylbutazone)
- Analgesics (Painkillers)
- Fluids: Large-volume bags of Ringers Lactate, Normal Saline for IV fluids.
- Bandages, Gauze, Antiseptics (Povidone-Iodine, Chlorhexidine) in bulk.

F. Vehicle & Base Support Systems

- Base Vehicle: A new or robust used 4x4 or 6x6 Truck Chassis (e.g., Tata, Ashok Leyland). A 6x6 is highly recommended for the worst off-road conditions.
- Customized Body: A reinforced, insulated container body with separate sections for surgery, diagnostics, and living quarters.
- Power Supply:
- Diesel Generator: 15-20 kVA, silent-type, mounted in a sound-proof compartment.
- Solar Power System: 3-4 kW system with panels on the roof, a battery bank (8-10 deep-cycle batteries), and a powerful inverter. This allows for silent, sustainable operation in the field.
- Water System: 300-500L fresh water tank with a pump and a separate grey water tank.
- Climate Control: A powerful, split-type air conditioning unit for the medical bay.
- External Lighting & Winch: Roof-mounted LED light bars for night operations and a heavy-duty winch for vehicle recovery.
- Staff Facilities: Fold-down bunks, small kitchenette with sink, and storage for food and personal gear.

G. Communication & Navigation·

- VHF Radio: For communication with Department of Wildlife Conservation (DWC) networks.
- Satellite Messenger/Phone: (e.g., Garmin inReach, Iridium) for areas with no cellular coverage.·
- Toughbook Laptop: For storing medical records and X-ray images.

Part 2: Estimated Cost in Sri Lankan Rupees (LKR)

Important Note: These are estimates. Prices can fluctuate due to import taxes, shipping, currency exchange rates, and supplier choice. A significant portion of the high-end medical equipment will need to be imported.

Cost Breakdown:

Category Estimated Cost Range (LKR) Notes

1. Vehicle & Chassis 25 - 40 Million New 6x6 truck chassis. A good-quality used chassis can reduce cost.

2. Custom Body & Fit-out 15 - 25 Million Includes insulation, electrical wiring, plumbing, partitions, awnings, and labour.

3. Medical Equipment 40 - 70 Million This is the most variable cost. A portable X-ray alone can be LKR 8-15 Million. Anaesthesia machines, monitors, and ultrasound are also very expensive.

4. Power & Utility Systems 4 - 7 Million Generator (LKR 1-1.5M), Solar System (LKR 1.5-2.5M), Water systems, A/C.

5. Immobilization & Pharmacy 8 - 15 Million Dart guns, initial stock of controlled drugs, and a full pharmacy.

6. Communication & Misc. 2 - 4 Million Radios, satellite device, laptop, tools, etc.

7. Contingency & Import Fees (10-15%) 10 - 20 Million Crucial. For unplanned costs, taxes, and agent fees.

8. First-Year Operational Cost 3 - 5 Million Fuel, maintenance, drug restocking, staff allowances.

TOTAL ESTIMATED PROJECT COST: LKR 107 - 186 Million

(Approx. USD 350,000 - 600,000 as of mid-2024)

- Key Recommendations and Next Steps1. Phased Approach: Given the high cost, consider a phased implementation:
  - Phase 1: Acquire the base vehicle and fit it with essential immobilization, surgical, and power systems.
  - Phase 2: Fundraise for high-cost diagnostic items like the X-ray and ultrasound.

2. Strategic Partnerships: Partner directly with the Department of Wildlife Conservation (DWC). They can facilitate import permits for controlled drugs and equipment and provide invaluable operational support.

3. Corporate Sponsorship: This project is ideal for CSR (Corporate Social Responsibility) funding from large Sri Lankan companies. The mobile unit can be branded with sponsor logos.

4. International Grants: Apply for grants from international conservation organizations like the IUCN, WWF, or the Born Free Foundation.

5. Equipment Donations: Approach international veterinary equipment manufacturers for donations or heavily discounted prices as part of their corporate social responsibility.

This mobile hospital truck represents a transformative investment in Sri Lanka's wildlife conservation. While the initial cost is significant, its potential to save dozens of endangered elephants every year, reduce immense suffering, and support frontline veterinarians makes it an invaluable and urgently needed asset.

"Let us breathe" (Elephant Guard) AI-Powered HEC Mitigation and Early Warning PlatformImplementing Organization

"Let Us Breathe" ProjectProject Location:Sri Lanka, with initials deployment in high-conflict zones

(e.g., North Western, North Central, Eastern, and Uva Provinces).

1.0 Executive Summary

The "Let us breath" project proposes a strategic, technology-driven solution to Sri Lanka's persistent and deadly Human-Elephant Conflict (HEC). By leveraging ten years of historical HEC data, modern sensor technology, and advanced Artificial Intelligence (AI), this project will establish a centralized monitoring and decentralized early warning system.

The system will feature a Main Control Room for data fusion, AI analysis, and strategic oversight, supported by Regional Control Offices for on-ground coordination. The core deliverable is a public-facing mobile application that delivers real-time, location-specific alerts to communities, empowering them to take proactive measures. This data-driven approach aims to transform HEC management from reactive to predictive, significantly reducing fatalities and economic losses for both humans and elephants.

2.0 Background and Problem Statement

Sri Lanka has one of the world's highest rates of HEC, with tragic consequences:

- Annual Deaths: Approximately 400-500 elephants and over 100 humans die each year.·
- Economic Loss: Widespread crop and property damage devastates rural livelihoods.
- Limitations of Current Methods: While physical barriers (electric fences) and traditional watchtowers are used, they are often:
- Reactive, not Proactive: They respond to elephant presence after it occurs.
- Spatially Limited: Fences can be breached, and they disrupt elephant corridors.
- Data Silos: Historical incident data is often underutilized, stored in disparate formats across different government departments, preventing holistic analysis.

There is a critical need for an integrated, intelligent system that can predict conflict before it happens and warn people instantly.

3.0 Project Goal and Objectives

Goal: To drastically reduce human and elephant casualties due to HEC by deploying a predictive, AI-powered early warning system.

Objectives:

1. To develop and train a proprietary AI model on 10 years of historical HEC data to identify high-risk zones and predict elephant movement patterns.
2. To establish a National HEC Control Room and a network of Regional Control Offices.
3. To deploy a hybrid sensor network (camera traps, community reports, satellite data) for real-time elephant location tracking.
4. To develop and launch a user-friendly mobile application ("Gaja-Suraksha") for disseminating early warnings and collecting community data.
5. To achieve a 50% reduction in HEC-related human and elephant fatalities in target districts within three years of full operation.

4.0 System Architecture: The "Gaja-Suraksha" Platform

The system is built on four interconnected pillars:

4.1 Data Layer: The Foundation

- ·Historical Data Ingestion: The AI will be trained on a decade of data from:
- Department of Wildlife Conservation (DWC) incident reports.
- Police records of HEC incidents.
- Satellite imagery (to map land-use changes, crop patterns, and water source availability over time).
- Climate and seasonal data (droughts, monsoons).· Real-Time Data Inputs
- Community Sighting Network: Citizens can report elephant sightings via the mobile app (with photo/video/GPS), creating a crowdsourced surveillance network.
- Strategic Sensor Grid: Motion-triggered thermal and infrared camera traps placed in key elephant corridors and conflict zones.
- Satellite & Drone Data: Periodic analysis of satellite imagery to detect herd movements and habitat changes.

4.2 AI & Analytics Layer: The "Brain"

- ·Predictive Modeling: The core AI engine will use Machine Learning (ML) algorithms to:
- Predict High-Risk Spatio-Temporal Zones: Identify when and where conflict is most likely based on historical patterns, crop ripening cycles, and lunar cycles (elephants are often more active on dark nights).
- Model Elephant Movement Corridors: Analyze past movement data to predict likely routes from forests to farmland.
- Real-Time Alert Triangulation: The AI will cross-reference a community sighting with other nearby sensor data and predicted risk models to validate the threat before issuing a widespread alert, minimizing false alarms.

4.3 Operational Layer: The "Nerve Center"

- Main Control Room (Colombo or Central Location):
- Houses the central servers and AI processing unit.
- Staffed by data scientists, wildlife biologists, and GIS specialists.
- Monitors the national picture, refines AI models, and coordinates with national agencies.·
- Regional Control Offices (e.g., Habarana, Thanamalwila):
- Located in high-conflict zones.
- Staffed by local operators and DWC liaison officers.
- Validate local alerts, manage the regional sensor network, and coordinate rapid response teams (e.g., DWC elephant drivers - Hakka Patas units).

4.4 User Interface Layer: The "Lifeline" - Mobile Application

The"Gaja-Suraksha" app will have two main interfaces:

- Public App (For Villagers and Farmers):
- Real-Time Alerts: Receive push notifications with critical details: "ELEPHANT ALERT: A lone tusker is 2km west of Village X, moving south. Stay indoors."
- Interactive Risk Map: View a live map showing current alerts, high-risk zones, and safe areas. ·
- Sighting Reporting: One-touch reporting to send an elephant's location, number, and direction of travel directly to the system.
- Educational Resources: Information on elephant behavior and safety procedures
- Admin Dashboard (For Control Rooms):
- A web-based platform to visualize all data streams, manage alert issuance, monitor system performance, and generate detailed reports on conflict trends and intervention effectiveness.

5.0 Technology Stack

- Backend: Cloud-based servers (AWS/Azure) for scalability, running Python/R for data science and AI model training.
- AI/ML Frameworks: TensorFlow, PyTorch for developing predictive models.
- Database: PostgreSQL with PostGIS extension for managing large, location-based datasets.·
- Frontend: React Native for the cross-platform mobile app.
- Mapping & GIS: Google Maps API or OpenStreetMap for real-time mapping and geolocation services.

6.0 Implementation Plan (Phased Approach)

- Phase 1: Foundation (Months 1-6): Data collection, cleaning, and AI model development. Establish the Main Control Room. Develop the app's core features.
- Phase 2: Pilot Deployment (Months 7-12): Launch in one high-conflict district (e.g., Hambantota). Set up one Regional Office. Deploy initial sensor network. Begin community onboarding and training.·
- Phase 3: National Rollout (Year 2): Expand to 3-4 additional districts, establishing more Regional Offices. Refine AI based on pilot data.
- Phase 4: Consolidation & Scaling (Year 3+): Full national coverage. Integration with other government systems (e.g., disaster management).

8.0 Stakeholders and Partnerships

- Lead: "Let Us Breathe" Project.
- Government Partners: Department of Wildlife Conservation (DWC) (essential for data and operational integration), Ministry of Environment, Sri Lanka Police.
- Technical Partners: Local universities (e.g., University of Peradeniya, Moratuwa for IT), software firms.
- Funding Partners: International development agencies (UNDP, World Bank), conservation NGOs, corporate CSR programs.
- End-Users: Rural farming communities, local village councils (Grama Niladhari).

9.0 Monitoring, Evaluation, and Sustainability (M&E)

- Key Performance Indicators (KPIs):
- Reduction in human and elephant fatalities/injuries.
- Number of active app users and alerts issued.
- Reduction in crop damage claims.
- Alert accuracy rate (minimizing false positives).
- Sustainability Model:
- Initial grant funding for setup.
- Long-term funding through government adoption into the DWC budget.
- Partnerships with telecom companies for free data transmission of alerts. ·
- Potential Premium Features: (Optional) Insurance tie-ups for farmers, where the app data verifies claims.

10.0 Conclusion

The "Let us breath" platform represents a paradigm shift in addressing Sri Lanka's HEC. By moving from a reactive to a predictive and proactive model, it empowers communities with information, optimizes government resources, and ultimately creates a safer coexistence for both humans and elephants. This project leverages Sri Lanka's high mobile penetration rate to create a national shield, saving lives and securing livelihoods through the power of data and artificial intelligence.

"Let us breathe" AI-Powered HEC Platform - Hardware, Software & Cost Analysis

Prepared for: "Let Us Breathe" ProjectFocus:Establishing the technological backbone for an AI-based Human-Elephant Conflict early warning system.

Part 1: Essential Hardware & Software Requirements

The system's architecture requires a blend of field sensors, central computing infrastructure, and sophisticated software. Here is a detailed breakdown.

A. Hardware Requirements

1. Data Center & Control Room Hardware (Main & Regional Offices):

- Main Control Room (Colombo/Central):
- High-Performance Servers: For hosting the AI models, database, and core application software.
- AI/ML Server: GPU-accelerated servers (e.g., with NVIDIA A100 or RTX 4090 cards) for rapid model training and inference.
- Database Server: High-RAM, multi-core server for handling large geospatial datasets.
- Application/Web Server: For hosting the admin dashboard and API.
- Network Attached Storage (NAS)/Storage Array: For storing 10+ years of historical data, satellite imagery, and real-time sensor data. Requires high capacity (100+ TB) and redundancy (RAID configuration).
- Network Infrastructure: Enterprise-grade routers, switches, firewalls, and redundant high-speed internet connections (fibre + 4G/5G backup).
- Workstations: High-spec PCs for data scientists and operators, with large monitors for the dashboard.
- Video Wall/Large Display: A large screen or video wall to display the live national risk map, active alerts, and system status.
- Regional Control Offices (e.g., Habarana, Thanamalwila):
- Ruggedized Workstations/Laptops: For local operators.
- Communication Hub: VHF/HF radio base stations to communicate with field staff and DWC networks.
- Uninterruptible Power Supply (UPS): For all critical equipment.
- Backup Power Generator: For extended power outages.

2. Field Deployment Hardware (Sensors & Data Collection):

- Thermal & Infrared Camera Traps: These are crucial for 24/7 monitoring, especially at night. They need to be:
- Weatherproof & Rugged.
- Solar-powered with battery backup.
- Equipped with 4G/LTE modems for real-time image transmission.
- Acoustic Sensors: To detect elephant vocalizations and human-generated noises (firecrackers, etc.) that indicate conflict.
- Community Kits: While most public use personal phones, providing a few rugged, weather-proof smartphones to key community "wardens" in remote villages ensures consistent reporting.·
- Drone (UAV) for Verification: A commercial-grade drone with a thermal camera for verifying alerts, tracking elephant movement from a safe distance, and assessing damage.

B. Software Requirements

1. Core AI & Data Analytics Platform:

- AI/ML Frameworks: TensorFlow or PyTorch for building, training, and deploying the predictive machine learning models.
- Data Processing & Analysis: Python with libraries like Pandas (data manipulation), Scikit-learn (classical ML), GeoPandas (spatial data), and Rasterio (satellite imagery).
- Geographic Information System (GIS) Software: QGIS (open-source) or ArcGIS (commercial license) for analyzing and visualizing spatio-temporal data, mapping corridors, and creating risk maps.

2. Database & Backend:

- Database System: PostgreSQL with the PostGIS extension. This is the industry standard for handling complex geospatial data (e.g., elephant movement points, village boundaries, risk polygons).
- Backend Framework: Node.js or Django (Python) to build the server-side logic, API endpoints, and handle user authentication.

3. Frontend & Mobile Applications:

- Mobile App (Public): Developed using a cross-platform framework like React Native or Flutter (for iOS and Android from a single codebase).
- Web Dashboard (Admin): Built using a modern JavaScript framework like React.js or Vue.js for a dynamic and interactive interface for control room staff.

4. Cloud & Infrastructure (Recommended):

- Cloud Hosting (AWS, Google Cloud, or Azure): More scalable and reliable than on-premise servers for a national-level project. Key services would include:
- EC2/Virtual Machines: For servers.
- S3/Cloud Storage: For data backup and image storage.
- Relational Database Service (RDS): For managed PostgreSQL.
- Mapping Services: Google Maps API, Mapbox, or OpenStreetMap for the base maps in the app and dashboard.

5. Communication & Integration:

- SMS Gateway API: For sending alerts to users without smartphones or in areas with poor data connectivity (e.g., via Dialog Axiata or SLT APIs).
- Push Notification Services: Firebase Cloud Messaging (FCM) for Android and Apple Push Notification Service (APNS) for iOS.

Part 2: Estimated Cost in Sri Lankan Rupees (LKR)

Important Note: These are estimates. Software development costs are highly variable based on team rates and feature complexity. Hardware costs are subject to import taxes and supplier markups.

Cost Breakdown:

ICategory Item Description Estimated Cost (LKR) Notes

1. Hardware & Infrastructure ~45,000,000 - 75,000,000
   Main Control Room Servers & Storage 15,000,000 - 25,000,000 GPU servers are a major cost.
   Main Control Room Networking & Displays 5,000,000 - 8,000,000 Video wall, routers, switches.

   Regional Office Setup (x4 offices) 8,000,000 - 16,000,000 Laptops, comms, generators (LKR 2-4M each).
   Field Sensors (Cameras, Acoustic) 12,000,000 - 18,000,000 50-100 units at LKR 120,000 - 250,000 each.
   Drones & Community Kits 5,000,000 - 8,000,000 2-3 professional drones + 50 rugged phones.

2. Software & Development ~25,000,000 - 50,000,000 Most variable cost.

- AI Model Development & Training 8,000,000 - 15,000,000 Data cleaning, model building, iteration.
- Mobile App Development (Public) 7,000,000 - 12,000,000 Cross-platform (iOS & Android).
- Web Dashboard Development (Admin) 6,000,000 - 10,000,000 Complex, real-time, with map visualizations.
- Backend & API Development 4,000,000 - 8,000,000 Server, database integration, logic.
- Third-party Licenses & APIs (3 yrs) 2,000,000 - 5,000,000 Map APIs, SMS gateways, cloud credits.

3. Data & Professional Services ~8,000,000 - 15,000,000

Historical Data Digitization & Cleaning 3,000,000 - 6,000,000 Labor-intensive process.
GIS Data Procurement & Setup 1,000,000 - 2,000,000 High-resolution maps, land-use data.
Project Management & System Integration 4,000,000 - 7,000,000 Essential for coordinating all parts.

4. Contingency (15-20%) ~12,000,000 - 20,000,000 For unforeseen costs and price fluctuations.

5. First-Year Operational Cost ~6,000,000 - 10,000,000 Salaries, cloud subscriptions, fuel, maintenance.

TOTAL ESTIMATED PROJECT COST LKR 96 - 170 Million

(Approx. USD 315,000 - 560,000 as of mid-2024)

Key Recommendations and Implementation Strateg

1. Phased Procurement & Agile Development:

- Phase 1 (Months 1-6): Focus on data digitization, AI model development, and building the core backend and a basic version of the mobile app. Procure essential servers and a pilot set of sensors.
- Phase 2 (Months 7-18): Develop the advanced admin dashboard, deploy the full sensor network in pilot districts, and establish the regional offices. Begin public rollout of the app.
- Phase 3 (Year 2+): National scaling, system optimization, and feature additions based on user feedback.

2.Strategic Partnerships to Reduce Cost:

- University Collaboration: Partner with universities like University of Moratuwa or Peradeniya. Computer Science students can contribute to software development as projects, and Environmental Science departments can assist with data analysis. ·
- Telecom Partnerships: Negotiate with Dialog, SLT Mobitel, etc., for heavily discounted or free SMS and data bundles for alerts and sensor transmission.
- Cloud Credits: Apply for cloud service grants (e.g., Google Cloud for Startups, AWS IMAGINE Grant) which can significantly reduce hosting costs.

3. Open-Source First: Prioritize open-source solutions (QGIS, PostgreSQL, TensorFlow) wherever possible to minimize licensing fees.

This comprehensive technological framework provides a solid foundation for the "Let us breath" platform. While the initial investment is substantial, the potential to save human and elephant lives, protect livelihoods, and create a national asset for wildlife conservation makes it a critically justifiable and impactful project.

"Let us breathe" (Elephant Protection) Road & Railway Elephant Crossing Early Warning System

Implementing Organization:"Let Us Breathe" ProjectProject Location:Sri Lanka, initially targeting high-fatality zones on railway lines (e.g., Galgamuwa-Palawatha) and roads (e.g., Habarana-Palawatha, Monaragala-Panama).

1.0 Executive Summary

The "Gaja-Raksha" project proposes a physical, on-ground early warning system to directly prevent collisions between vehicles/trains and wild elephants at identified high-risk crossing points. This system complements the proposed AI-based mobile app by providing an immediate, localized visual alert for drivers.

The system utilizes a network of thermal and motion sensors to detect large animal movement approaching the road or railway. Upon detection, it triggers highly visible flashing warning lights and LED signage powered by solar energy, alerting drivers to slow down and proceed with caution. Installed on both sides of the transit corridor, this system operates 24/7, providing a critical layer of protection to reduce elephant and human fatalities, safeguard livelihoods, and prevent economic damage.

2.0 Background and Problem Statement

Collisions with trains and vehicles are a significant and gruesome cause of death for Sri Lanka's wild elephants.

- Railway Collisions: Dozens of elephants are killed on railway tracks every year, particularly on stretches cutting through known elephant corridors. These incidents often occur at night and result in devastating injuries to the animals and significant damage to trains.
- Road Accidents: Elephants crossing roads, especially at night, are frequently hit by speeding vehicles, leading to death, injury, and dangerous situations for passengers.
- Current Limitations: Existing measures, such as signboards, are passive and often ignored. There is no active, real-time warning system that alerts a driver to an elephant's immediate presence on the track or road ahead.

3.0 Project Goal and Objectives

Goal: To eliminate fatalities and injuries to wild elephants and humans caused by collisions on roads and railways in Sri Lanka through an automated, solar-powered early warning system.

Objectives:

1. To identify and map the top 10 most critical elephant crossing points on railways and roads within the first 3 months.
2. To design, install, and commission a robust, solar-powered sensor-and-light warning system at all 10 locations within 12 months.
3. To achieve a 90% reduction in elephant-vehicle collisions at the implemented sites within one year of operation.
4. To create a modular and scalable system model for future nationwide deployment.

4.0 System Design & Technical Specifications

The system is designed for reliability, energy independence, and minimal maintenance.

4.1 Detection System:

- Primary Sensor: Long-Range Passive Infrared (PIR) Motion Sensors coupled with Thermal Imaging Cameras. The dual-system reduces false alarms (e.g., from deer or cattle) by confirming the heat signature and size of an elephant.
- Placement: Sensors are mounted on 4-5 meter high poles, set back 50-100 meters on both sides of the road/railway, creating a "detection curtain" that triggers as an elephant approaches.

4.2 Warning System:

- Visual Alerts:
- High-Intensity Flashing Amber Beacons: Powerful, weatherproof LED lights that begin flashing upon detection. These are highly visible from a long distance, especially at night.
- LED Message Signs (Optional but recommended): Solar-powered variable message signs that display warnings like "ELEPHANT ON TRACK AHEAD - SLOW DOWN" or "ELEPHANT CROSSING - STOP".
- Placement: Warning lights and signs are installed on both sides of the road/railway, 300-500 meters before the crossing point, giving drivers adequate time to react.

4.3 Power & Control System:

- Solar Power:
- Solar Panels: High-efficiency monocrystalline solar panels (200W-300W per unit) mounted on the same poles.
- Battery Bank: Deep-cycle, maintenance-free lead-acid or Lithium-ion batteries with sufficient capacity (100Ah-200Ah) to power the system for 3-5 cloudy days.
- Control Unit: A central, weatherproof Programmable Logic Controller (PLC) at each site that:
- Processes data from the sensors.
- Activates the warning lights/signs.
- Can be programmed for sensitivity and delay settings.
- Includes a GSM/GPRS module to send alert data and system status reports (e.g., low battery, fault) to the main control room.

4.4 Structural Components:

- Galvanized Steel Poles: To mount sensors, lights, and solar panels, resistant to rust and elephant interference.
- Reinforced Concrete Foundations: To ensure stability and deter elephants from pushing over the units.

5.0 Implementation Plan

- Phase 1: Site Identification & Survey (Months 1-3):
- Collaborate with the Department of Wildlife Conservation (DWC) and railway authorities to analyze past accident data.
- Conduct field surveys to confirm elephant movement paths and identify the optimal points for system installation.
- Phase 2: System Design & Procurement (Months 4-6):
- Finalize technical designs.
- Procure all hardware components.
- Phase 3: Installation & Commissioning (Months 7-12):
- Install poles, foundations, and all hardware.
- Configure the control systems and test the detection and warning sequences. Integrate with the central monitoring system.
- Phase 4: Monitoring, Evaluation & Training (Ongoing):
- Monitor system performance and collision data.
- Train local DWC staff.
- Configure the control systems and test the detection and warning sequences.
- Integrate with the central monitoring system.
- Phase 4: Monitoring, Evaluation & Training (Ongoing):
- Monitor system performance and collision data.
- Train local DWC staff.

7.0 Stakeholders and Partnerships

- Essential Partners:
- Department of Wildlife Conservation (DWC): For permits, site selection expertise, and ongoing monitoring.
- Sri Lanka Railways: For access to railway land and coordination with train schedules during installation.
- Road Development Authority (RDA): For permission to install systems along national roads.·
- Technical Partners: Local engineering firms, solar energy companies.
- Community: Local villages to help protect the infrastructure from vandalism and report any issues.

8.0 Sustainability, Maintenance, and Monitoring

- Sustainability: The project's sustainability is high due to its solar-powered design, eliminating electricity costs. The simple, robust technology requires minimal maintenance.
- Maintenance Plan:
- Routine Checks: Quarterly visits to clean solar panels, check electrical connections, and test system functionality.
- Remote Monitoring: The GSM module allows for remote system health checks, alerting technicians to faults before a site visit is needed.
- Monitoring & Evaluation (M&E):
- Primary KPI: Number of elephant-vehicle/train collisions at the site before and after installation. ·
- Secondary KPIs: System uptime (target: 98%), number of false alarms, driver compliance (can be observed via speed reduction).

9.0 Conclusion

The "Let us breat" Road & Railway Early Warning System is a practical, cost-effective, and directly impactful solution to a specific and deadly aspect of Human-Elephant Conflict. By providing an immediate, unambiguous warning to drivers, it empowers them to take action that saves lives. This project serves as a critical tangible intervention that can be deployed quickly and scaled effectively across Sri Lanka's most dangerous transit corridors, creating a safer future for both its people and its iconic elephant population

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

PROTECTING ASIAN ELEPHANTS FROM LINEAR TRANSPORT INFRASTRUCTURE

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

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

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

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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

Contents

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

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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

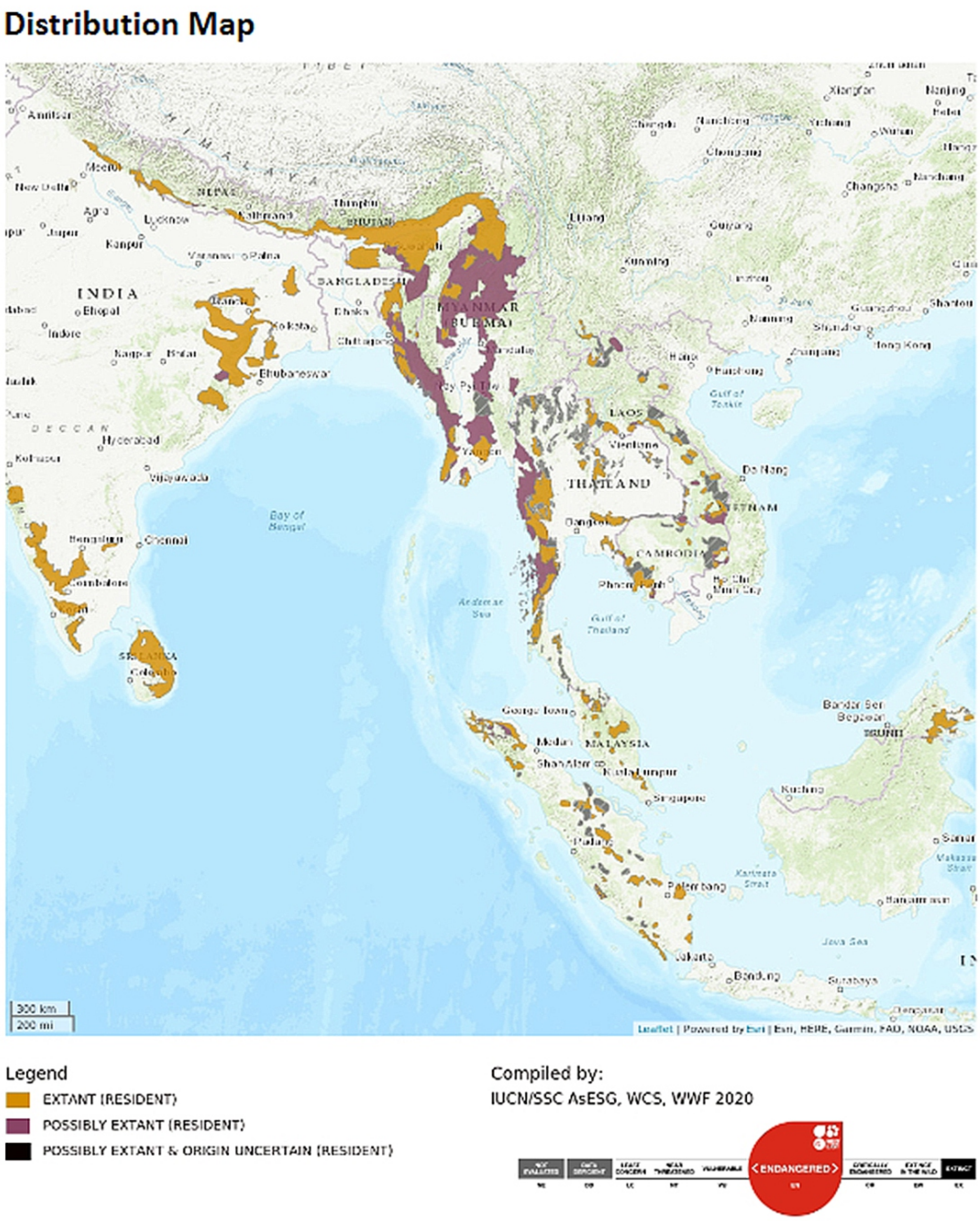


Figure 1. Map of historic and current wild Asian elephant population distribution.
| IUCN/SSC ASIAN ELEPHANT SPECIALIST GROUP, WILDLIFE CONSERVATION SOCIETY, WWF
(SOURCE: IUCN RED LIST OF THREATENED SPECIES, VERSION 2020-3)

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.

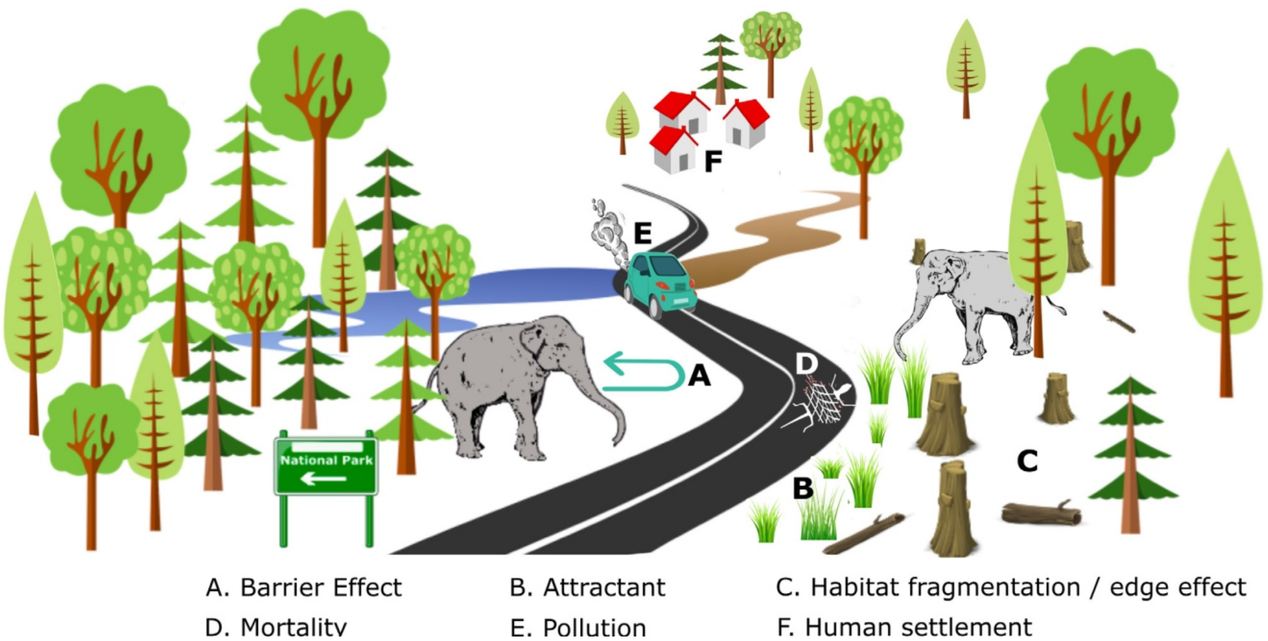


Figure 2. Schematic of ecological impacts from linear transport infrastructure.
| MELISSA BUTYNSKI / CENTER FOR LARGE LANDSCAPE CONSERVATION

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

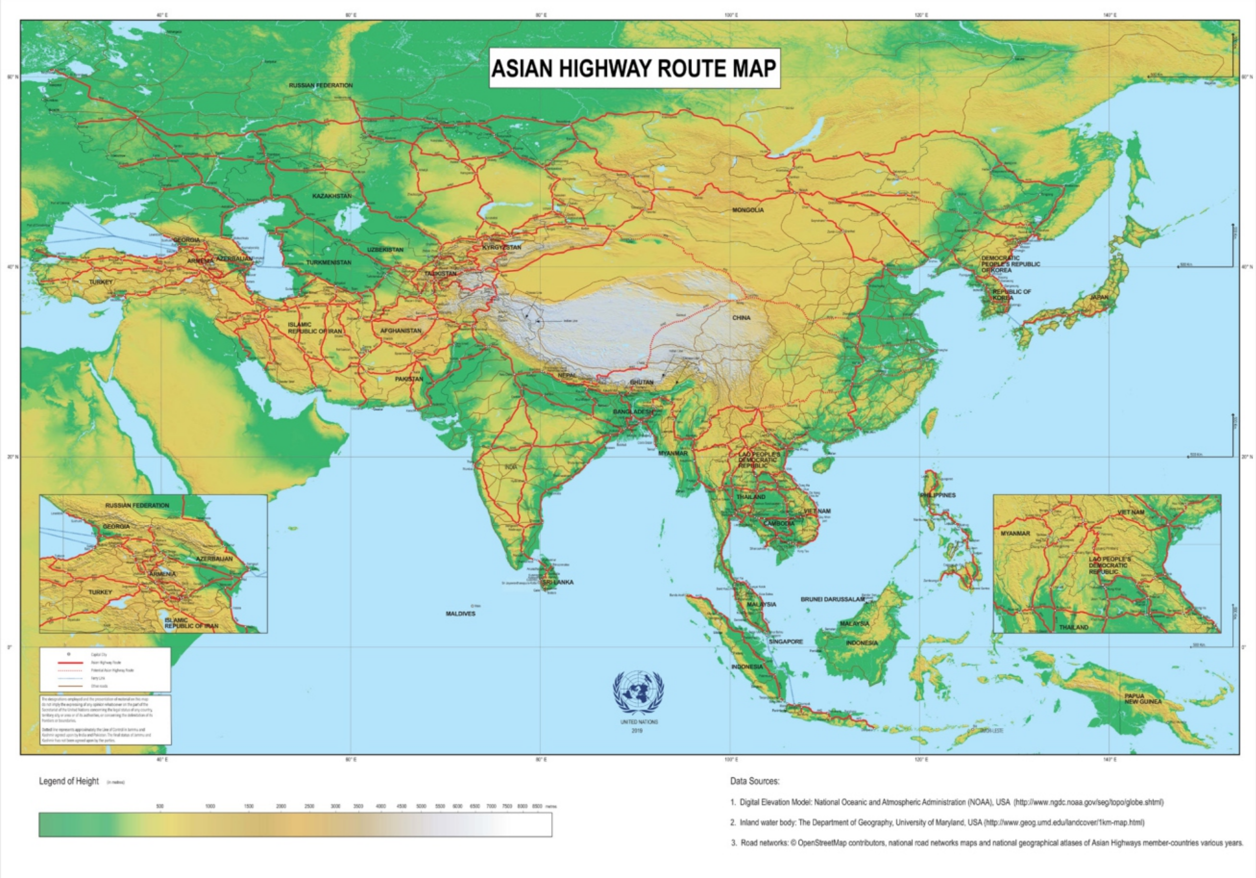


Figure 3. Map of the Asian Highway Network. | SECRETARIAT OF THE UN ECONOMIC AND SOCIAL COMMISSION FOR ASIA AND THE PACIFIC

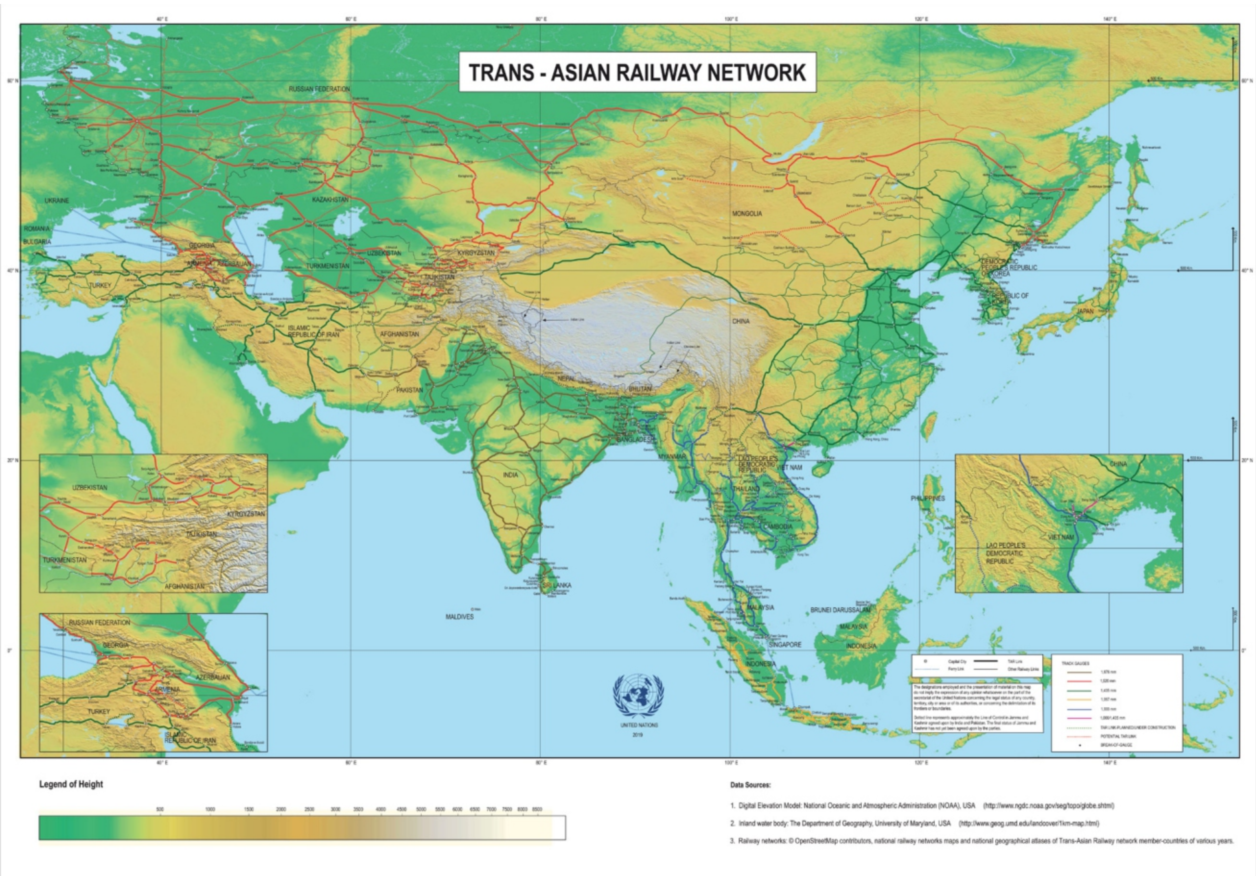


Figure 4. Map of the Trans-Asian Railway Network. | SECRETARIAT OF THE UN ECONOMIC AND SOCIAL COMMISSION FOR ASIA AND THE PACIFIC

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).

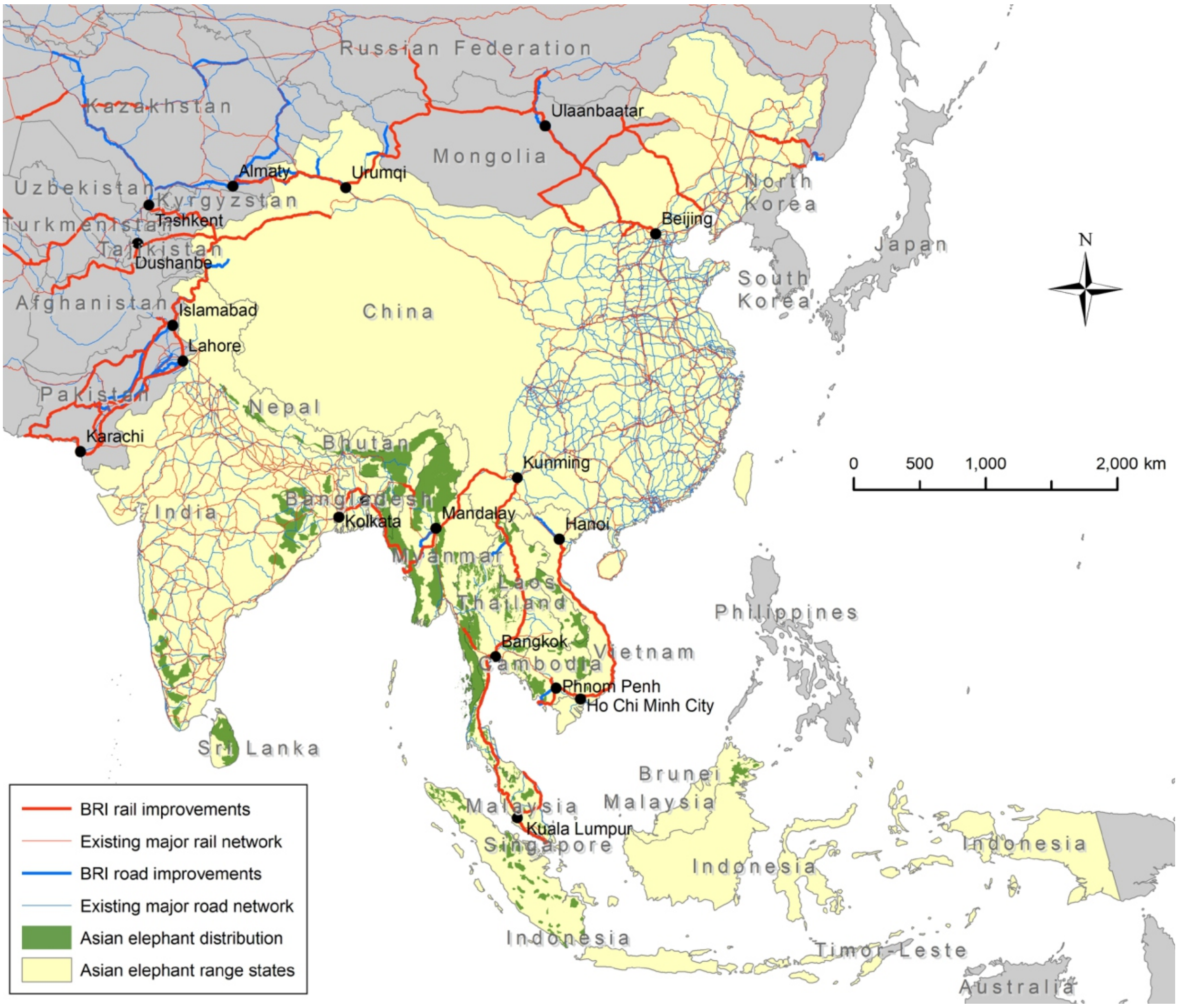


Figure 5. Map of Asian elephant distribution and the larger regional context of China's Belt and Road Initiative based on best available data in 2021. | TYLER CREECH / CENTER FOR LARGE LANDSCAPE CONSERVATION

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:

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

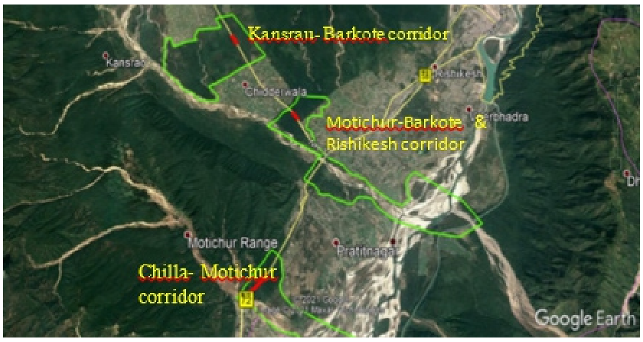
4.6. Bangladesh: Chittagong-Cox's Bazar Railway – Mitigating Impacts in Three Protected Areas

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

ADOBE STOCK

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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.

http://conservationcorridor.org/ccsg/working-groups/asetwg/
https://conservationcorridor.org/ccsg/membership/
connectivity@largelandscapes.org