ECO-FRIENDLY
MEASURES TO MITIGATE IMPACTS OF LINEAR INFRASTRUCTURE ON *wildlife*

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भारतीय वन्यजीव संस्थान
Wildlife Institute of India

Ministry of Environment, Forest & Climate Change

भारतीय राष्ट्रीय राजमार्ग प्राधिकरण
सड़क परिवहन एवं राजमार्ग मंत्रालय, भारत सरकार
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CONTENTS

अनिल माधव दवे
Anil Madhav Dave

सत्यमेव जयते

राज्य मंत्री (स्वतंत्र प्रभार)
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ENVIRONMENT, FOREST & CLIMATE CHANGE
भारत सरकार / GOVERNMENT OF INDIA

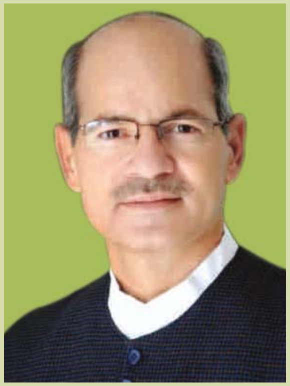
Message

'Development without Destruction' is the key facet of working of the Central Government and 'faster clearance but rigorous compliance' is the operational focus of the Ministry of Environment, Forest and Climate Change (MoEFCC). The challenge currently faced by the MoEFCC, Government of India, is to promote efficient and green infrastructure that facilitates economic growth and development, minimizes environmental impacts and protects biodiversity and ecosystem functions. Roads, railway tracks, power transmission lines and other linear infrastructure have become a pervasive component of the natural landscapes in India and their rapid expansion has the potential to radically transform these landscapes. The need of a proactive approach for a balanced growth provided the idea of preparing this guidance document.

This guide aims to give clear messages about the objectives and relevance of planning green infrastructure. It seeks to serve as a tool to enable road and rail agencies to work together with conservation agencies to maximise the opportunities presented by transportation and powerline projects, to minimise environmental impacts and enhance biodiversity and ecosystem services by promoting the development of green infrastructure.

I must compliment Dr. S. S. Negi, Director General of Forests & Special Secretary to the Government of India, MoEFCC and Dr. V. B. Mathur, Director, Wildlife Institute of India and their competent teams for preparing this excellent guidance document.

It is hoped that these guidelines will become standard good practice to linear infrastructure planners, helping to ensure that through better location and design, as well as ongoing 'learning by doing', the future of India's wildlife will be ensured whilst simultaneously minimising health and safety risks to people and rapidly promoting economic development.



Anil Madhav Dave

09 December, 2016
New Delhi

डॉ. एस. एस. नेगी
Dr. S. S. Negi

वन महानिदेशक एवं विषेष सचिव
भारत सरकार
पर्यावरण, वन एवं जलवायु परिवर्तन मंत्रालय
DIRECTOR GENERAL OF FOREST & SPL. SECY.
GOVERNMENT OF INDIA,
MINISTRY OF ENVIRONMENT, FOREST AND
CLIMATE CHANGE

Foreword

There needs to be a balance between development and conservation of nature including forest ecosystems. This assures more significance because many of our forest areas particularly tiger and elephant landscapes are becoming increasingly fragmented by roads, railways and other forms of linear developments that include powerlines and canals.

In order to address the challenges of harmonizing conservation and development, the MoEF&CC assigned the responsibility of preparing this guidance document to the Wildlife Institute of India. It is based on best available practices and concepts both nationally and globally and relevant to the Indian situation.

I congratulate Wildlife Institute of India for this timely effort of presenting eco-friendly measures to make developments in road and rail sectors both smart and green.

Dr. S.S. Negi

08 December, 2016
New Delhi

B.S. Bonal

सत्यमेव जयते

Additional Director General (Wildlife)
& Member Secretary,
National Tiger Conservation Authority,
Ministry of Environment, Forest and Climate Change
Indira Paryavaran Bhawan, New Delhi

Foreword

The paradox of socio-economic benefits from transportation and the deterioration of the natural systems at a still greater pace have compounded the complexities of issues for road planners and wildlife managers. Paved roads, rail and power transmission lines are increasingly becoming a prominent invasive feature of the natural landscapes that invariably include the tiger habitats across the country. Conservation community and the linear infrastructure development agencies need to work together to create unique opportunities to strategically promote linear developments for connecting people without compromising the quality of natural habitats that harbour wild animal and plant species.

This guidance manual is intended to share good practices and successful examples to help construct wildlife-friendly transportation systems. I see this as a significant contribution and an important step towards taking forward the conservation of tiger, the national animal of India, its co-predators, prey and the protection of wildlife habitats throughout the country.

B.S. Bonal

07 December, 2016
New Delhi

RAGHAV CHANDRA, I.A.S.
CHAIRMAN
राघव चंद्रा, आई.ए.एस.
अध्यक्ष

सत्यमेव जयते

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Foreword

As our lives are closely linked with the ability to travel and to transfer goods from one place to another, developments in road transportation sector are undeniably essential. We are also conscious of the fact that increased transportation opportunities can sometimes pose a conspicuous threat to the environment and the natural landscapes traversed by roads. It is essential, hence, to bring about ways to balance our needs and activities with respect to their effect on biodiversity and to ensure that transportation becomes 'greener' and more sustainable, so as to reduce its share in environmental threats.

Environmental protection, mitigation and sustainability have become the hallmark of NHAI's road building practice. The NHAI's intent is to encourage better, greener and more sustainable road systems across the expanses of our country. This holds true while considering not only the new road projects that are to be planned and constructed, but also the existing roads and motorways, and the way they are operated and maintained.

This guidance document prepared by WII should be a valuable resource for NHAI in building efficient road networks that help linking transportation and conservation.

Raghav Chandra

(Raghav Chandra)

13 May, 2016
New Delhi

Preface

The need to promote practices that integrate conservation concerns in infrastructure development are being universally acknowledged by planners, transportation agencies and ecologists in most countries. The need is even more emergent in India and other developing countries where the challenge to maintain healthy, living landscapes with the benefits they deliver invariably come in conflict with the expanding infrastructure development.

This practice document, perhaps the first for the country and also for South Asia region, has been developed to respond to this challenge of bridging the conservation-development divide by offering smart solutions to 'promote development with caution' in wildlife habitats within integrated landscapes. The principles, practices and advisories contained in this document are strongly grounded in science and are based on the efficacy of tried and tested interventions on ground by donor agencies such as the World Bank.

From being a ready reference for quick hints on 'what impacts how', this practice guide structured in four parts, provides detailed guidance for planning, locating, designing, implementing and operating smart green roads, railways and powerlines.

Part I, the introductory section of the guideline sets the scene: it starts by explaining the need for, and trends in, addressing wildlife conservation in the planning and implementation of linear infrastructure development, at an international and national level. It goes on to describe the current and projected future situation with regard to the development of roads, railway lines and powerlines in India, recognising the need for this development but simultaneously the potentially significant impacts and risks both for wildlife and people. An overview of the regulatory requirements related to roads, railways and powerline developments is then given, focusing on the environmental and forestry laws and responsibility for their application.

The spectrum of potential impacts typically linked to roads and railways, and to powerlines, is then systematically described and illustrated, drawing on experience and case studies both internationally and within India. Recognising the need to improve linear infrastructure planning, the guideline introduces and explains the hierarchy of mitigation measures that needs to be followed, prioritising avoidance or prevention of impacts, followed by their minimisation and adaptive management, and finally, compensation.

Part II sets out engineering (structural) and non-structural options for mitigation, focusing on the priority need to keep landscapes permeable and connected, allowing and encouraging wildlife movements and thus the viability of populations in the long term. Special sections of the document emphasise on the suitability of design of linear infrastructure in elephant and tiger habitats. Beyond engineering design options, non structural measures are described to minimise impacts of noise and lights, and to use a range of media, including signage, early warning systems and other approaches to minimise safety risks both to people and wildlife.

Part III of the guideline is devoted to the effective mitigation of powerline impacts on birdlife.

Part IV introduces the readers to a range of other valuable resources from around the world on more specific topics to complement the learning from this practice guide without essentially being conflicting or repetitive.

We strongly believe that concerted capacity building efforts are necessary to improve the uptake of guidance by key stakeholders particularly infrastructure planners, builders, multilateral finance institutions, donor agencies, environmental impact consultants, wildlife managers, environmental regulators, decision makers and policy analysts. Well-designed learning modules are being planned and these would be subsequently delivered for enhancing capacity for the uptake of learning from this practice document.

Dr. V.B. Mathur
Director
Wildlife Institute of India

LIST OF ACRONYMS & ABBREVIATIONS

Addl. PCCF	Additional Principal Chief Conservator of Forests
BRO	Border Roads Organisation
ADS	Animal Detection Systems
APLIC	Avian Power Line Interaction Committee
AVC	Animal Vehicle Collisions
CCF	Chief Conservator of Forests
CEC	Central Empowered Committee
CF	Conservator of Forests
Ckm	Circuit kilometre
CRZ	Coastal Regulation Zone
CZMA	Coastal Zone Management Authority
CZMP	Coastal Zone Management Plan
DAS	Distributed Acoustic Sensing
DC	District Commissioner
DFO	Divisional Forest Officer
DM	District Magistrate
Dy. Com.	Deputy Commissioner
EAC	Expert Appraisal Committee
EC	Environmental Clearance
EIA	Environmental Impact Assessment
ESZ	Eco-Sensitive Zone
FAC	Forest Advisory Committee
FC Rules	Forest Conservation Rules
GIS	Geographic Information System
GQ	Golden Quadrilateral
HVDC	High Voltage, Direct Current
HWC	Human-Wildlife Conflict
IAA	Impact Assessment Agency
IBA	Important Bird Area
IR	Indian Railways
IRF	International Road Federation
ITBP	Indo Tibetan Border Police
IUCN	International Union for Conservation of Nature
LAC	Line of Actual Control
LWE	Left Wing Extremism
MoEFCC	Ministry of Environment, Forest and Climate Change
NBWL	National Board for Wildlife
NGO	Non-Governmental Organisation
NH	National Highway
NHAI	National Highway Authority of India
NHDP	National Highway Development Programme
NPV	Net Present Value
NS-EW	North-South East-West
NTDPC	National Transport Development Policy Committee
NTFP	Non-Timber Forest Products
NCZMA	National Coastal Zone Management Authority
PA	Protected Area
PIT	Passive Integrated Transponder
RCC	Reinforced Cement Concrete
PCCF	Principal Chief Conservator of Forests
PMGSY	Pradhan Mantri Gram Sadak Yojana
PPP	Public Private Partnership
PWD	Public Works Department
RF/PF	Reserved Forest/ Protected Forest
RBS	Regional Base Station
SARDP-NE	Special Accelerated Road Development Programme in North East
SC-NBWL	Standing Committee - National Board for Wildlife
SEAC	State-level Expert Appraisal Committee
SEIAA	State Environmental Impact Assessment Authority
SH	State Highway
SPCB	State Pollution Control Board
TOR	Terms of Reference
UAV	Unmanned Aerial Vehicle
UNESCO	United Nations Educational, Scientific and Cultural Organization
UTPCC	Union Territory Pollution Control Committee
VIE	Visible Implanted Elastomer
WHO	World Health Organisation
WII	Wildlife Institute of India
WPA	Wildlife (Protection) Act
WTI	Wildlife Trust of India
ZP	Zila Parishad

LIST OF BOXES, FIGURES AND TABLES

BOXES

FIGURES

TABLES

INTRODUCTION

PART I

This section examines why it is important to consider biodiversity in linear infrastructure planning and design. It describes trends in a number of linear development sectors in India and touches on the regulatory procedures for obtaining environmental clearance for projects. The section then gives an overview of ecological impacts of linear developments and looks at core principles for impact mitigation.

01 RELEVANCE OF MAINSTREAMING BIODIVERSITY CONSERVATION IN LINEAR INFRASTRUCTURE DEVELOPMENT

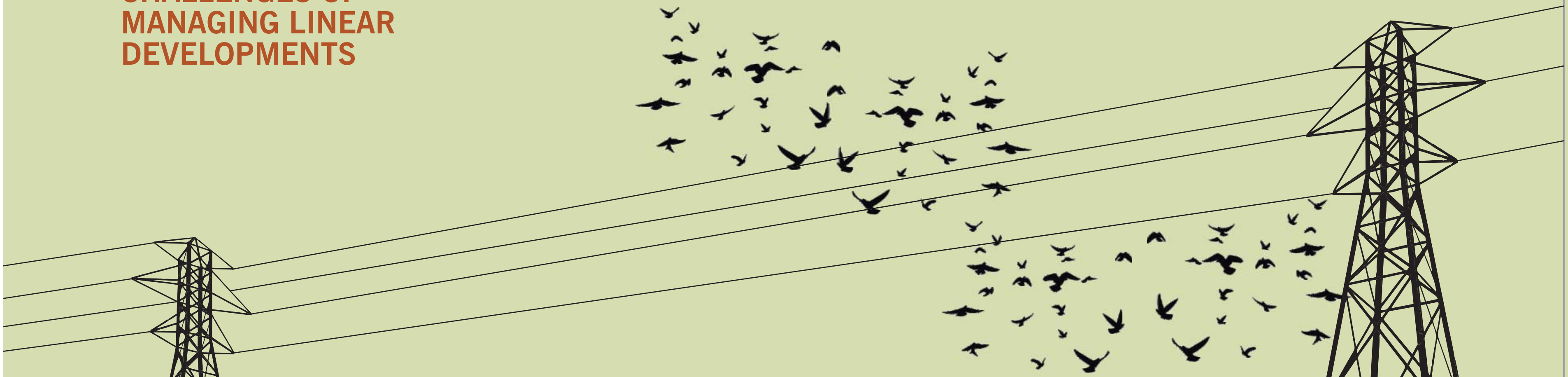
WILDLIFE CONSERVATION: APPROACHES AND PRACTICE

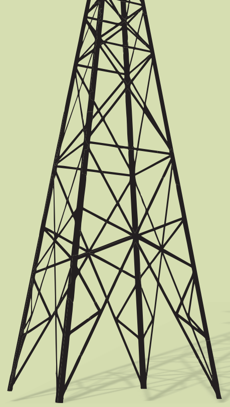
'Wildlife' encompasses both wild animals and plants. Wildlife conservation is not just a strategy aimed at protection of rare, threatened and endemic biodiversity but is a well-recognised means of achieving ecological security, human wellbeing and sustainable development of any country. Establishment of Protected Areas (PAs) is a globally-accepted planning approach for the protection of wildlife, and conservation of biodiversity and valued ecosystem services. Fifty years ago, when environmental protection was poorly regulated, PAs were managed as natural 'islands' that remained largely untouched by human influence. Today, it is recognised that conservation cannot succeed by managing discrete PAs alone: these areas are part of a global matrix and their survival—and the persistence of biodiversity—depends upon a wide variety of human and natural factors that operate at different scales. For this reason, PAs need to be managed as a network of interacting and interdependent areas, to safeguard their biodiversity values and ecosystem functioning in the long term.

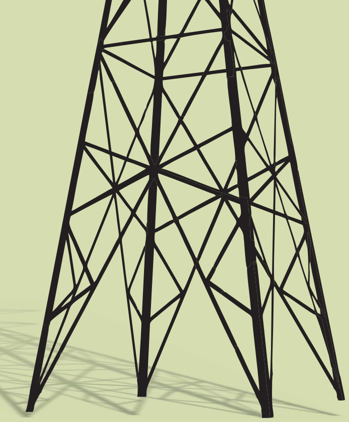
The forest cover in India is 21.34% of the total geographical area of the country, out of which the PA network covers about 4.89% presently comprising 103 national parks, 536 wildlife sanctuaries, 67 conservation reserves and 26 community reserves (http://www.wii.gov.in/national_wildlife_database). This network's core land use and purpose are biodiversity conservation. The average size of PAs in India is, however, small and a significant proportion of wildlife populations exists outside the PA network. To manage this situation, the concept of PA management has gradually expanded to landscape conservation, where areas adjoining as well as outside the PAs have a significant role to play in supporting wildlife. Tiger reserves have, in fact, legalised their management on the basis of a landscape approach that involves designation of core and buffer areas, and areas that provide important connecting corridors.

In many of these PAs and protected landscapes, linear developments such as roads, railway lines, powerlines and canals are invariably in conflict with the objectives of wildlife conservation.

CHALLENGES OF MANAGING LINEAR DEVELOPMENTS







Within many of India's PAs, roads, railway lines and transmission lines cut across the landscape, fragment wild habitats and often result in mortality of animals, thus endangering many of the species that have already been severely affected by development. Some of the prominent examples of these negative effects include the National Highway (NH) 72 and 74 crossing Rajaji National Park; NH 67 and 212 passing through Bandipur National Park; NH 209 bisecting Sathyamangalam Wildlife Sanctuary in Tamil Nadu; NH 6 and 7 intersecting at least 6 tiger corridors in the Vidarbha region of Maharashtra; State Highway (SH) 54 passing through Balram Ambaji Sanctuary; seven state highways and the railway lines through Gir National Park and Sanctuary; NH 37 through Kaziranga National Park; NH 54 through Borail Wildlife Sanctuary in Assam; NH 54E passing through Lumding Reserve Forest in Assam and the Poily-Ranjitpura approach road passing through Jambughoda Wildlife Sanctuary (Rajvanshi et al. 2001; WII 2007; Joshi & Dixit 2012; Habib et al. 2015).

Major roads including national highways, state highways and roads of the Public Works Department traverse—for varying distances—as many as 26 PAs declared as tiger reserves in the country (Rajvanshi et al. 2013).

Wide-ranging species require contiguity of their habitats across landscapes. The increase in extent of linear developments in most landscapes outside PAs thus presents a major challenge for wildlife management and conservation, since these linear developments often create barriers or breaks in habitat, which is detrimental to the long-term conservation of species and ecosystems. There is a pressing need for conservation and development to go hand in hand, complementing—rather than conflicting with—each other.

MAINSTREAMING BIODIVERSITY IN LINEAR DEVELOPMENTS

Harmonising biodiversity conservation and linear development will require the twin actions of i) creating and strengthening protected areas; and ii) mainstreaming biodiversity conservation in linear developments.

The general concept of working to embed conservation values in development has been pursued for many years under many names; 'mainstreaming' is one such name. 'Mainstreaming' biodiversity has no single agreed-upon definition. According to the Merriam-Webster Dictionary, 'mainstreaming' refers to 'integrating' biodiversity into development.

According to Kosmus et al. (2012), the overall goal of biodiversity mainstreaming is to have biodiversity principles included at every stage of the policies, plans, programmes and project cycles, regardless of whether international organisations, businesses or governments lead the process. A recent definition (Huntley & Redford 2014) describes biodiversity mainstreaming as 'the process of embedding biodiversity considerations into policies, strategies and practices of key public and private actors that impact or rely on biodiversity, so that biodiversity is conserved, and sustainably used, both locally and globally'.

All these definitions reflect the view that biodiversity conservation goals are not seen as distinct from, or contradictory to, the goals of development and economic growth. Rather, the approach is intended to shift the focus of development policies and interventions towards better incorporation of the values of biodiversity. Integration of biodiversity considerations into the location, design and operation of infrastructure projects would not only have the advantage of reducing the environmental, social and economic costs, but of creating win-win results for biodiversity conservation and human safety which lie at the core of all development initiatives.

Mainstreaming Approaches

Mainstreaming can best be understood as an attempt to influence landscape-level plans and strategies by incorporating clear biodiversity goals. It would, for example, mean having to ensure that linear infrastructure development would be 'animal friendly' by providing pathways for movement of species. In addition, linear infrastructure would need to be 'green' to mitigate any negative impacts on sensitive habitats. Importantly, designing 'green' infrastructure can encourage community support for—and reduce opposition to—economic development.

'SMART AND GREEN' INFRASTRUCTURE WHAT DOES IT MEAN?

Green infrastructure may sound like a new or an uncommon term, but it is certainly not a new concept! It has its roots in the founding principle of conservation planning that emphasises preserving and linking natural areas to benefit biodiversity. This approach helps to counter the negative impacts of habitat fragmentation.

Green infrastructure can thus be understood simply as a 'design and develop with nature' concept: it looks at conservation values and actions in concert with land development, growth management and built infrastructure planning (Benedict 2000). It aims to respect and avoid important biodiversity and sensitive habitats, including natural corridors across the landscape. It also aims to maintain, strengthen and restore ecosystems at all spatial scales, thereby ensuring sustained benefits to people from the goods and services they provide. Green infrastructure helps to build robust healthy and enduring landscapes which enable species and their communities to move and adapt (Lucius et al. 2011).

In addition to ecological issues, green infrastructure has to take into account a number of human dimensions such as safety and economic considerations, and ways to utilise the landscape in an optimum way. Human safety is particularly relevant in the planning of roads and railways: wild animal-vehicle collisions have a significant cost for both human and animal populations.

Green infrastructure offers a blueprint for 'smart conservation' (Benedict & McMahon 2002) in the same way that engineering plans provide a blueprint for future roads, railway lines, canals and powerlines. It can create a sound framework for future growth while making sure that significant natural resources will be conserved for future generations.

GREEN INFRASTRUCTURE PRINCIPLES

1

Large to local scale

- Understands the wider landscape and the development context

2

Proactive

- Identifies and avoids areas that are significant for biodiversity
- Identifies and protects natural processes and resources of value or benefit to people
- Identifies, protects and/or restores natural corridors and networks

3

Harmonising

- Considers the human dimensions (safety and economy)
- Seeks to integrate human and ecological values and goals
- Provides a framework for sustainable development

4

Rigorous

- Applies good science, land use theory and practice

Key Message

Green infrastructure promotes both smart growth and smart conservation

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02 PROGRESSIVE TRENDS IN LINEAR DEVELOPMENT SECTORS IN INDIA

Roadways, railways and powerlines constitute the predominant linear infrastructure in India, with plans for substantial expansion; they therefore pose the greatest threat of harmful impacts on wildlife. For these reasons, this guideline focuses on these three forms of linear infrastructure development.

An understanding of the scale and type of linear development is essential if ecological concerns are to be mainstreamed in all new initiatives of the transportation and energy transmission sectors. This factor becomes even more pertinent for a country the size of India, where road, rail and power infrastructure is becoming the most pervasive form of linear features that traverse the entire length and breadth of the country. These linear structures are essential links for transporting people, transmitting energy and improving access for rapid economic development. The expansion of the road and rail networks, upgrading of existing roads and railway lines, and planning of superior and more sophisticated surface transportation options such as expressways and metro rails have thus become priorities for central agencies such as the National Highway Authority of India (NHAI) and the Indian Railways (IR).

According to the National Transport Development Policy Committee (NTDPC 2012), the demand for road-based transport services has dramatically accelerated following economic liberalisation, and has provided for as much as 90% of the total passenger traffic, leaving a meagre 10% for rail. Rail and road freight traffic is expected to grow at about 12% and 8% per annum respectively, to achieve a 50% share each in the total freight traffic at the end of 15th Plan.

Other factors that are strongly contributing to growth in transportation infrastructure are growth of freight traffic due to industrialisation, increase in urban conglomerations and rising demand for urban mass transportation, increasing requirements of safety and modernisation, and increasing participation of the private sector.

The subsequent sections of this chapter present the trends in development of roads, railways and powerlines.

ROAD NETWORK IN INDIA

With the rapid progress in the development of new road lengths and upgradation of existing corridors, India represents the second largest road system in the world with ca 5.2 million km, after the United States of America with the largest road network of over 6.0 million km of public roads. The density of India's highway network at 0.66 km of highway per km^2 of land is, however, on a par with that of the United States (0.65) and much greater than China (0.16) or Brazil (0.20).

India has about 5.2 million km of road network. The length of various categories of roads is as under:-

NATIONAL HIGHWAYS	STATE HIGHWAYS	OTHER ROADS
1,00,475 km	1,48,256 km	49,83,579 km

Source: *Ministry of Road Transport and Highways (http://pib.nic.in/newsite/PrintRelease.aspx?relid=133917)*

Contracts for 5331 km length of national highways have been awarded while 3480 km have been constructed in 2015-16.

The major highway programmes currently underway include:

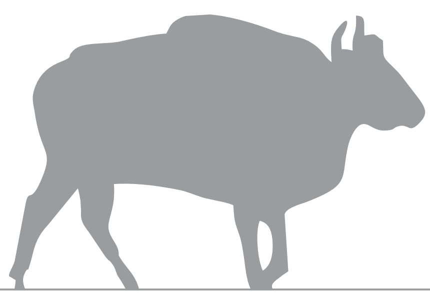
- **National Highways Development Programme**
- **SARDP-NE (Special programme for NE)**
- **LWE (Left Wing and Extremism) affected areas**

The Government launched National Highways Development Project (NHDP) to upgrade and strengthen national highways (Table 2.1).

Table 2.1. Phase-wise details of NHDP.

Sl. No.	NHDP component	Total length (km)	Completed length (km) as on 30.10.15	Under implemen -tation (km)	Balance for award of civil works (km)	Estimated cost (Rs. in crores)
1.	GQ under NHDP Phase I	5,846	5,846	0	0	30,300 (NHDP Phase I) + 34,339 (NHDP Phase II) = 64639
2.	NS-EW Corridors under NHDP Phase I & II	7,142	6,414	461	267	NHDP Phase I & II
3.	Port Connectivity under NHAI	402	379	23	0	
4.	Other NHs with NHAI	1859	1518	341	0	
5.	NHDP Phase III	12,403	6,634	3,602	2,167	80,626
6.	NHDP Phase IV	20,000	2,441	8,034	9,525	27,800
7.	NHDP Phase V	6,500	2,264	1,401	2,835	41,210
8.	NHDP Phase VI	1,000	0	135	865	16,680
9.	NHDP Phase VII	700	22	19	659	16,680
	Total	**55,852#**	**25,518**	**14,016**	**16,318**	**247,635 (USD 36.51 bn)**

(# included 48428 km of total NHs, 24 km length of Chennai-Ennore port connectivity road, 700 km NH length under NHDP -VII, other than overlapping length of NHs (5700 km NH length is common under NHDP-I and NHDP-V).



The Government has approved a scheme for development of about 1,177 km of NHs and 4,276 km of state roads in Left Wing Extremism (LWE) affected areas as a Special Project with an estimated cost of about Rs. 7,300 Crore (USD 1.08 bn).

The following are some key strategies for growth in the road sector:

- Develop a total expressway network of about 18,637 km by 2031 to provide unhindered movement of traffic;
- Develop road connectivity to 24 airports;
- Provide urban linkages to national expressways;
- Upgrade entire SH of 1,00,000 km (i.e. inclusive of the additional length of new highways of about 29,000 km proposed to be added) to at least 2-lane standards;
- Develop full access-controlled facilities, whenever 2-lane NHs are upgraded to 4-lanes;
- Plan for bypasses in cities with a population above 1 million on the NH network, and
- Identify a core network of major arterial routes, with a corridor concept.

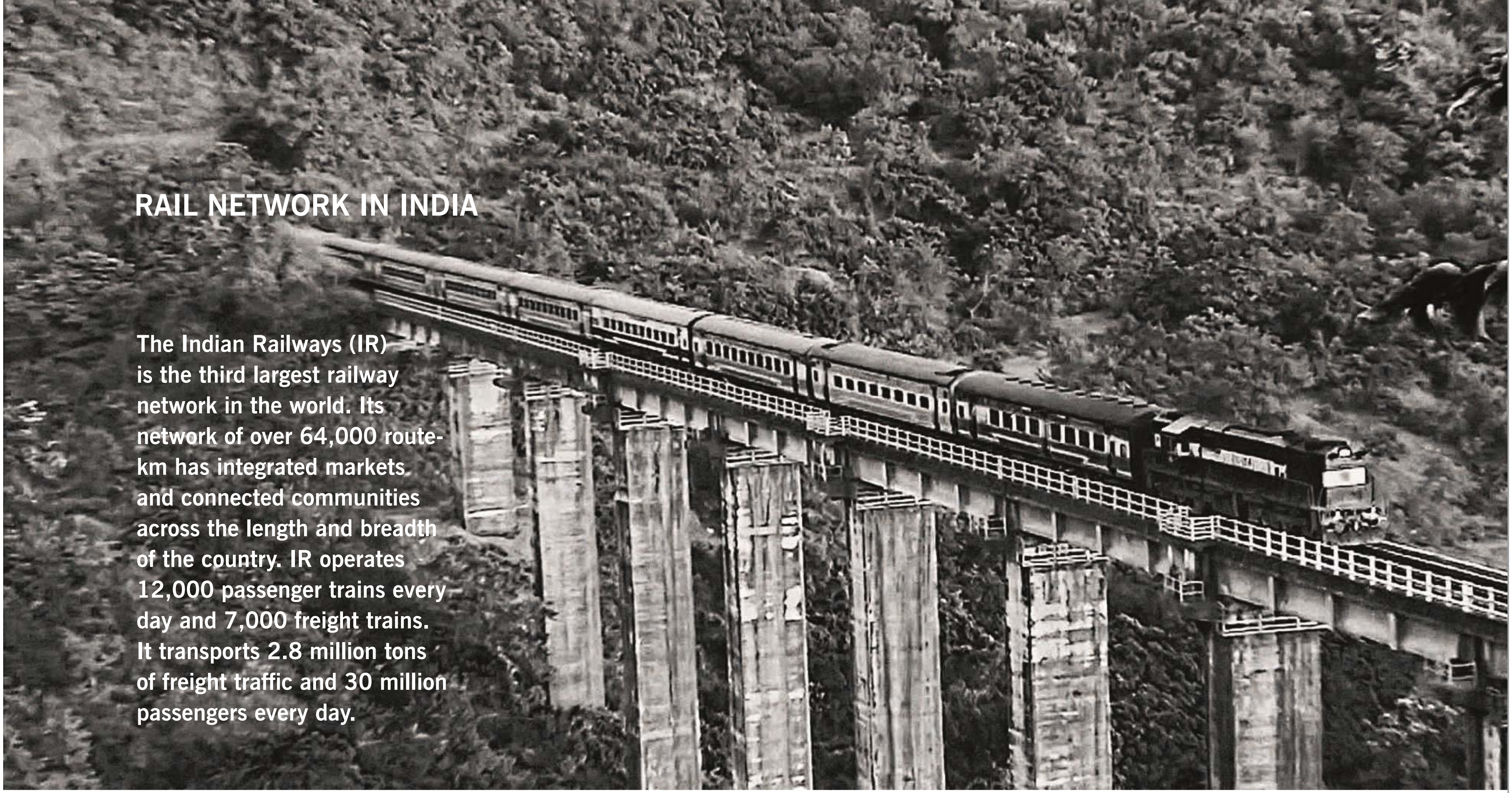
Under its new initiatives, the following programmes are included:

I. Bharat Mala: 5,500 km - to develop roads along the international borders and coastal areas

II. Special Scheme: 6,000 km - roads facilitating connectivity to religious/tourist places and providing connectivity to backward regions

III. District Connectivity: development of national highways providing connectivity to district headquarters

IV. Setu Bharatam: All the level crossings and narrow/weak bridges to be replaced by railway over/under bridges and new constructions



RAIL NETWORK IN INDIA

The Indian Railways (IR) is the third largest railway network in the world. Its network of over 64,000 route-km has integrated markets and connected communities across the length and breadth of the country. IR operates 12,000 passenger trains every day and 7,000 freight trains. It transports 2.8 million tons of freight traffic and 30 million passengers every day.

Indian Railways run on three gauges: the meter and narrow gauges are mostly single line and non-electrified; broad gauge contributes about 91% of total track km and accounts for 97.9% of passenger and almost 100% of the freight traffic.

Table 2.2. Gauge-wise Indian Railways network (percentage share).

GAUGE	ROUTE KM	RUNNING TRACK KM	TOTAL TRACK KM
Broad Gauge (1676 mm)	86.62	89.96	90.99
Meter Gauge (1000 mm)	9.83	7.49	6.78
Narrow Gauge (762 mm and 610 mm)	3.56	2.56	2.23
Total (km)	**64,600**	**89,801**	**115,062**

Source: *Ministry of Railways (2012)*

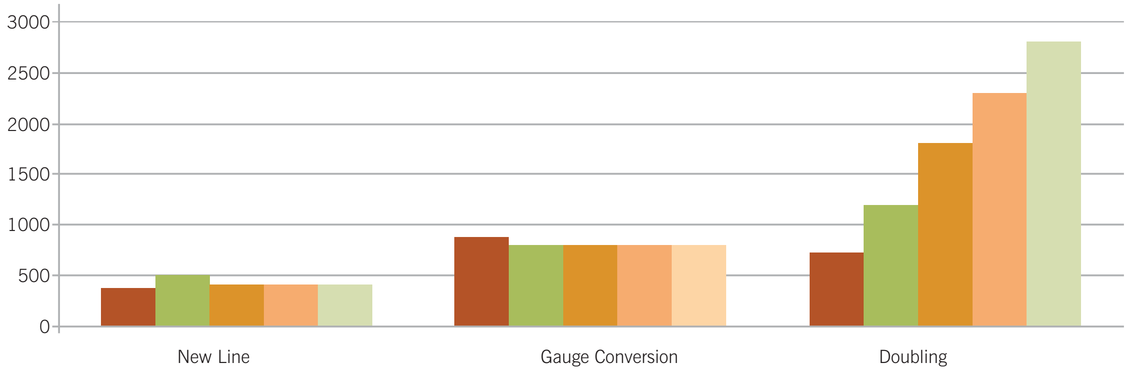


Figure 2.1. Targets for commissioning (km) train lines.

Table 2.3. Targets for commissioning of railway lines (in km).

New Line	Gauge	Conversion	Doubling
2014-2015	380	880	723
2015-2016	500	800	1200
2016-2017	400	800	1800
2017-2018	400	800	2300
2018-2019	400	800	2800

Source: *http://www.indianrailways.gov.in*

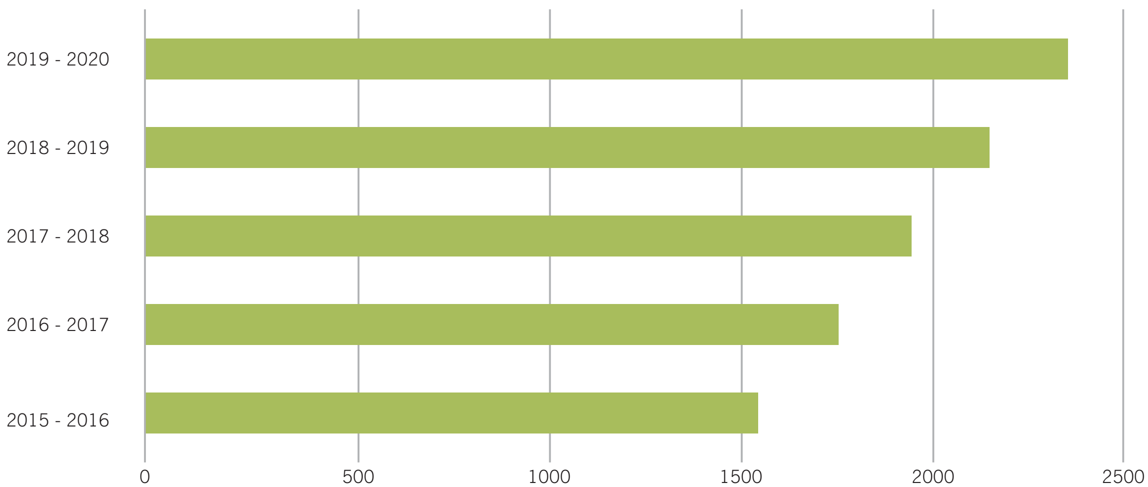
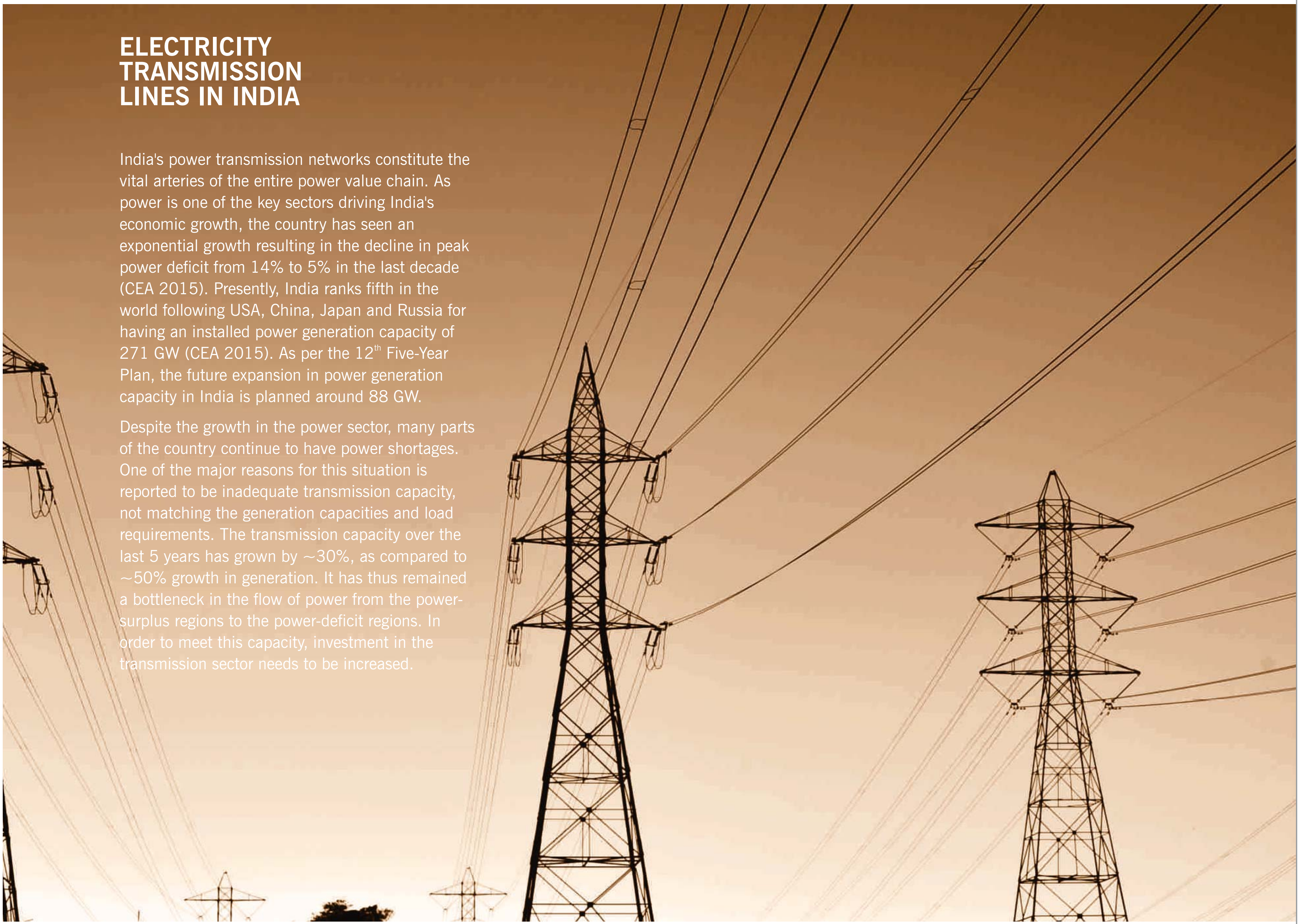


Figure 2.2. Targets for electrification (route km). **Source:** *http://www.indianrailways.gov.in*

According to Vision 2020 document of the Ministry of Railways, Government of India (2009) and the Union Budget for year 2015, the Indian Railways would strive to:

- Add 25,000 km of new lines by 2020, supported by government funding and a major increase in Public Private Partnerships (PPPs);
- Convert the entire rail network to broad gauge;
- Have more than 6,000 km of quadrupled lines, with segregation of passenger and freight services into a separate double-line corridor;
- Raise speed of passenger trains from 130 - 110 km/h to 160-200 km/h on segregated routes, and speed of freight trains from 60-70 km/h to 100 km/h;
- Achieve electrification of 33,000 km of routes, and
- Construct 4 high-speed rail projects to provide bullet trains at the speed of 250 km/h.



ELECTRICITY TRANSMISSION LINES IN INDIA

India's power transmission networks constitute the vital arteries of the entire power value chain. As power is one of the key sectors driving India's economic growth, the country has seen an exponential growth resulting in the decline in peak power deficit from 14% to 5% in the last decade (CEA 2015). Presently, India ranks fifth in the world following USA, China, Japan and Russia for having an installed power generation capacity of 271 GW (CEA 2015). As per the 12th Five-Year Plan, the future expansion in power generation capacity in India is planned around 88 GW.

Despite the growth in the power sector, many parts of the country continue to have power shortages. One of the major reasons for this situation is reported to be inadequate transmission capacity, not matching the generation capacities and load requirements. The transmission capacity over the last 5 years has grown by ~30%, as compared to ~50% growth in generation. It has thus remained a bottleneck in the flow of power from the power-surplus regions to the power-deficit regions. In order to meet this capacity, investment in the transmission sector needs to be increased.

The transmission line capacity expanded from 52,034 circuit kilometres (ckm) during the 6th plan to 221,549 ckm during the 11th plan (up to Jan 2010), as shown in Figure 2.3.

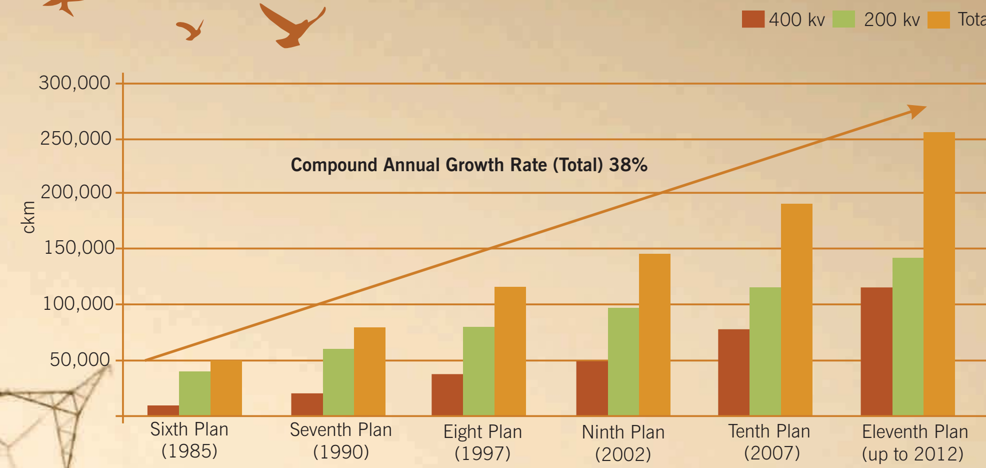


Figure 2.3. Transmission line growth.
Source: *CEA, D&B Research.*

Table 2.4. Transmission Addition Programme in India.

Transmission lines	Addition by 2012 (Ckm)	Addition by 2017 (Ckm)
765 kV	7,612	25000 - 30000
HVDC Bipole	11,078	4000 - 6000
400 kV	1,25,000	50000
220 kV	1,50,000	40000
Total	2,93,852	119,000 - 126,000
Substations	**Addition by 2012**	**Addition by 2017**
HVDC	14,700 MW	16,000 - 22,000 MW
765 kV	53,000 MVA	1,10,000 MVA
400 kV	1,45,000 MVA	80,000 MVA
220 kV	2,30,000 MVA	95,000 MVA
Total Capacity	4,28,000 MVA	2,85,000 MVA
Inter-Regional Transfer Capacity	**38,000 MW**	**75,000 MW**

Under the 12th Plan, the power transmission network across the country spans 3,20,099 ckm as on July, 2015 (www.powermin.nic.in).

High capacity transmission corridors comprising 765kV AC and ± 800kV 6000MW HVDC system along with 400kV AC, and ± 500kV/600kV 2500MW/6000MW have been planned to facilitate transfer of power from remotely-located generation complexes to bulk load centres (Table 2.4). This increase will also facilitate strengthening of the national grid capacity to 75,000MW by 2017.

Overall, an addition of 90,000 ckm of transmission lines is needed to meet the power generation requirements envisaged during 2012-2017 (FICCI 2013). Already, 90,317 ckm total powerline length passes through forested areas.

(www.powergridindia.com)

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03 REGULATORY PROCEDURES FOR ENVIRONMENTAL CLEARANCE OF PROJECTS

The legal framework of the country consists of several acts, notifications, rules, and regulations to protect the environment and wildlife. The most relevant of these in the context of roads and powerlines include the EIA Notification of 2006 (and its amendments), Forest (Conservation) Act, 1980, Coastal Regulation Zone (CRZ) Notification 2011 and the Wildlife (Protection) Act, 1972 (and its amendments). The key elements of the legal framework, the administrative arrangements for the appraisal of EIA reports and decision-making, the procedure for granting of forest clearances, and the co-ordination of different regulatory requirements, are addressed in separate sections below.

DISCLAIMER

The contents of this chapter reflect only the indicative procedures and are not directly taken from any order or circular of the Government. This information is to be therefore confirmed from the relevant statutes. The information provided in the following text must not be used for legal purposes. Further, the regulations governing environmental and clearance procedures for different sectors are likely to get amended from time to time. All concerned must therefore always refer to the most recent and original sources of legislations, rules, orders and subsequent amendments and also take note of any updates published after that.

EIA NOTIFICATION OF 2006 AND ITS AMENDMENTS

As per the provisions of this notification, as amended up to 1 December 2009, any person who desires to undertake the execution of any new road, upgrades of existing road sections, widening and conversion to multi-lanes, and laying of powerlines in any part of India shall submit an application to the Ministry of Environment, Forest and Climate Change (MoEFCC), Government of India, in accordance with the guidelines issued from time to time by the Ministry.

Linear projects fall into either A or B categories of Schedule I of this Notification (Box 3.1).

Box.3.1. Categorisation of development projects as per EIA Notification, 2006, and subsequent amendments.

Category A projects:	Category B1 projects	Category B2 projects
Environmental Clearance (EC) would be granted by the MoEFCC at central level through an Expert Appraisal Committee (EAC) constituted by the MoEFCC in case of the following road projects: • New national highways, and • Expansion of national highways greater than 100 km, involving additional right of way or land acquisition greater than 40 m on existing alignment and 60 m on re-alignments or bypasses.	The State Environmental Impact Assessment Authority (SEIAA) constituted by MoEFCC at state level would grant EC to the following projects. • All new state highway projects; and • State highway expansion projects in hilly terrain (above 1000 m AMSL) and/or ecologically sensitive areas State-level Expert Appraisal Committee (SEACs) would be involved in appraising EIAs.	These projects are not listed in either A or B1 categories. They do not require an EIA: they are appraised based on the application in Form-I accompanied by a pre-feasibility report and other documents. Powerline projects and roads in border areas fall in this category.

General conditions to be applied to all category of projects

1. If the proposed projects within categories B1 and B2 are to be located within close proximity of/or within the 10 km boundary of the sensitive areas (Box 3.2), critically polluted areas and/or culturally significant sites, then they are assigned to Category A

Box.3.2. Categories defining sensitive sites

- Environmentally sensitive areas
- Religious and historic places
- Archaeological monuments/sites
- Scenic areas
- Hill resorts/mountains/hills
- Beach resorts
- Health resorts
- Coastal areas rich in corals, mangroves, breeding grounds of specific species
- Estuaries rich in mangroves, breeding grounds of specific species
- Gulf areas
- Biosphere reserves
- National parks and wildlife sanctuaries
- Natural lakes, swamps, marshes, seismic zones, tribal settlements
- Critical habitats important for threatened, rare, or restricted range species
- Areas of scientific and geological interest
- Defence installations, especially those of security importance and sensitive to pollution
- Border areas (international) and inter-state boundaries
- Airports
- Tiger reserves, elephant reserves, turtle nesting grounds
- Habitats of migratory birds
- Lakes, reservoirs and dams
- Streams, rivers, estuary, seas
- Railway lines
- Highways
- Urban agglomeration

2. The requirement regarding distance of 5 km of the state boundaries can be reduced or completely done away through an agreement between the respective states/union territories sharing the common boundary in case the activity does not fall within 10 km of the other areas specified in Box 3.2.
3. All highway projects included as Category 'A' in the Schedule I of the EIA Notification, 2006 and its subsequent amendments require prior environmental clearance from the Central Government in the Ministry of Environment, Forest and Climate Change (MoEFCC) on the recommendations of an Expert Appraisal Committee (EAC) constituted by the Central Government;
4. All highway projects included as Category 'B' in the above Schedule which fulfill the General Conditions (GC) stipulated in the Schedule, require prior environmental clearance from the State/Union territory Environment Impact Assessment Authority (SEIAA). The SEIAA bases its decision on the recommendations of a state or UT level Expert Appraisal Committee (SEAC).

In the absence of a duly constituted SEIAA or SEAC, a Category 'B' project shall be treated as a Category 'A' project.

Environmental clearance for border roads

The MoEFCC (vide letter No. 11-246/2014-FC dated 4 July, 2014, and vide letter F.No. 11-246/2014-FC dated 29 January, 2015) has granted general approval under the Forest (Conservation) Act, 1980, for diversion of forest land required for:

i. Construction and widening of two lane roads by the Border Roads Organisation (BRO) and other road construction agencies in the area falling within 100 km aerial distance from the Line of Actual Control (LAC),

ii. Widening of roads which are identified by the Ministry of Defence, Govt. of India, as link roads, between border roads in the area within 100 km aerial distance from the LAC and NH/SH/other state roads (subject to certain conditions), and

iii. Construction of roads for Indo Tibetan Border Police (ITBP) within 100 km aerial distance from the LAC.

FOREST (CONSERVATION) ACT, 1980

According to the Forest (Conservation) Act, 1980, every project requiring diversion of designated forest land for non-forestry purposes requires clearance from MoEFCC. The Forest (Conservation) Rules, 2003 (FC Rules) provides the procedure to obtain prior approval of Central Government under section-2 of the Forest (Conservation) Act, 1980.

The forestry clearance is granted through a two-stage process:

- Stage I involves reaching agreement 'in principle' on the project proposal. At this stage, the conditions relating to transfer, mutation and declaration as RF/PF under the Indian Forest Act, 1927 of non-forest land, wherever required, for compensatory afforestation, funds for raising compensatory afforestation thereof, realization of Net Present Value (NPV) are addressed.
- Stage II involves formal approval under the Act after receipt of a Compliance Report from the State Government in respect of the stipulated conditions. Under this law, project proponents must obtain administrative approval from the Forest Department to clear over five hectares of designated forest land. Although the land is under the control of State Government, approval of Central, Regional or State Government for using the land for road or rail corridor must be granted due to its protected status.

PLEASE NOTE

While the provisions of the EIA Notification (1994) and its subsequent amendments do not apply to railway projects, the provisions of the Forest (Conservation) Act, 1980 and all procedures stipulated for transfer of forest land are applicable to railway projects routed through forest land. These provisions will also apply to gauge conversion, and electrification of existing railway lines.

COASTAL REGULATION ZONE NOTIFICATION, 2011

This notification establishes a specific procedure for obtaining clearance for the various permitted development activities in coastal areas. As per provisions of this notification, roads and pipelines passing through Coastal Regulation Zones (CRZ) require clearance from their respective Coastal Zone Management Authority (CZMA) at the State level, and the National Coastal Zone Management Authority (NCZMA). For activities requiring clearance, the notification requires the proponents to submit, *inter alia*, the following documents:

i. Detailed information regarding the physical location, nature, and environmental impacts of the activity in a comprehensive Environmental Impact Assessment (EIA).

ii. Disaster and risk assessment as well as a management plan.

iii. CRZ map that indicates all CRZ-I, II, III and IV, and other notified ecologically sensitive areas.

iv. 'No Objection Certificate' from the concerned State Pollution Control Board.

WILDLIFE (PROTECTION) ACT, 1972

As per the WPA 1972, for any activity (including linear projects) proposed within a protected area (national park, wildlife sanctuary) consultation with National Board for Wildlife (NBWL)/State Board for Wildlife (SBWL) is required before the State Govt. accords approval. The SC (Standing Committee) of the NBWL performs this task for NBWL. As per orders of the Hon'ble Supreme Court of India, all cases within wildlife sanctuaries also need to be referred to SC-NBWL, though the Act provides for consultation with SBWL.

Cases of such activities, if any, proposed within tiger reserves are also needed to be referred to NBWL (SC-NBWL) through NTCA for approval under different sections (Box 3.3 and Figure 3.1) of WPA 1972.

Cases referred to SC-NBWL in other regulatory mechanisms like EC (Environmental Clearance) cases located within 10 km of a national park/wildlife sanctuary are also placed before SC-NBWL in the same manner.

Box 3.3. Functions of NTCA as defined under relevant sections of the Wildlife (Protection) Act, 1972, for regulating developments in tiger conservation zones.

Section 38 (O) (1) (b)

- evaluate and assess various aspects of sustainable ecology and disallow any ecologically unsustainable land use such as, mining, industry and other projects within the tiger reserves.

Section 30 (O) (1) (g)

- ensure that the tiger reserves and areas linking one protected area or tiger reserve with another protected area or tiger reserve are not diverted for ecologically unsustainable uses, except in public interest and with the approval of the National Board for Wildlife and on the advice of the National Tiger Conservation Authority;

Section 38 V (3)

- The State Government shall prepare a Tiger Conservation Plan including staff development and deployment plan for the proper management of each area referred to in sub-section (1), so as 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 corridor for spill-over population of wild animals from the designated core areas of tiger reserves or from tiger breeding habitats within other protected areas.

Section 38 (O) (2)

- The National Tiger Conservation Authority may, in the exercise of its powers and performance of its functions under this Chapter, issue directions in writing to any person, officer or authority for the protection of tiger or tiger reserves and such person, officer or authority shall be bound to comply with the directions.

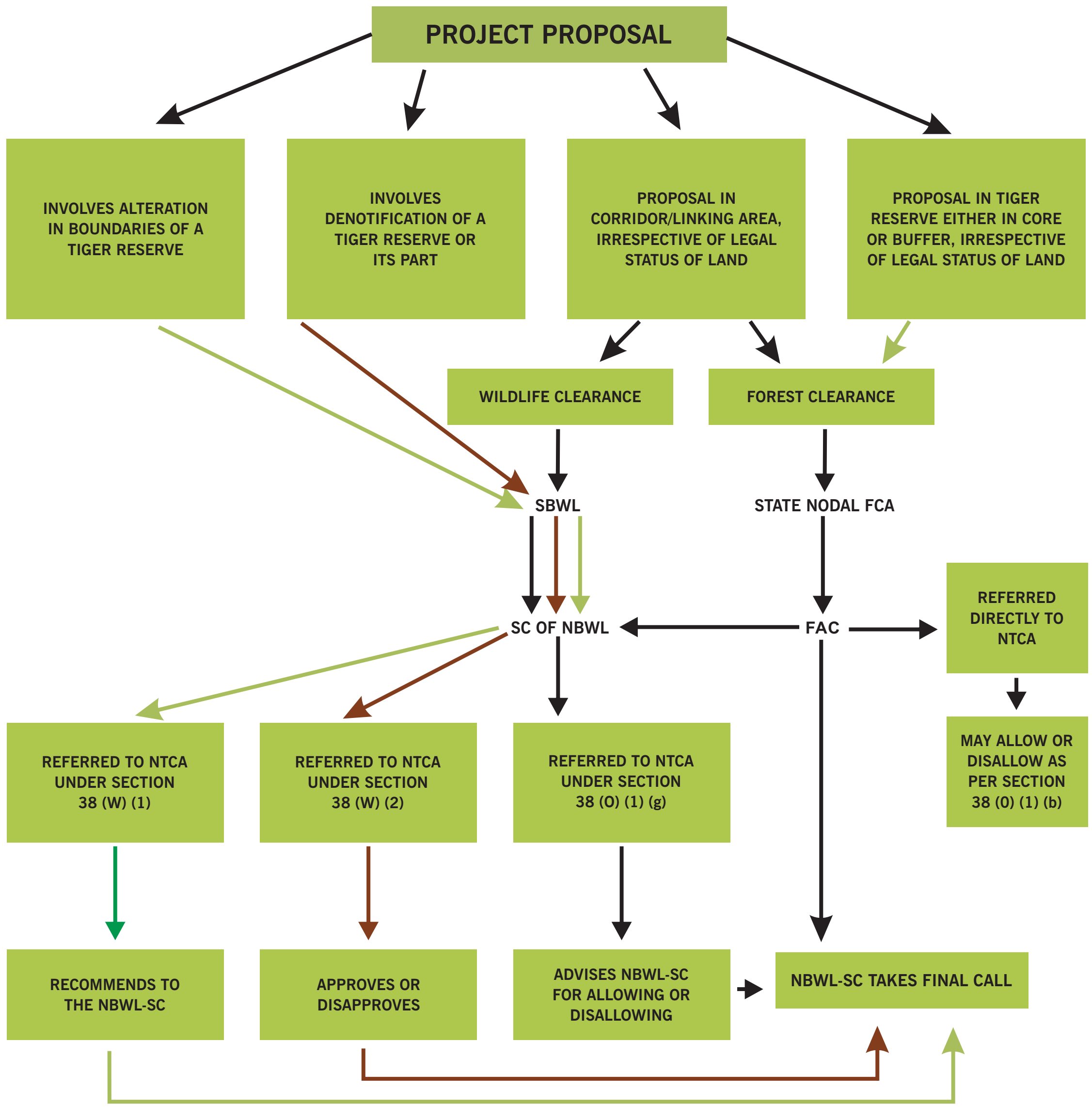
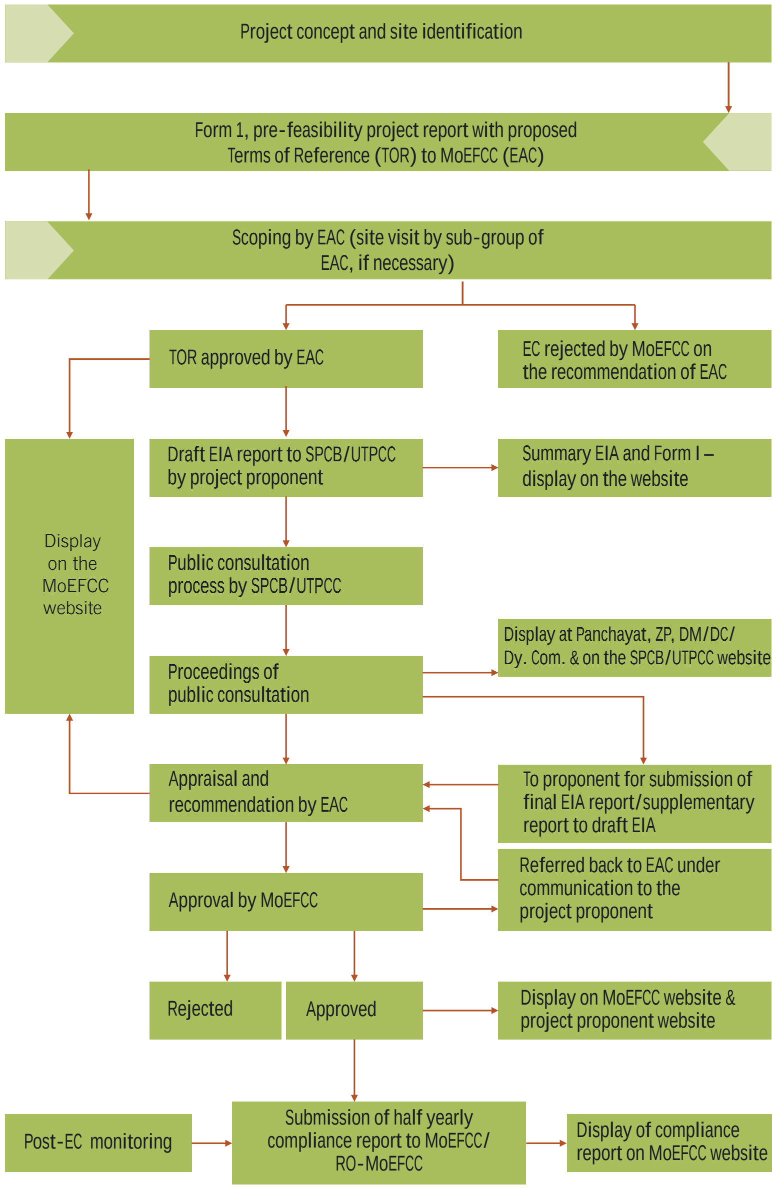


Figure 3.1. Project proposals to be processed by NTCA

ADMINISTRATIVE ARRANGEMENTS FOR APPRAISAL OF EIA REPORTS AND DECISION-MAKING

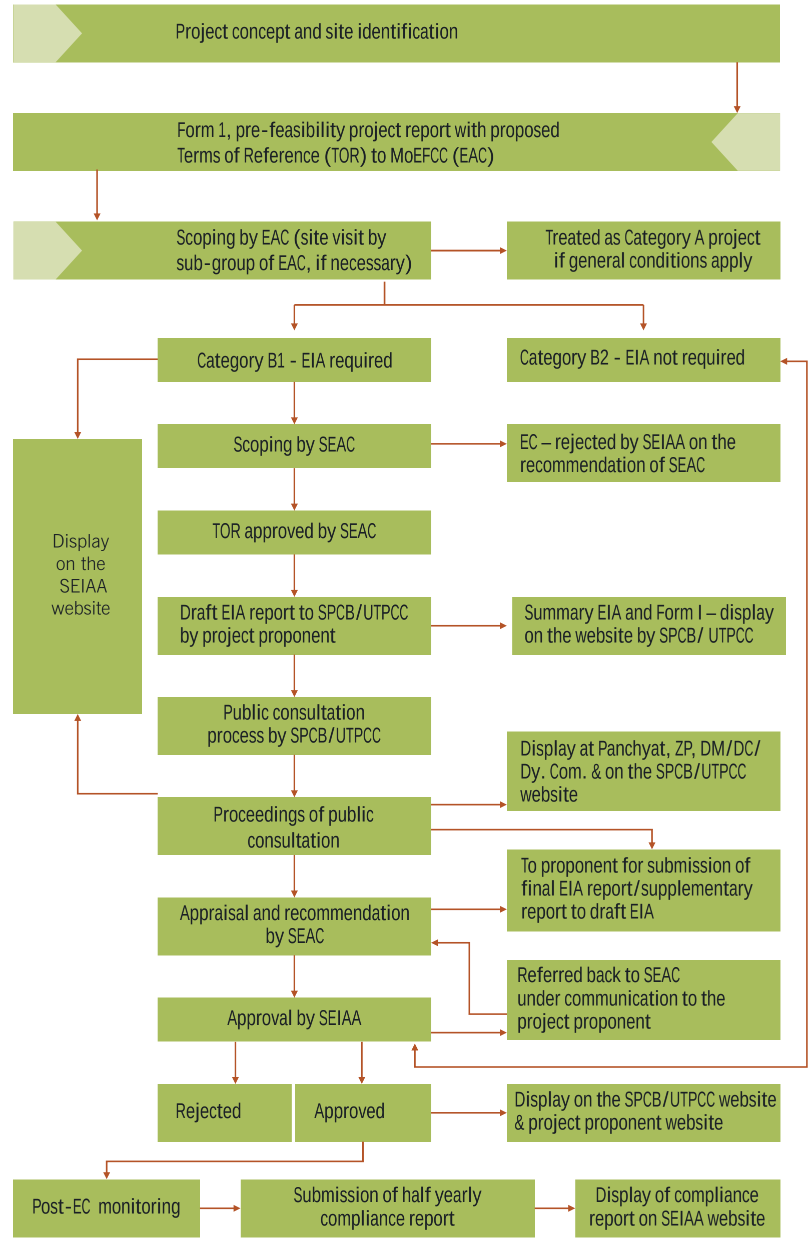
The Impact Assessment Agency (IAA) falls under the Government of India's Ministry of Environment, Forest and Climate Change (MoEFCC). It has the overall responsibility to administer and enforce the provisions related to EIA through its three Impact Assessment (IA) Divisions. The Forest Conservation Division in the MoEFCC examines projects that involve diversion of forest land for non-forest uses, along with these IA Divisions.

The central government and various state-level supervising and approving agencies assist in the appraisal of EIA prior to granting of EC to the projects. The procedures for obtaining EC for Categories A and B road and powerline projects are given in Figures 3.2 and 3.3.



*The proponent should apply for CRZ clearance, as per applicability

Figure 3.2. Prior environmental clearance process for Category A projects.



*The proponent should apply for CRZ clearance, as per applicability

Figure 3.3. Prior environmental clearance process for Category B projects.

PROCEDURE FOR GRANT OF FOREST CLEARANCE

According to the stipulated procedures issued by MoEFCC (Office Memorandum J·II015/20012008·IA.II (M) dated 19 March, 2011) for consideration of projects for environmental clearance of forest land, the project proponent shall first explore the feasibility to execute the project without affecting forest land (i.e. avoiding impacts on forest).

If it is not feasible to undertake the project without use of forest land, the project proponent shall submit an application seeking prior approval under the Forest (Conservation) Act, 1980 for diversion of forest land, before submitting the application for grant of Terms of Reference as per the procedure stipulated in the EIA Notification of 2006.

All proposals involving the development of roads and railway lines located either within a protected area (PA) or within 10 km from the boundary of a PA are referred to the National Board for Wildlife (NBWL).

The procedure for obtaining clearance for diversion of forest is presented in Figure 3.4.

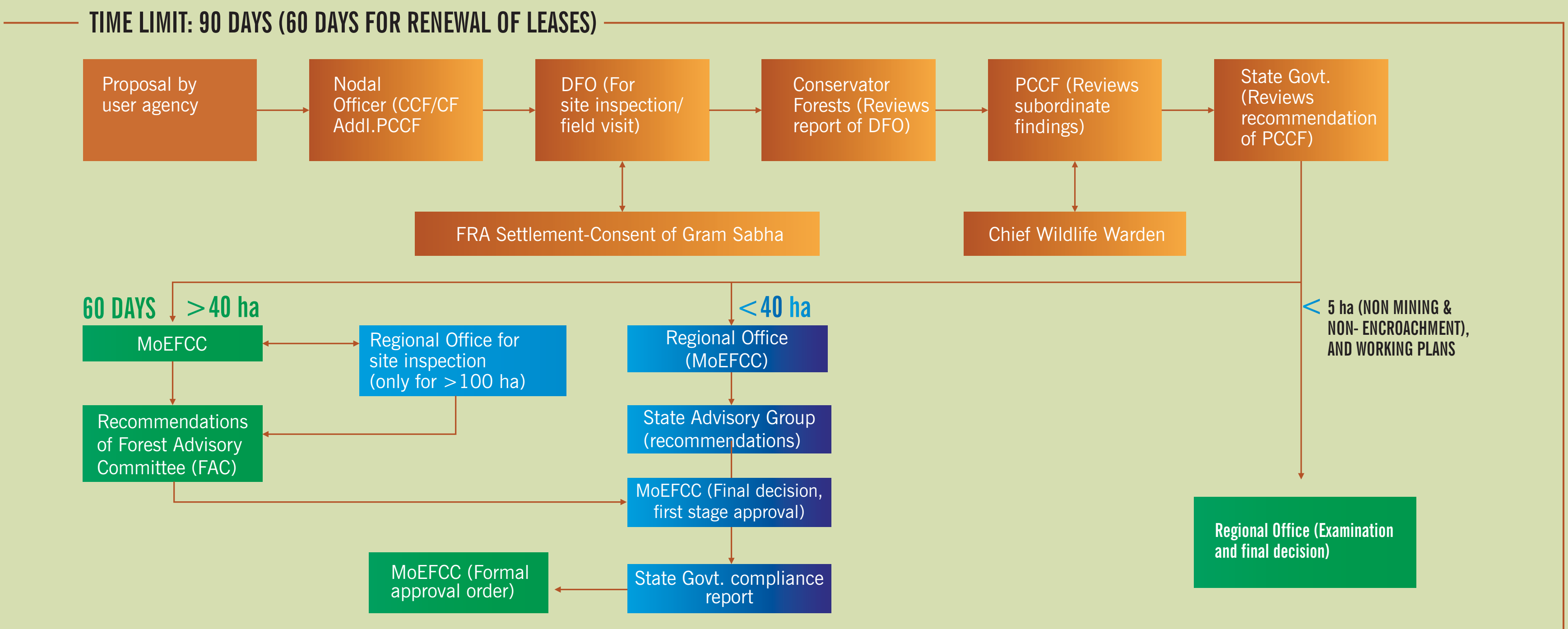


Figure 3.4. Procedure for obtaining forest clearance for development activities.

** All proposals involving diversion of forest land for linear projects such as roads, railway lines, transmission lines, pipelines etc., irrespective of the area of forest land involved, are sent to the concerned Regional Office of the Ministry of Environment, Forest and Climate Change (MoEFCC) located at Chandigarh, Lucknow, Bhopal, Bangalore, Bhubaneswar, Shillong, Ranchi, Dehradun, Chennai and Nagpur.*

LINKAGES BETWEEN GRANT OF ENVIRONMENT AND FOREST CLEARANCE

According to the Office Memorandum issued by MoEFCC vide No. J.IIOIS/200/2008-IA.II (M) dated 31 March, 2011, environmental clearance for projects involving forest land was to be issued only after stage-I approval under the Forest (Conservation) Act, 1980 for diversion of forest land required is obtained.

The MoEFCC received representations from various stakeholders to delink granting of environment clearance from that of forest clearance in case of linear projects such as roads, transmission lines, pipelines etc. involving patches of forest land along their alignment, often stretching to several hundred kilometre. In response to these representations, MoEFCC issued revised stipulations through an office memorandum (NO. J-110 13/41/2006-IA.II-1) dated 9 September, 2011. This memorandum states that, pending grant of Stage I approval under the Forest (Conservation) Act, 1980, for non-forestry use of the forest land, environment clearance for linear projects may be issued subject to the condition that at the stage of consideration of proposals for TOR in respect of the projects involving forest land, the project proponents would submit a credible proof in support of the fact that they have already submitted their application to the concerned competent authority for diversion of the forest land involved in the project and that the EAC will take cognizance of the involvement of forest land and its status in terms of forestry clearance and make their recommendations on the project on its merits.

Subsequently, memorandum J·II015/20012008·IA.II(M) dated 19 March, 2013 issued by MoEFCC in partial modification of the MoEFCC's O.M. dated 9 September, 2011, states that pending grant of stage-I approval under the Forest (Conservation) Act, 1980 for non-forestry use of the forest land, environment clearance to linear projects may be issued subject to the following additional conditions:

i. Work on non-forest land may only be executed up to such point (to be selected by the user agency) on either side of forest land if it is explicitly certified by the user agency that, in case approval under the Act for diversion of forest land is declined, it is technically feasible to execute the project along an alternate alignment without involving diversion of forest land. Details of all such stretches, along with alternate alignments identified to bypass the forest land, should be explicitly provided in the proposal seeking approval under the Act, and the EIA Notification, 2006.

ii. Commencement of work on non-forest land will not confer any rights on the user agency with regard to grant of approval under the Act.

iii. The projects involving widening and/or, upgrading of existing roads will only be allowed to be executed on the entire stretch located in non-forest land, provided that the user agency submits an undertaking that execution of work on non-forest land shall not be cited as a reason for granting approval under the Act. In case approval under the Act for diversion of forest land is declined, the width of the portion of road falling in the forest land will be maintained at its existing level.

PROCEDURE FOR SEEKING RECOMMENDATION OR APPROVAL OF THE NATIONAL BOARD FOR WILDLIFE

Opinion of the Standing Committee of the National Board for Wildlife (SC-NBWL), is a pre-requisite for use of forest land located in PAs. When linear developments such as roads, railway lines and pipelines pass through a protected area (PA), viz., a national park, wildlife sanctuary and conservation reserves, prior consultation with SC-NBWL is necessary even if the project does not involve diversion of forest land from the PA. In case forest land diversion is also involved, the proposal of forest clearance for such areas is also processed simultaneously, both online, and in hard copies.

PROCEDURE FOR GRANT OF CRZ CLEARANCE

As per Notification dated 6 January, 2011 under section 3(1), section 3(2)(v), and section 5(3)(d) of the Environment (Protection) Act, 1986, certain coastal stretches have been declared as Coastal Regulation Zone (CRZ) and activities in the CRZ are thereby regulated. In general, if a highway project passes within 500 m from high tide line or crosses back water/creak, etc., prior CRZ clearance is required from Coastal Regulation Zone Management Authorities (CRZMA) and MOEFCC.

The concerned authority is required to examine the application for CRZ clearance in accordance with the approved CZMP and the CRZ Notification and then make recommendations to the State Government or the MoEFCC to proceed for the grant of clearance. The clearance accorded to the projects is valid for five years. The procedure for obtaining CRZ clearance is presented in Figure 3.5.

Application to be submitted to CRZMA in the respective state or union territory

↓

CRZ status map from recognized institute

↓

Consideration of application by CRZMA in the respective state or union territory

↓

CRZMA forwards application with recommendation to MoEFCC

↓

Grant of CRZ clearance by MoEFCC

Figure 3.5. Procedure for obtaining CRZ clearance.

PLEASE NOTE

For a highway or other linear projects not otherwise requiring environmental clearance as per the provisions of EIA notification, 2006, EC may still require CRZ clearance in case the project alignment falls in CRZ area.

Acronyms used in figures

Addl. DGF (FC)	Additional Director General of Forests (Forest Conservation)
Addl. PCCF	Additional Principal Chief Conservator of Forests
BRO	Border Roads Organisation
CCF	Chief Conservator of Forests
CEC	Central Empowered Committee
CF	Conservator of Forests
CRZ	Coastal Regulation Zone
CRZMA	Coastal Regulation Zone Management Authority
DC	District Commissioner
DFO	Divisional Forest Officer
DIG	Deputy Inspector General
DM	District Magistrate
Dy. Com.	Deputy Commissioner
EAC	Expert Appraisal Committee
EC	Environmental Clearance
FAC	Forest Advisory Committee
FC Act	Forest (Conservation) Act
FRA	Forest Rights Act
IAA	Impact Assessment Agency
ITBP	Indo Tibetan Border Police
LAC	Line of Actual Control
NBWL	National Board for Wildlife
PA	Protected Area
PCCF	Principal Chief Conservator of Forests
SC	Supreme Court
SC-NBWL	Standing Committee - National Board for Wildlife
SEAC	State-level Expert Appraisal Committee
SEIAA	State Environmental Impact Assessment Authority
SPCB	State Pollution Control Board
ToR	Terms of Reference
UTPCC	Union Territory Pollution Control Committee
ZP	Zila Parishad

04 OVERVIEW OF ECOLOGICAL IMPACTS OF LINEAR INFRASTRUCTURE

Understanding the nature of ecological impacts of linear infrastructure is essential to the identification of measures to avoid, reduce or remedy them. The development of roads, railway lines and transmission lines can impact wildlife in a variety of ways; these effects have been well studied and documented (Jalkotzy et al. 1997; Seiler 2002; van der Ree 2015).

The impacts of roads and railways on wildlife are similar, as they convert a strip of land into an area where fast-moving cars or trains can collide with and kill or injure animals. Roads and railways also emit noise, light and chemical pollution (Dorsey et al. 2015), and can act as barriers to movement.

Railways are generally believed to provide a more eco-friendly mode of transport than roads and highways (Borken-Kleefeld et al. 2010). This view is true only in terms of fuel efficiency and air emissions. Their ecological impact is also relatively low when compared to that of roads because of smaller direct spatial footprint due to a narrower ROW and lower induced impacts resulting from settlements, logging, poaching etc., in natural areas through which they pass. Railways are known to have a negative impact on ecosystems during the construction phase (e.g. laying of tracks and erecting buildings, bridges and other infrastructure) and in the operational phase (e.g. running of trains, maintenance of tracks, etc.).

Impacts of railways have been documented mostly in Europe, North America, Australia, and more recently in China (e.g. Andrews 1990; De Santo & Smith 1993; Carpenter 1994; Jackson 2000; Berthoud 2003; Trocmé et al. 2003; Xia et al. 2007; Yang & Xia 2008). Studies on the ecological impacts of railways on wild animals in India are, however, generally lacking, with the exception of a few studies that have highlighted mortalities of animals like elephants and tigers on railway tracks (e.g. Singh et al. 2001). In part, this paucity of studies is thought to be due to the fact that railways have been kept out of the scope of the Environmental Impact Assessment (EIA) rules promulgated by the Ministry of Environment, Forest and Climate Change (MoEFCC) on 27 January, 1994 and re-notified on 14 September, 2006.

Globally, literature on the ecological effects of roads and traffic is expanding rapidly (Nietvelt 2002). In India, interest in the area of road ecology is relatively recent (Baskaran & Boominathan 2010; Gubbi et al. 2012; Joshi & Dixit 2012; Prakash 2012; Krishna et al. 2013; Rajvanshi et al. 2013).

Transmission lines have been criticised for fragmenting forests and other natural habitats, and for causing collisions and electrocutions of birds and other animals (Faanes 1987; Bevanger 1994; Manitoba Hydro 1995; Janss 2000; Janss & Ferrer 2000; Dixon et al. 2013; Harness et al. 2013; WII 2014).

The various types of ecological impacts typically associated with linear developments are discussed in two separate sections below, covering roads and railways, and powerlines. A concluding section gives an overview of the ecological impacts of these forms of linear infrastructure on different animal groups.

IMPACTS OF ROADS AND RAILWAY LINES

Direct loss of habitat

The construction of new roads and railways destroys or damages vegetation such as trees, shrubs and grasses (Figure 4.1); this vegetation may provide valuable habitat for wildlife. Any linear development through a closed forest that would lead to loss of habitat would result in a reduced carrying capacity of the landscape to sustain wildlife. The degree of impact is likely to be proportional to the width and length of the disturbance corridor.

Figure 4.1. Direct loss of habitat resulting from clearing of vegetation for roads and powerlines.
Source: *Photographs by (a & d) Asha Rajvanshi (b) Bilal Habib (c) Phuntso Thinley.*

Degradation of habitat quality

The condition of wildlife habitats adjacent to roads and railways often suffers as a result of construction activities such as trenching and digging and the presence of construction camps. Impacts typically include invasion by exotic weeds, and pollution due to liquid or solid wastes or emissions (Figure 4.2). The effects of heavy metals such as lead from motor vehicle on trees and soils, and numerous chemical elements arising from roads, vehicles, fuels and corrosion, and wear and tear of vehicle components, are recognised impacts. In addition, the habitat may become less attractive to wild animals due to noise, lights or human presence.

Likewise, railways may pollute water and air, cause noise, act as a source of garbage and human wastes, and facilitate the spread of invasive species within wildlife habitats. Altered drainage patterns and pollution or sedimentation of aquatic ecosystems can also lead to degradation of habitats.

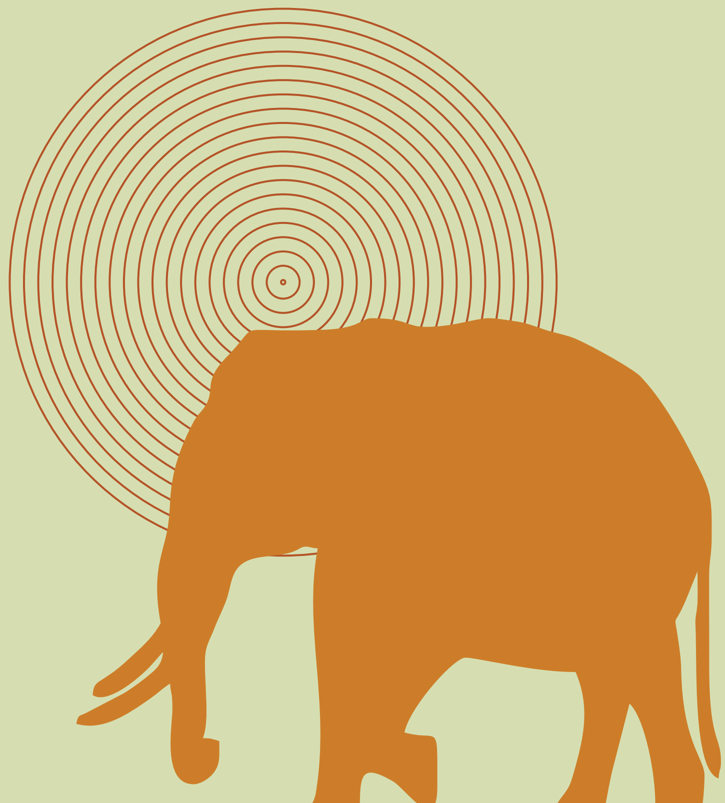
Disturbance from poorly-supervised construction workers could pose additional threats of unauthorised activities.

Water, land and air pollution may adversely impact the general health and fertility of wild animals (and livestock). Trains transporting petroleum products, compressed/ liquefied gases, chemicals and other toxic or hazardous materials are akin to factories in their potential impacts.

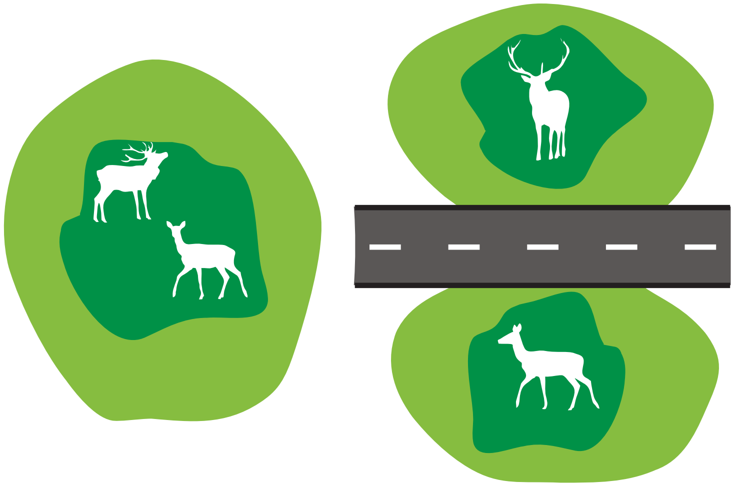
Figure 4.2. Degradation of roadside habitat during construction and operation of a road.
Source: *Photographs by T R Shankar Raman & Asha Rajvanshi.*

Noise-induced physiological and behavioural changes

The impact of noise on wild animals is a contentious issue: Berthoud (2003) reported that, in general, wild animals seem to adapt well to the frequent passing of trains. Hanson (2008) refers to the debate between the sceptics on the one hand, who hold that habituation to transportation noise is common among wild animals, and the environmentalists on the other hand, who insist that loud noise interferes with the communication systems of wild animals, brings out a 'flight or fight' response, and interferes with the behaviour of both predator and prey. He points out that research has been inconclusive regarding effects on wild animals from transportation noise sources. According to Parris (2015), if the noise is loud enough and present for long it can have serious and significant impacts.



But the fact remains that a large number of wild animals rely heavily on auditory signals for their sustenance, defence and reproduction. The precautionary principle suggests that all artificial sources of noise in a natural ecosystem should be minimized.



Habitat loss and fragmentation

Roads and railway lines dissect contiguous habitat patches, resulting in smaller patch sizes and higher edge-to-interior ratios, making them increasingly vulnerable to outside disturbance. The fragmentation of habitat into spatially isolated parts is a major cause of the decline of biodiversity; e.g. habitat loss and fragmentation of amphibian populations worldwide has led to a substantial decline in their numbers during the last century (Stuart et al. 2004).

Habitat fragmentation has become a global issue associated with most linear forms of infrastructure development, including road and rail. The fragmentation process initiates a shrinking in available habitat, which in turn leads to a progressive reduction in species diversity in the landscape, with consequent isolation of species (Figures 4.3 and 4.4). The contraction in available habitat together with isolation becomes the most important impact (Harris 1984).

Figure 4.3. Habitat fragmentation results in far greater reduction in area of available habitat for species in bisected patches.
Source: *Rajvanshi et al. 2013.*

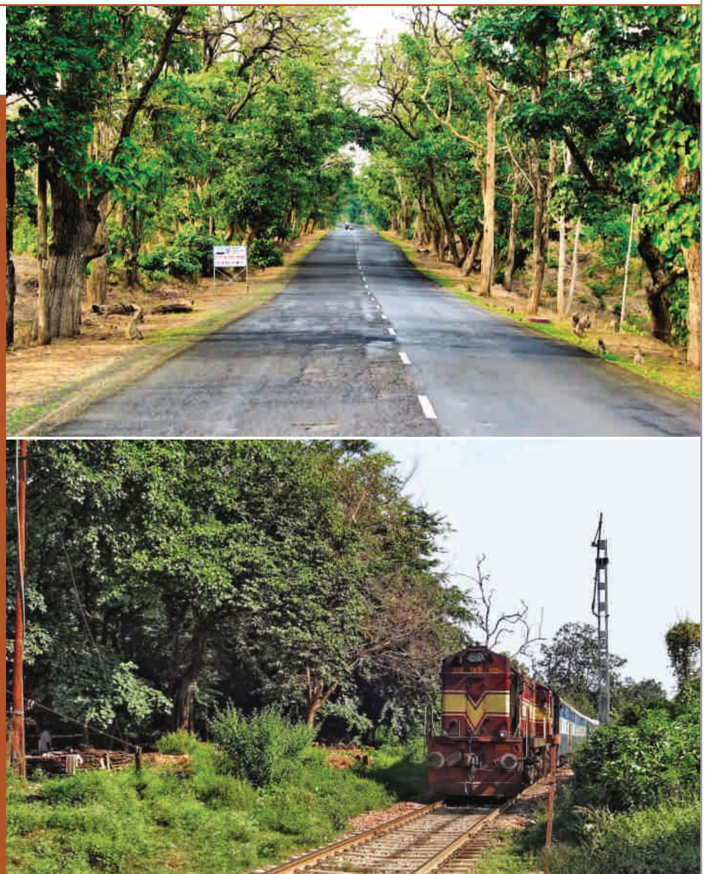


Figure 4.4. Fragmentation of forests by rail and road infrastructure.
Source: *Photographs by A. Pragatheesh and Akanksha Saxena*.

Impacts of headlight glare on wildlife

Artificial lights may contribute to disturbance of wildlife near roads (Seiler 2001). It may disorient birds (Poot et al. 2008), disturb breeding and foraging behaviour in birds (Hill 1992), repel spiders and beetles (Mader 1988; Mader et al. 1990), and influence the behaviour of nocturnal frogs (Buchanan 1993). It is also thought that a flash of artificial light causes an animal to become temporarily blind, popularly called the 'deer-in-the-headlights' effect, reducing its chances of avoiding collisions with vehicles (Rich & Longcore 2006).

Headlight glare can interfere with the flights of birds and bats. It can disrupt homing behaviour and mating calls (croaking) of amphibians in wetland habitats, and influence navigational ability and decline in population of reptiles (Beier 2006; Perry & Fisher 2006). For migrating and dispersing animals, highway lights can be disorienting. Beier (1995) found that dispersing pumas avoided highways while looking for new habitats and travelled only when they could see clearly the land beyond the highways.

However, the singular impacts of headlight are of marginal importance unless they contribute to the mortality and barrier effects, multiplying the overall impact (Seiler 2001).

All new developments should use the latest management technologies so that continued growth and expansion leads to no increase in the impact of light pollution (Salmon 2003).

Road or rail avoidance

Repeated disturbances along road or railway corridors may deter animals from using habitats in their vicinity. Avoidance of habitats close to transport corridors may vary diurnally, seasonally and in relation to traffic in these corridors. Some animals avoid habitat in the vicinity of roads because of human activity associated with them. Complete avoidance of habitats traversed by roads can dramatically curtail dispersal, ultimately leading to the isolation and reduced viability of the affected population. The impacts of roads on birds are substantively influenced by behavioural traits such as road surface avoidance, traffic disturbance avoidance, vehicle avoidance and road attraction (by scavenging birds). The effect of traffic noise on communication among birds has been well studied (Brumm 2004; Slabbekoorn & Ripmeester 2008; Kociolek et al. 2011).

Injury and mortality

Road-induced mortality of animals has always been of concern to biologists (e.g. Stoner 1925; Trombulak & Frissell 2000). Road and rail induced mortality is probably the most acknowledged effect on wildlife: kills ranging from those of snakes to small rodent to deer, to large cats and mega herbivores such as elephant are a common view along roads and on the rail tracks (Figure 4.5). Deaths of elephants due to trains have been well documented (Singh et al. 2001; Williams et al. 2001; Roy et al. 2009; Sharma 2009; Joshi 2010; Rangarajan et al. 2010).

The number of casualties appears to be growing constantly as traffic increases and infrastructure expands. According to Forman and Alexander (1998), roads have overtaken hunting as the leading direct human cause of vertebrate mortality on land. The number of kills on most roads is likely to be higher than immediately visible, as many animals that are hit by vehicles die later and elsewhere from injuries or shock. In India, mortality of herpetofaunal species has been extensively recorded (Das et al. 2007; Bhupathy et al. 2011; Pragatheesh & Rajvanshi 2013). Road deaths in snakes have been attributed to their thermoregulatory needs (Rosen & Lowe 1994; Shine et al. 2004) and seasonal movements; these deaths have been identified as a population-level threat to several species (Clark et al. 2010, Rouse et al. 2011).

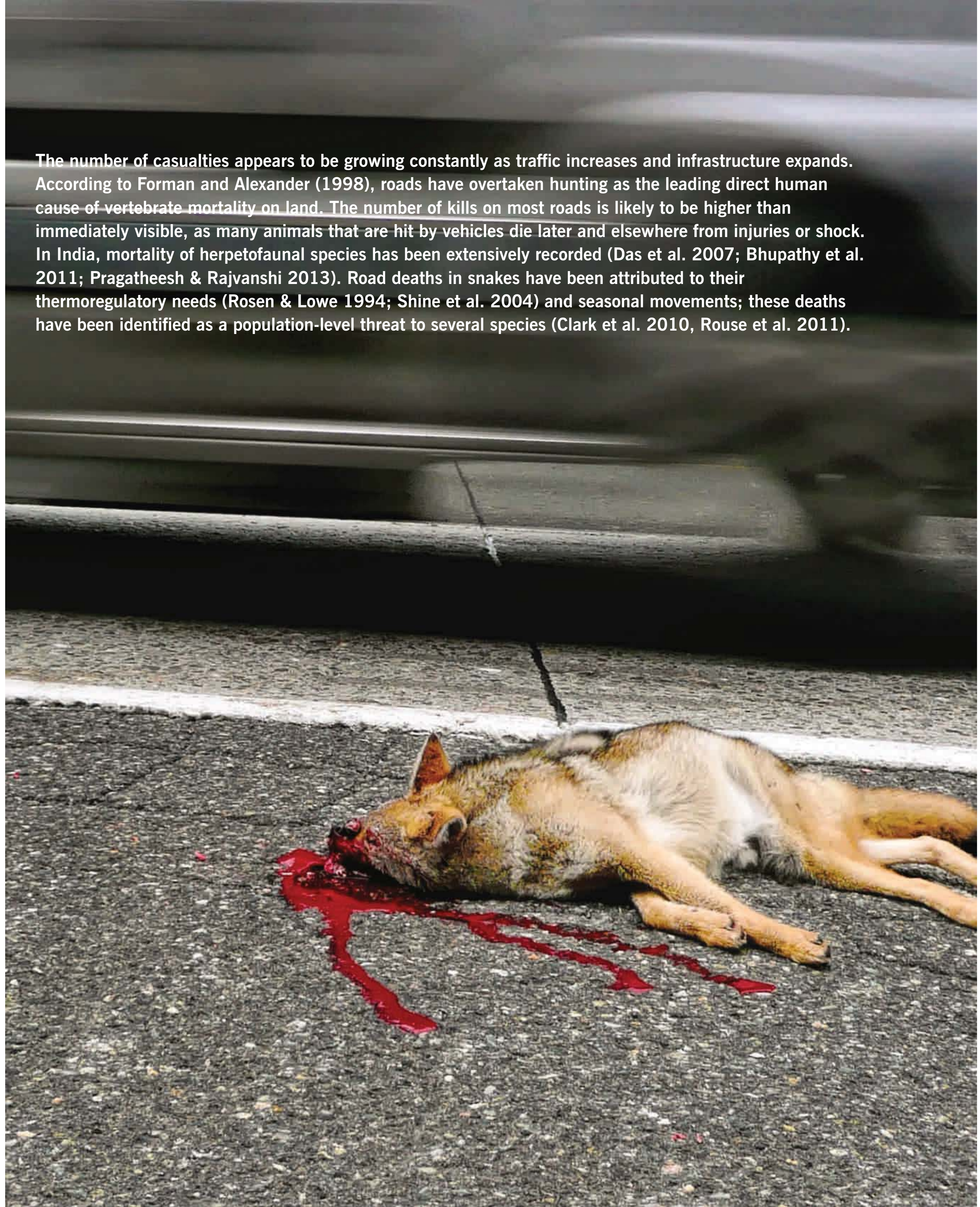
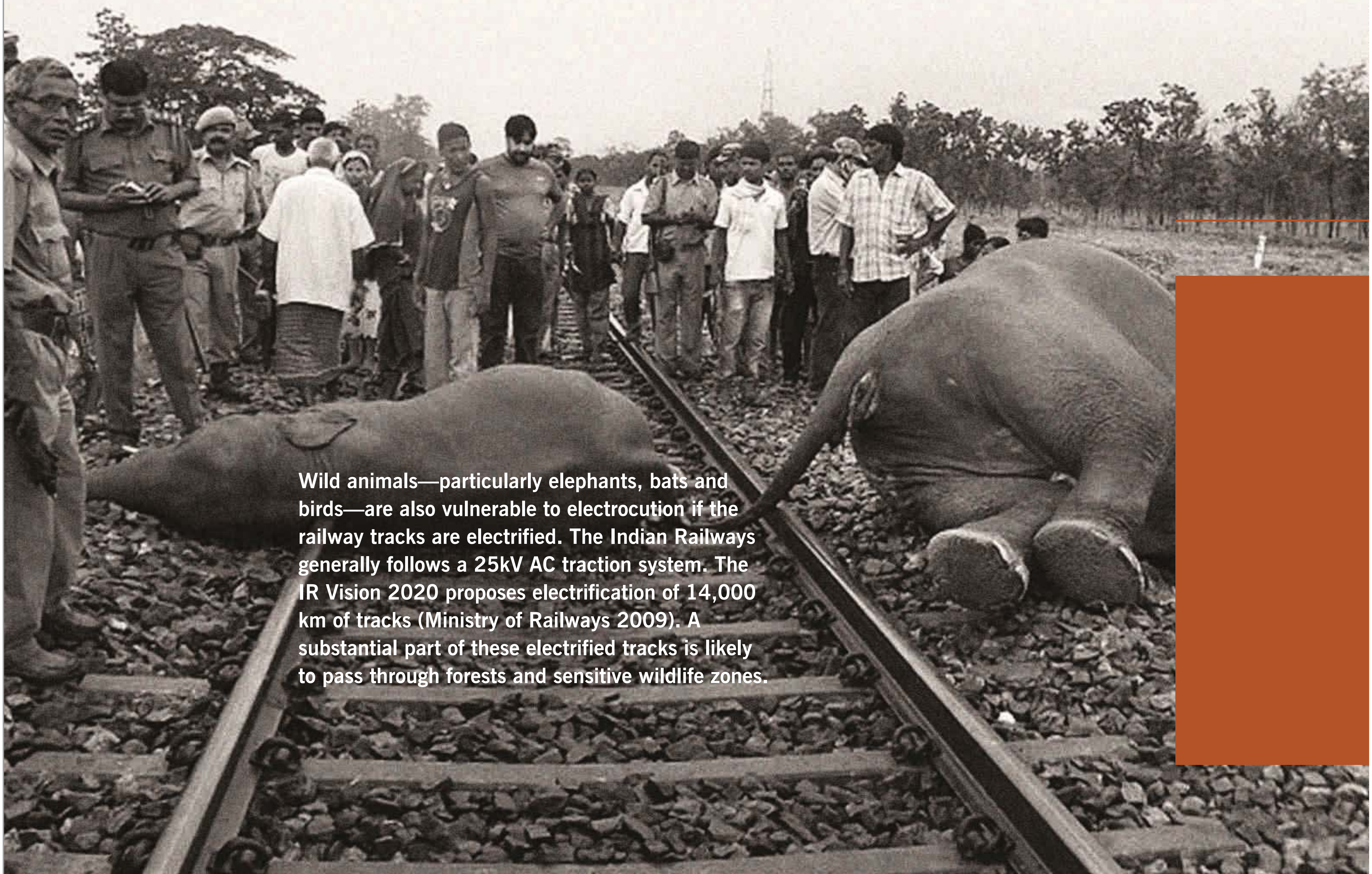


Figure 4.5. Road-induced mortality of sambar (above), langur and red fox (below).
Source: *Photographs by Bivash Pandav.*

Trains cause mortality by direct collision, electrocution, entrapment and wire strikes (Dorsey et al. 2015). A large number of wild animals are run over by trains in India every year. In the past two and half decades, India has lost over 200 elephants (*Elephas maximus*) as a consequence of hits by trains (WTI 2013) in different parts of the country (Figure 4.6).



Wild animals—particularly elephants, bats and birds—are also vulnerable to electrocution if the railway tracks are electrified. The Indian Railways generally follows a 25kV AC traction system. The IR Vision 2020 proposes electrification of 14,000 km of tracks (Ministry of Railways 2009). A substantial part of these electrified tracks is likely to pass through forests and sensitive wildlife zones.

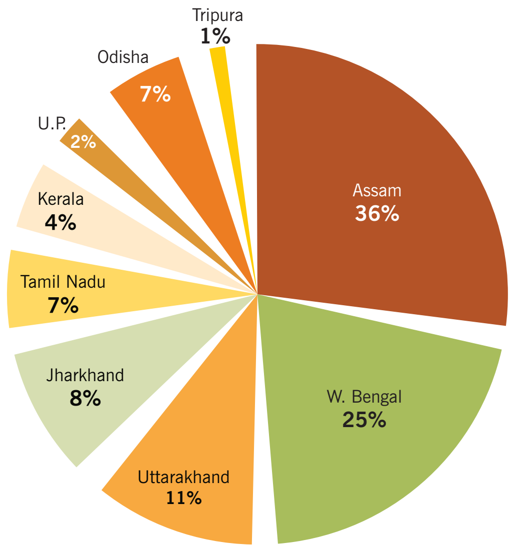


Figure 4.6. Elephant mortality due to trains in India (1987-2013).
Source: *WTI 2015.*

Cases of mortalities on railway tracks have also been recorded for many other wildlife species including tiger (Panthera tigris), lion (Panthera leo persica), leopard (Panthera pardus), rhinoceros (Rhinoceros unicornis), gaur (Bos gaurus), sloth bear (Melursus ursinus), fishing cat (Prionalurus viverrina), leopard cat (Prionailurus bengalensis), wild boar (Sus scrofa), hog deer (Axis porcinus), chital (Axis axis), barking deer (Muntiacus muntjak), sambar (Rucervus unicolor), blue bull (Boselaphus tragocamelus), goral (Nemorhaedus goral), porcupine (Hystrix indica), crocodile (Crocodilus palustris), monitor lizard (Varanus spp.), python (Python molurus) and various species of turtles, snakes and frogs. Many of these species are either listed in Schedule I of the Wildlife (Protection) Act, 1972, or included as threatened species in the IUCN Red List.

Experience has shown that the frequency of accidents involving wild animals on railway tracks and roads generally increases with traffic intensity, train speed, and animal activity and density. This may not always be the case because beyond a threshold traffic volume, the collisions will actually drop because the animals are too scared to cross (Figure 4.7).

MODELLING 'BARRIER EFFECT' ON INDIAN ROADS: EFFECT OF TRAFFIC VOLUMES AND HETEROGENEITY ON THE MOVEMENT OF WILD ANIMALS

Highway agencies often say that four laning of the existing two lane highway would not have any negative impact on the movement of wild animals. Wildlife biologists on the other hand feel that all such upgradations lead to enhancement of both traffic volumes and velocity and therefore can become a hindrance to animal movement across the highway leading to their avoidance of the highway for crossing over. This phenomenon has been termed as the 'barrier effect' and it manifests in several forms. We modelled the 'barrier effect' of a 2- and 4-lane section of NH 7 on four species – tiger, leopard, gaur and chital to demonstrate that reduced number of their road kills observed after upgradation of road needs to be evaluated from a different perspective. This highway receives an average traffic volume (452 vehicles/hr) which is largely heterogeneous and include buses, cars, trucks and multi-axle vehicles. We used several species-specific characteristics such as body length, behaviour, average group size, average time taken to cross the road, road width, traffic volume and heterogeneity as factors that can influence the success of crossing over by the animal species.

The results of this modelling have been shown in Figure 4.7. In each of these figures, three categories of crossing over probabilities have been considered. These include: (i) Pass Zone (where 100 to 50% of the individuals are able to cross the road) (ii) Killer Zone (where a maximum of 25% of the individuals are able to cross the road) and (iii) Deterrent Zone (where more than 75% of the individuals are repelled from crossing the road).

It is evident from the results of the model illustrated in Figure 4.7, that, for most of the species, the current traffic volume (452/hr) on NH 7 is already posing a 'barrier' to their movement. This barrier effect will prevent species from getting on to the road and crossing it. While it may reflect in a decline in their mortality, it would also deprive them from using their entire habitat and may ultimately lead to a decline in their genetic fitness.

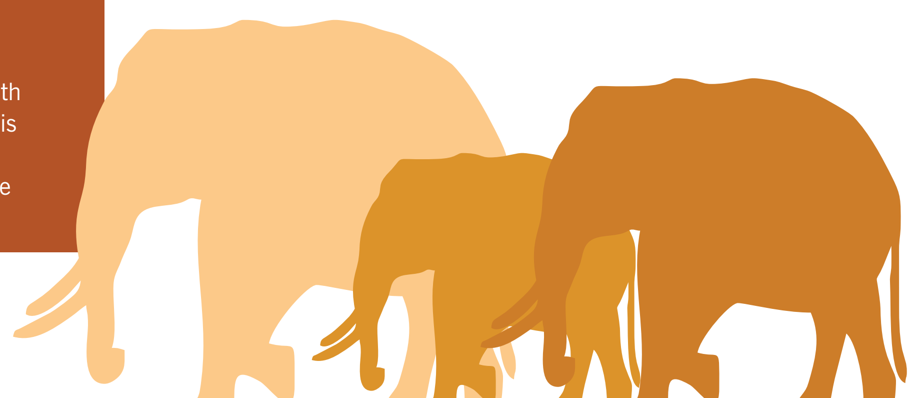
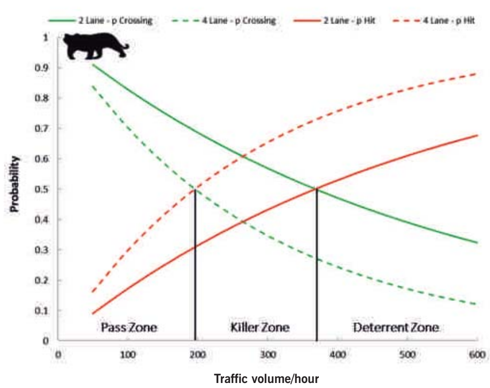
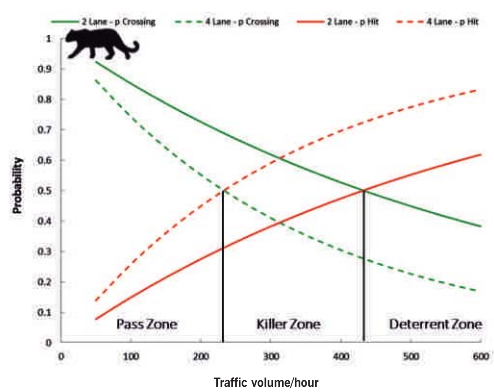


Table 4.1: Traffic volume (vehicle/hr) with respect to different zones of animal crossing on NH 7.

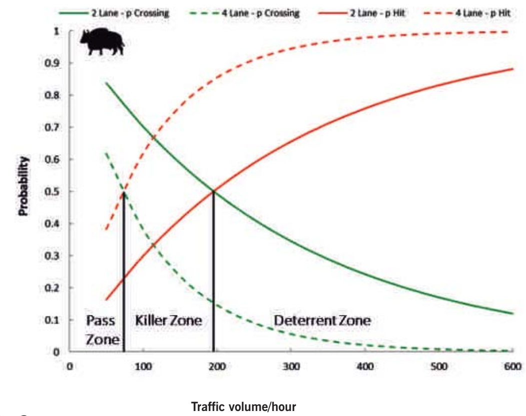
Species	Road type	Pass Zone (0-0.5)	Death Zone (0.5-0.75)	Deterrent Zone (0.75-1)
Tiger	2 Lane	0-375	375-600	>600
	4 Lane	0-195	195-390	>340
Leopard	2 Lane	0-430	430-600	>600
	4 Lane	0-230	230-450	>450
Gaur	2 Lane	0-190	190-380	>380
	4 Lane	0-80	80-145	>145
Chital	2 Lane	0-160	160-320	>320
	4 Lane	0-80	80-160	>160



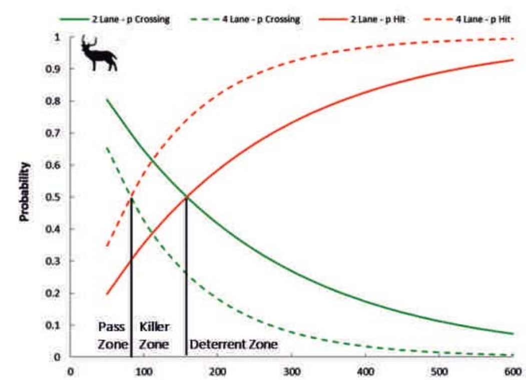
(A): Tiger



(B): Leopard



(C): Gaur



(D): Chital

Traffic volume/hour

Figure 4.7: Traversability models showing probability of hit (red lines) or successful crossing (green lines) of (A) Tiger (B) Leopard (C) Gaur and (D) Chital on NH 7 with respect to available traffic volume (452 vehicles/hr) and heterogeneity as on March 2015.

Source: *Habib et al. 2015.*

Barrier to movement

Although roads and railways can serve as a corridor for species moving across landscapes, they may restrict, inhibit or prevent the movement of species. This barrier effect on wildlife results from a combination of factors, from traffic noise, train movement, pollution and human activity to physical hindrances and traffic mortality (Trocmé et al. 2003).

A railway line or a road can act as a strong barrier on a number of counts: the embankment may be too high to climb, constructed of material (e.g. loose gravel or large stones) that cannot be navigated by some species, or present a visual barrier that discourages crossing by species used to long lines of sight. The railway tracks themselves may deter passage, and traffic movement or volumes may hinder or prevent crossing by many species.

The rate of animal movement through road or rail corridors may be lower than in intact natural habitat. Linear infrastructure thus acts as a filter to movement in that corridor, affecting its so-called 'permeability'.

Other factors influencing the barrier effect are presented in Figure 4.8.

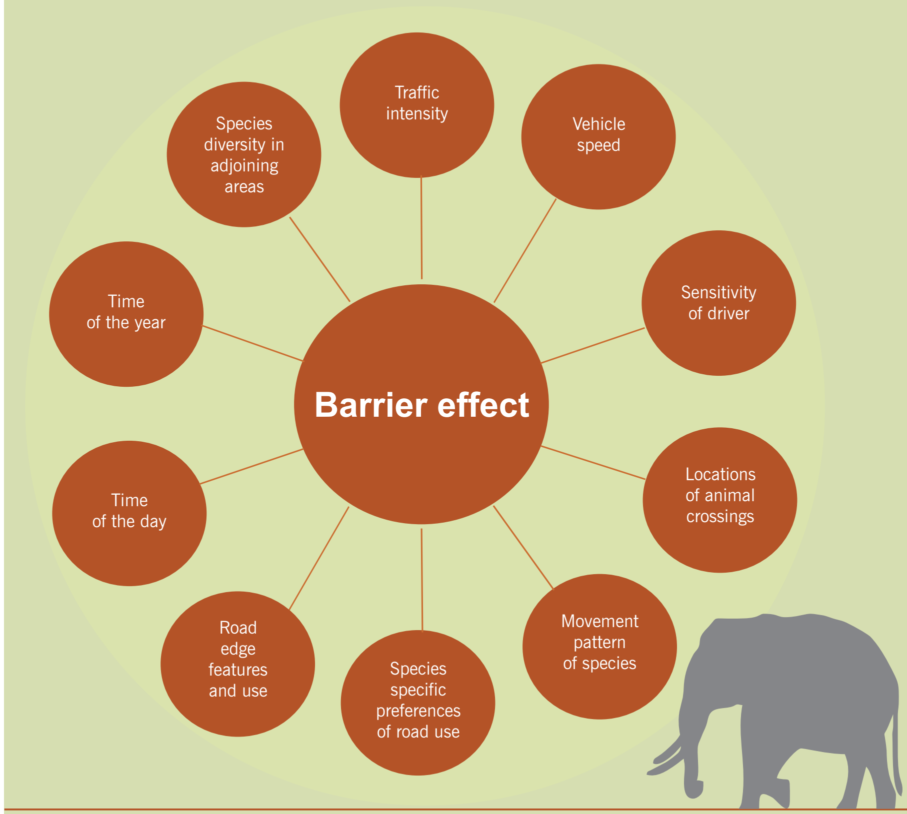


Figure 4.8. Factors influencing barrier effects of roads.

Roads and railways may break canopy connectivity, which is essential for the movement of arboreal species such as lion tailed macaque (*Macaca silenus*), hoolock gibbon (*Hoolock hoolock* and *Hoolock leuconedys*) and giant squirrels (*Ratufa* spp.), amongst others (Figure 4.9).

Roads and railways may reduce access to saltlicks or waterholes by wild animals in general, access to summer and winter ranges by ungulates, to wetland breeding sites by amphibians, and to upland nesting habitat by turtles.

Figure 4.9. Roads or railways may break the canopy connectivity that is vital for arboreal mammals.
Source: *Photograph by A. Pragatheesh.*

Disruption of processes that maintain regional wildlife populations

Roads and railways aligned through otherwise undisturbed and integrated landscape can affect natural (ecological and evolutionary) processes, which in turn may have long-term implications for wildlife. They can change fire or burning patterns and hydrological regimes (e.g. through alteration in runoff from surfaced areas), introduce and enable the spread of invasive and alien species, and influence genetic drift.

Roads and railway lines can act as a source of ignition of fire in a landscape, or can create firebreaks that prevent the spread of natural fires that may be important in wildlife management.

Animal movements among meta-populations are vital for their long-term viability. Roads and railways may block movement of some small animal species and subdivide their populations. Smaller populations are more vulnerable to genetic changes due to genetic drift and inbreeding depression, and to extinction risk.

Increased human pressure

Road and rail corridors may provide access to previously inaccessible areas, increasing the pressures associated with human presence. Roads may induce ribbon development along their length; cases of encroachment on railway land either within or on the fringes of forests are common.

Road and rail corridors may also increase human access for poaching of wild plants and animals, and illegal removal of timber, firewood and other non-timber forest products (NTFPs). Increased access and human pressures are particularly likely during construction and maintenance of road and railway tracks when large number of workers enter and camp within forests.

Railways are known to be misused by the mafias in certain areas to smuggle timber and wildlife from forests[1].

[1] *For example, see "Palamau Tiger Reserve and ECR Dhanbad Division lock horns over timber smuggling" (Railnews, 16.12.2013) and "RPF, Odisha Forest Officials busted turtle smuggling gang" (Railnews, 28.8. 2013), www.railnews.co.in.*

Human accidents and economic losses

Road traffic injuries are a major but neglected public health challenge that requires concerted efforts for effective prevention. Of all the systems with which people have to deal every day, road traffic systems are the most complex and the most dangerous. Worldwide, an estimated 1.2 million people are killed in road accidents each year and as many as 50 million are injured or disabled (WHO 2004). Both World Health Organisation (WHO) and World Bank data show that, without appropriate action, these injuries will rise dramatically by the year 2020, particularly in rapidly-motorising countries. Not only is 90% of the current burden borne by low-income and middle-income countries, but the increase in casualty rates will be greatest in these countries (WHO 2004).

The Planning Commission, in its 2001–2003 research, estimated that traffic collisions resulted in an annual loss of $10 billion (INR 550 billion) during the years 1999–2000. In 2012, the International Road Federation (IRF) estimated that traffic collisions result in an annual loss of $20 billion (INR 1 trillion (short scale)) in India. This figure includes expenses associated with the accident victim, property damage and administration expenses.
(https://en.wikipedia.org/wiki/Traffic_collisions_in_India).

Photograph by A. Pragatheesh

Increased human-wildlife conflict

Roads and railways may disrupt the normal home ranges of elephant families, forcing them to explore new areas for foraging where they may come into conflict with human beings.

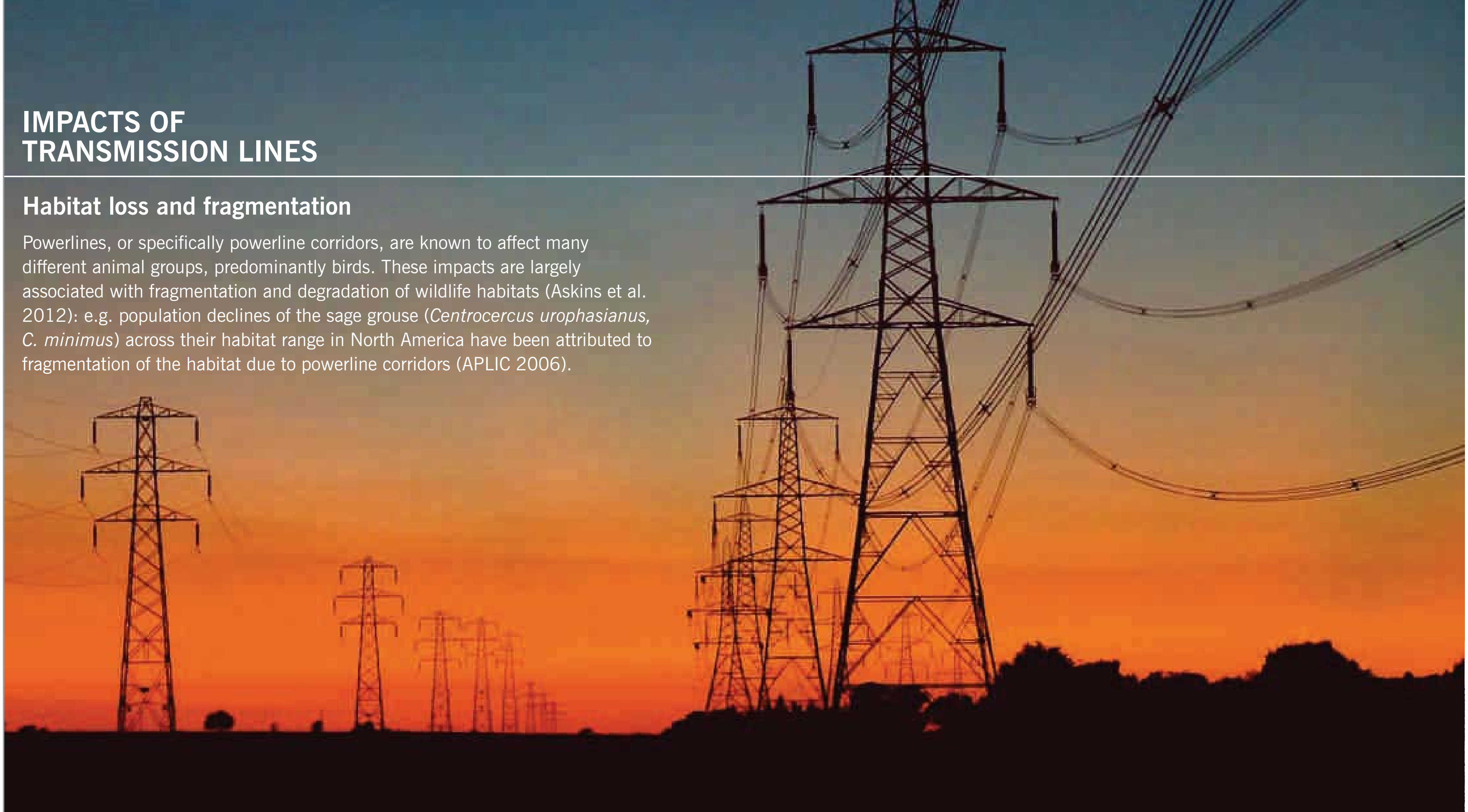
Human settlement or cultivation of land along road or railway corridors may also increase human-wildlife conflict (HWC) and, occasionally, lead to mortality of wild animals.

In case of already fragmented habitats, wild animals are known to use particular corridors to move between various patches. If roads or railways obstruct these corridors, the animals may stray into human localities and feed on crops and livestock, increasing conflict.

IMPACTS OF TRANSMISSION LINES

Habitat loss and fragmentation

Powerlines, or specifically powerline corridors, are known to affect many different animal groups, predominantly birds. These impacts are largely associated with fragmentation and degradation of wildlife habitats (Askins et al. 2012): e.g. population declines of the sage grouse (*Centrocercus urophasianus, C. minimus*) across their habitat range in North America have been attributed to fragmentation of the habitat due to powerline corridors (APLIC 2006).



Powerline corridors, where vegetation has been cleared or cut back along wayleaves or servitude areas, also affect animal movement and permeability of habitat, similar to road and railway corridors.

Electrocution

Electrocution has grown to become a significant threat for a range of animals, from small birds to large mammals such as elephants that have been electrocuted by sagging powerlines (Raman 2011).

Powerlines cause large-scale mortality of birds around the world due to electrocution and collision (Bevanger et al. 1998; Rubolini et al. 2005; Jenkins et al. 2010; Prinsen et al. 2011; Margalida et al. 2012; Dixon et al. 2013; Loss et al. 2014). Powerlines located close to important bird areas (especially water bodies having large congregation of birds, or carcass or garbage dumps), or bisecting critical flight paths, pose a significant risk of electrocution or collision in birds.

Transmission lines (typically $\geqslant$ 66 kV) are placed on tall metal lattice towers holding multiple conductor wires on cross arms. The phase-to-phase and phase-to-ground separation in transmission lines is usually sufficient to prevent electrocution of birds (APLIC 2006). However, electrocution of birds can occur when a bird, perched on a live wire, power pole or on the metal cross-arm, comes in contact with another live or earth wire (also called grounded wire), power pole or cross-arm (Janss & Ferrer 1999; Prinsen et al. 2011). Other structural components on the distribution power poles such as the pin-type insulators and jumpers have also been reported to cause mortality in birds (Tinto et al. 2010; Harness et al. 2013).

Apart from structural aspects of the powerline, biological characteristics of birds, including body size, age class and behaviour, affect electrocution risk (Bevanger 1998). Birds with large wing spans that show preference for using power poles during hunting, or for perching and roosting—particularly raptors—are known to be more susceptible to electrocution (Janss 2000). Raptors and storks are reported to be most at risk of electrocution, since they use power poles extensively as nesting platforms (Prinsen et al. 2011).

Figure 4.10. Electrocution due to powerlines is a threat to the Critically Endangered great Indian bustard. **Source**: *Photograph by D. K. Chindage*

A recent survey of 675 power poles in western Rajasthan recorded 162 birds which had been electrocuted, including five species of raptors (Harness et al. 2013). In the past ten years, six great Indian bustards died as a consequence of collision or electrocution by powerlines (Figure 4.10).

Ecological factors such as the availability and distribution of prey, and landscape features, are also known to affect electrocution risk in birds: high prey availability in a particular habitat attracts many predatory birds like raptors, leading to an increased risk. In habitats devoid of tall vegetation, especially in arid landscapes and in grasslands, powerlines provide suitable perch sites (APLIC 2006), thus increasing the risk of electrocution (Figure 4.11).

Figure 4.11. Powerlines and power poles are commonly used by birds of prey like (a) black-shouldered kite (b) buzzard (c) shikra (d) common kestrel (e) short-toed snake eagle and (f) eagle.

Source: *Photographs by (a) Chetan Misher (b) Akshit Suthar (c) Chetan Misher (d) Hemant Bajpai (e) Chetan Misher (f) Akshit Suthar.*

Figure 4.12. Mortality of mammals due to electrocution by transmission lines.

Source: *Photographs by (a) http://indiasendangered.com (b) Chetan Misher (c) Shankar Raman (d) Pavan Josh.*

Electrocution of wild animals is not limited to birds, however mammals such as bats, apes and elephants are also vulnerable (Figure 4.12).

Collision

Collision occurs when a bird in flight physically connects with overhead powerlines, resulting in death or serious injury; collision is most common with high voltage transmission lines. Collision occurs specifically with the earth wire on the transmission lines that is less visible to birds (Faanes 1987). In India, 1% of the total sarus crane (*Grus antigone*) population is reported to be killed every year due to collision with powerlines (Sundar et al. 2005). Tere and Parasharya (2011) recorded mortality of 150 flamingos (*Phoeniconaias minor* and *Phoenicopterus roseus*) due to collision with high-tension powerlines passing through their breeding colony in Gujarat, western India (Figure 4.13).

Figure 4.13. Mortality of flamingos after collision with transmission lines.
Source: *Photograph by R.D.Meriya.*

The risk of bird collisions with powerlines is affected by biological and ecological factors. Collisions are mainly reported to occur in fast-flying species with poor manoeuvrability and poor forward vision (Prinsen et al. 2011): bustards, eagles and cranes, which have a large blind sector in their forward-facing visual field (Martin & Shaw 2010), are more prone to collision with powerlines. Migratory birds are said to be more susceptible to collisions as juveniles are unfamiliar with new landscapes; this factor is reported to be the main cause of mortality in fledged whooping cranes (*Grus americana*) that migrate from Canada to Texas (Stehn & Wassenich 2008). Reduced visibility in poor weather— particularly foggy conditions in winter—is reported to have caused a high number of bird collisions with powerlines (Prinsen et al. 2011).

SUMMARY OF ECOLOGICAL IMPACTS OF LINEAR INFRASTRUCTURE ON DIFFERENT ANIMAL GROUPS

The relative impacts of linear infrastructure development on different animal groups, and the degrees to which these groups are affected, are summarised in Table 4.2.

Table 4.2. Relative impacts of roads, railway lines and powerlines on different animal groups.

Taxa		MAJOR IMPACTS														
		Habitat loss			Habitat fragmentation			Disturbance-induced behavioural changes			Injury/mortality			Impediment to movement		
		Roads	Railway lines	Powerlines	Roads	Railway lines	Powerlines	Roads	Railway lines	Powerlines	Roads	Railway lines	Powerlines	Roads	Railway lines	Powerlines
Mammals	Large mammals	Moderate	Moderate		High	Moderate		High	Moderate		High	High	High	High	Moderate	Moderate
Mammals	Medium and small mammals	High	Moderate		High	Moderate		High	Moderate		High	High		High	Moderate	
Mammals	Arboreal animals/gliders	High	Moderate	Moderate	High	Moderate	Moderate	High	Moderate	Moderate	High	High	Possible	High	High	Moderate
	Birds	Moderate	Moderate	Moderate	Moderate		Moderate		Moderate	Moderate	High	Moderate	High		Possible	High
	Reptiles	High	Possible		High			High	Moderate		High	Moderate		High	Possible	
	Amphibians	High	Possible		Moderate	Moderate			Moderate		High			High	Possible	
	Invertebrates	Moderate	Moderate		Moderate			High	Moderate		High			High		

Key High impact · Moderate impact · Possible impact

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05 MITIGATION PRINCIPLES

Mitigation refers to measures to avoid, reduce or remedy harm.

In the context of developing linear infrastructure such as roads, railway lines and powerlines, the purpose of mitigation is to identify strategies and measures that will address the conservation concerns likely to be associated with the development proposals. In order to deliver the potential benefits of green infrastructure development, these strategies and measures must follow a set of key mitigation principles, as set out below.

MITIGATION SHOULD BE GOAL ORIENTED

Mitigation should be focused on achieving explicit conservation goals within clear timeframes, to be integrated in the broader 'green infrastructure development' approach. These goals should be informed by the significance of affected biodiversity, priority of conservation goals and the values of natural systems to affected communities.

Use of the SMART approach is recommended to evaluate the likely effectiveness of alternative mitigation strategies or measures: 'SMART' refers to measures that are specific, measurable, achievable, realistic and timely.

Mitigation should aim to address not only direct 'footprint' impacts on natural systems, but also ecological effects caused by the development of linear infrastructure which may only be manifest in decades to come (Forman et. al. 2003), affecting regional populations of wild animals (Figure 5.1).

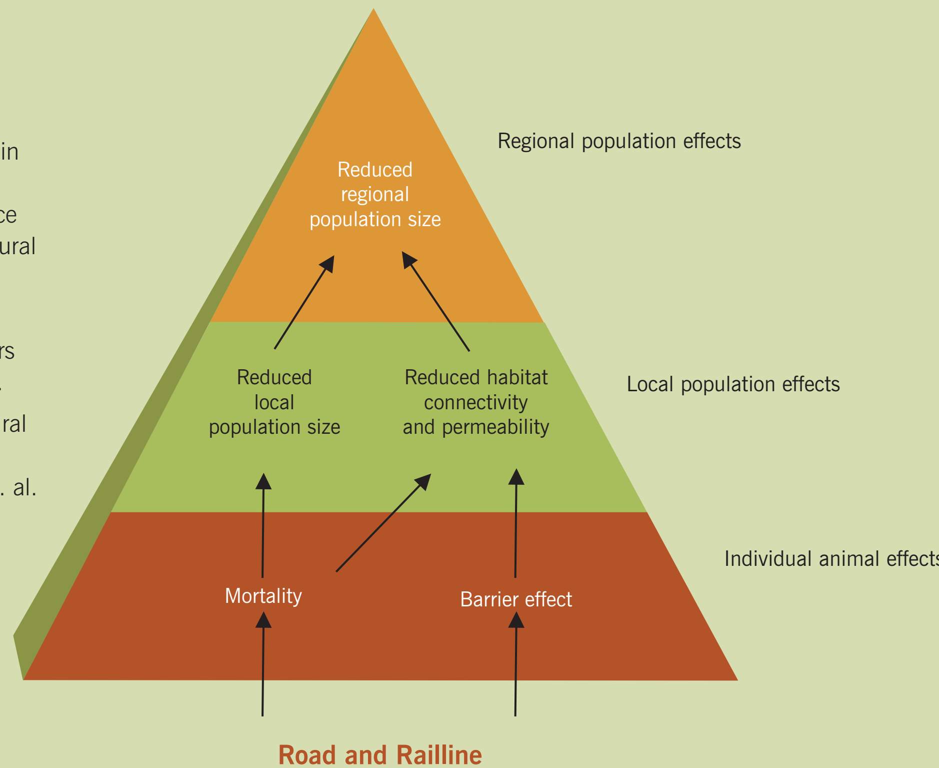


Figure 5.1. Effects of roads and rail tracks on individual animals and wildlife populations.
Source: *Adapted from Forman et al. 2003.*

MITIGATION MUST FOLLOW A HIERARCHY OF MEASURES

- First, avoid or prevent adverse impacts as far as possible by considering spatial or design alternatives. Where impacts are highly significant or could lead to loss of irreplaceable biodiversity or conservation assets, avoidance is the only real option if development is to be sustainable;
- Second, minimise or reduce adverse impacts to 'as low as practicable' levels;
- Third, restore areas damaged by construction; and
- Fourth, remedy or compensate for adverse residual impacts which are unavoidable and cannot be reduced further.

MITIGATION MUST BE ADDRESSED AS AN INTEGRAL PART OF PROJECT PLANNING AND IMPLEMENTATION

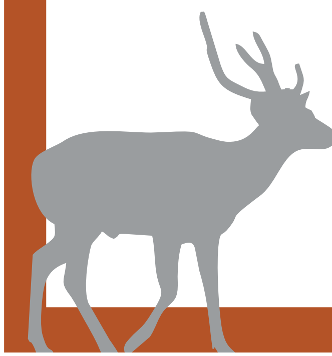
- Mitigation strategies should be considered and applied early in the planning stages of the project cycle.
- Mitigation measures for impacts of each linear development proposal should consider the combined (cumulative) effects of existing projects on biodiversity, as well as the anticipated impacts of infrastructure foreseen to be developed over the next 10-20 years: conservation values are eroded by multiple developments in a given landscape. These measures should be reviewed and adapted over the long term, based on an improved understanding of these combined impacts.
- Mitigation must address impacts not only at project site level, but at the level of the wider living landscape, respecting the need to maintain corridors and networks of natural habitat: linear infrastructure development has impacts across multiple habitats, species ranges, watersheds and land-use zoning.
- The design of mitigation measures must consider that each species is unique, with different ecological requirements, capacities, behavioural patterns and responses to linear infrastructure.
- Competent wildlife ecologists from recognised institutions should be engaged at the planning stage to identify impacts and develop optimum mitigation measures: this approach would save lot of time and resources, and be beneficial for society and for conservation in the long term.
- Mitigation measures should be incorporated in the tender and contract documents for implementation during the construction and operational phases.

MITIGATION MEASURES NEED TO TARGET SIGNIFICANT IMPACTS

- Mitigation must focus on the most extinction-prone taxa and habitats in the landscape under consideration, as well as those species that are most sensitive to the specific development impacts.
- Mitigation needs to include measures to sustain prey populations and other elements of the ecosystem that support conservation of charismatic or umbrella species (e.g. the tiger) which command high conservation significance.
- Mitigation should first consider avoidance of development ('no go' option) in source areas of threatened taxa. If avoidance is not possible, stringent measures need to be stipulated in areas representing specialised habitats, the habitat ranges of protected species, migratory routes and bottlenecks in ecological corridors that are crucial to effective conservation in the long term.
- The mitigation plan should include implementation schedule, clear institutional responsibilities for implementation of measures and the cost estimates for mitigation action.

PLEASE NOTE

Better planning at an early stage can greatly help avoid problems. It is therefore recommended to do a thorough and more comprehensive upstream approach in planning for development in all sectors.



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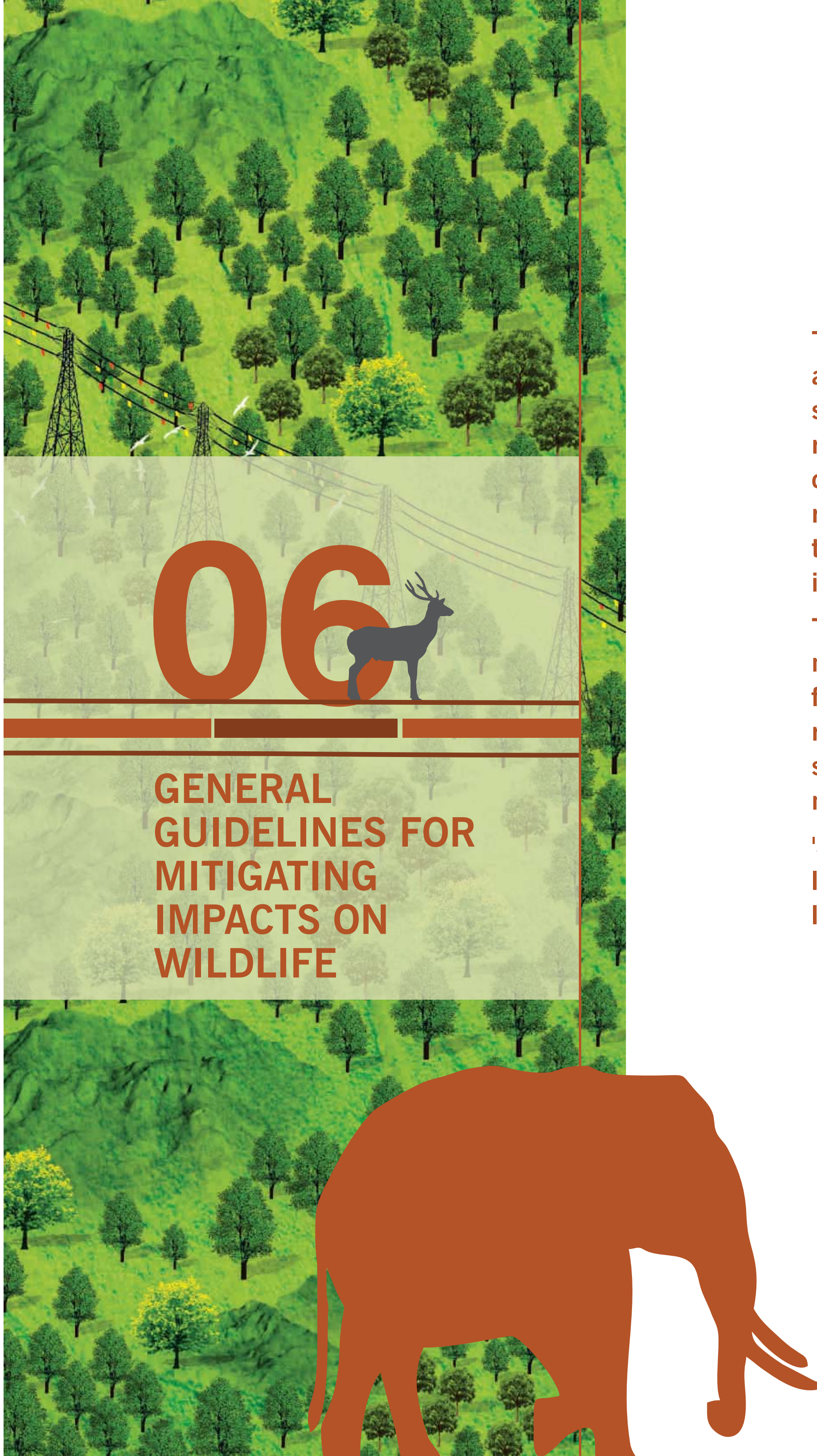
Forman, R. T. T., D. Sperling, J. A. Bissonette, A. P. Clevenger, C. D. Chutshall and V. H. Dale et al., 2003. Road ecology: science and solutions. Island Press, Washington.

MITIGATION OF IMPACTS OF ROADS AND RAILWAY LINES

PART II

Ideally, the routing of roads and railways in the landscape should be planned at a strategic landscape level, in such a way that they are located and concentrated in areas of little importance to wildlife and would not bisect or fragment their habitats. In reality, however, there are numerous corridors of linear infrastructure in place that are having a significant negative impact on wildlife, and decisions on new roads and railways have already been taken. While there is thus a need in the longer term to encourage a more strategic, landscape-scale approach, there is an urgent need to improve the design and uptake of appropriate wildlife-friendly technology in existing infrastructure and in projects that have been authorised. This Part of the guideline therefore focuses on these project-level design and technology needs.



06 GENERAL GUIDELINES FOR MITIGATING IMPACTS ON WILDLIFE

Transportation planners know that highway and railway systems must accommodate other elements of human infrastructure (e.g. water supply systems, sewer systems, electric and gas utilities). Biologists and natural resource planners can define networks of core conservation areas and connectivity zones, effectively defining the ecological infrastructure for a region. They can then work with transportation agencies to ensure that transportation systems are designed to accommodate this ecological infrastructure.

Traditionally, highway impacts on wildlife have been viewed in terms of road mortality and threats to selected populations of animals. Viewing this issue from a wider perspective, however, it is clear that both highways and railways have the potential to undermine ecological processes at a landscape scale through the fragmentation of wildlife populations, restriction of wildlife movements, and the disruption of gene flow and meta-population dynamics.

'Smart' or 'green' linear infrastructure must aim to reduce mortality and make linear structures conducive to safe movement of animals across the landscape (Figure 6.1).

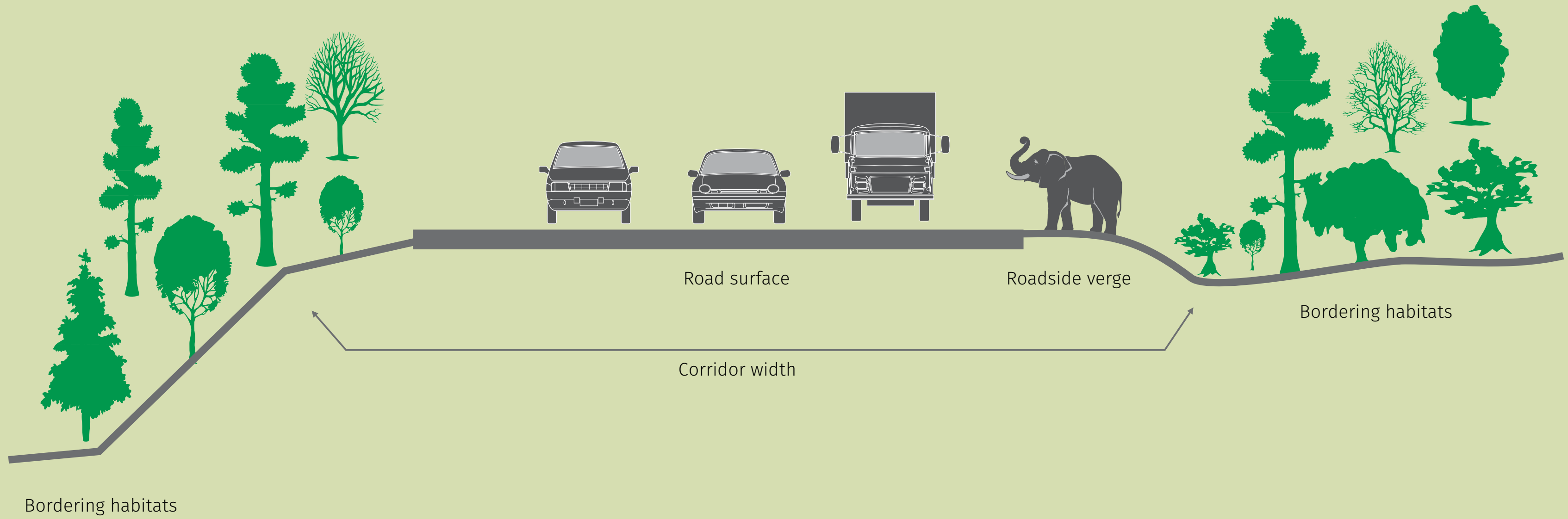


Figure 6.1. Components of a road transportation corridor. **Source:** *Illustration by N. S. Bist*

Many questions remain about how to design roads, highways, and passage structures for wild animals that will effectively mitigate the impact of roadways on animal movements and wildlife populations. Based on learning from projects around the world, current approaches to mitigation should aim to achieve at least two important and measurable conservation outcomes that should prevent decline in wild animal populations in the long term, namely (i) increased population viability and (ii) a significant reduction in infrastructure-induced mortality of animals.

Mitigation measures essentially fall into two categories, as illustrated for roads in Figure 6.2:

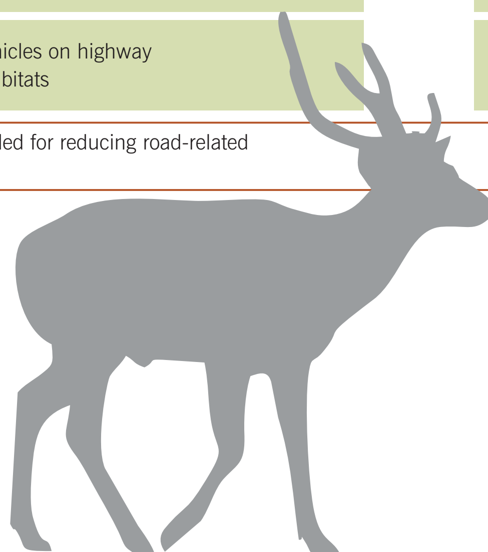
(1) regulatory or prescriptive measures that are intended to alter human behaviour, and

(2) measures to manage habitat on or near the site that are intended to influence animal responses.

TRANSPORTATION-INDUCED IMPACTS

	Measures to alter human behaviour	Measures to alter animal responses
	Regulatory or prescriptive measures	**On-site construction and habitat**
1	Speed control	Clearing vegetation for improving visibility along road
2	Temporary road closure	Erection of animal-proof fencing to prevent animals entering road
3	Control on feeding of wild animals on the road	Installation of wildlife detection systems
4	Regulatory guidelines for laying/upgrading road through sensitive habitats and wilderness areas	Increasing permeability of a road corridor by facilitating movement through construction of appropriately designed and positioned culverts or underpasses
5	Prescriptions for width of verge to be retained in different landscapes and habitats	Retrofitting existing drainage culverts to facilitate wildlife crossing by animals
6	Restrictions on stopping/parking of vehicles on highway segments passing through sensitive habitats	Maintenance of hedgerows along the road to serve as movement corridors

Figure 6.2. Mitigation approaches recommended for reducing road-related mortality of animals.



Measures specifically to address habitat fragmentation effects of transportation infrastructure fall into two broad categories: engineering (structural) options and non-structural options. These two groups of options are discussed in separate sections below, and presented and evaluated in Table 6.2.

ENGINEERING OPTIONS

There are several types of crossing structures that are used to mitigate impacts of highway and railway corridors on animal movement and safety, each with different levels of effectiveness and cost. Fundamentally, these structures are designed either to allow animals to travel below the infrastructure (underpasses) or over it (overpasses). The crossing structures are primarily about maintaining connectivity and animal movement, and less about reducing animal mortality.These different types of structures are presented in Table 6.1.

Table 6.1. Types of structures to enable animal crossing.

Land bridge

Also known as an ecoduct or a wildlife bridge, it is a 30-70 m wide bridge that extends above roads or railway lines. The bridge is typically enhanced with habitat features such as native vegetation, rocks and logs.

These structures allow for natural movement of wild animals as they are less confining, quieter, have ambient natural conditions of rainfall, light and temperature, and can be used by a wide range of fauna.

Design considerations:

- The bridge may be rectangular or hour-glass shaped.
- Human activities and disturbance (noise and artificial light) should be minimised.
- Fencing should be used to funnel the animals towards the structures and away from the road or rail.

Acceptability to wild animals should be achieved by planting and maintaining native vegetation.

Source: *Photograph by Benjamin P. Y-H. Lee (University of Kent).*

Canopy bridge

This is a rope, pole, rope or wooden ladder or walkway suspended above the road or railway, either from vertical poles or trees, and installed for tree-dwelling species.

Design considerations:

- The bridge should be located in areas having important populations of arboreal species with a high risk of mortality.
- Structures should be taut and wide enough for animals to walk on.
- Each end of the bridge should be connected to trees or bushes for cover.

A thin rope above the bridge can prevent predation of small arboreal mammals by birds.

Source: *Photograph by T R Shankar Raman.*

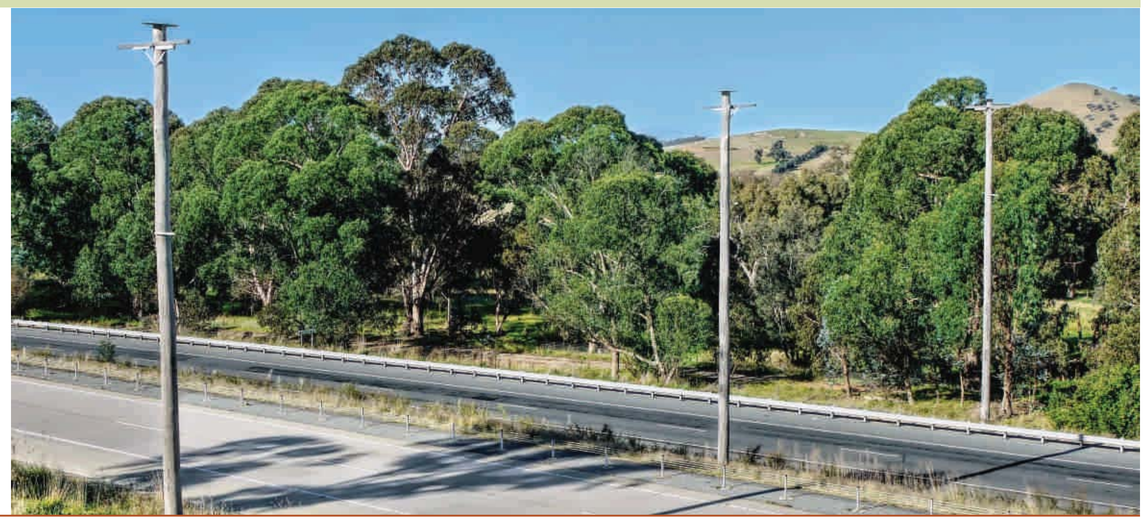
Glider poles

These are vertical poles placed in the centre median or on the road or rail verge to provide intermediate landing and launch opportunities for gliding species.

Design considerations:

- Poles should be constructed on the centre median of roads which are wider than the gliding distance of the local gliding mammals.
- While erecting glider poles, the gliding ability of juvenile animals should be taken into account. It is important to consider the ability of juvenile animals to land on a narrow pole after a 50 m glide and their ability to glide as far as adults.

Nest boxes should also be provided for the animals to rest and hide from predatory birds.



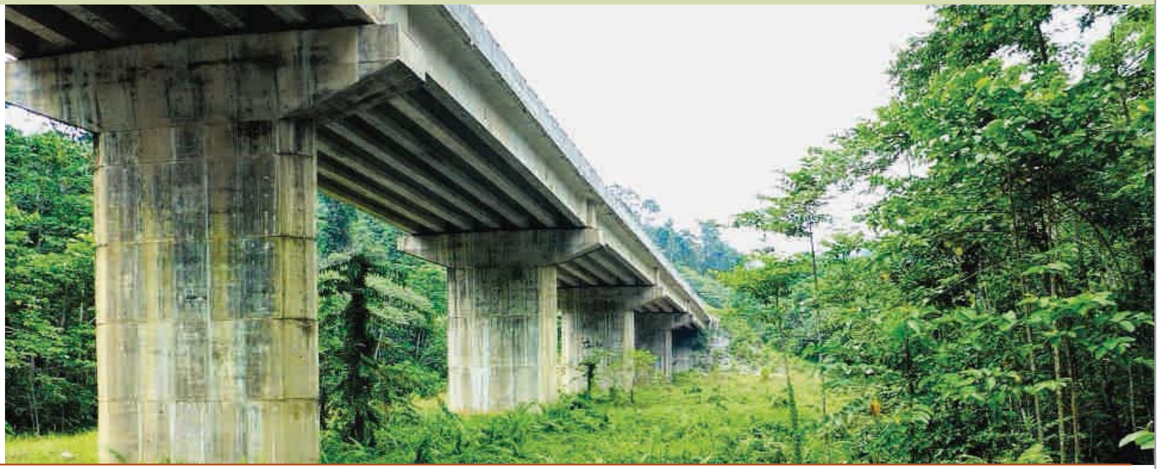
Source: *Photograph by Kylie Soanes.*

UNDERPASSES

Bridge or viaduct

This type of structure maintains or elevates the grade of the road or railway, allowing for the passage of fauna below. There may be seasonal drainage associated with the viaduct.

Viaducts are useful near valley bottoms to lead roads or railway lines across the valley.



Source: *Photograph by Rimba; myrimba.org.*

Box culverts

These are typically square or rectangular structures built under the linear infrastructure for passage of fauna (including aquatic species) and/or water.

Design considerations:

- Culverts may be of different types depending on their shape and size, and the need to cater for natural drainage.
- Adding ledges or planks above the water level in culverts has been shown to encourage many terrestrial species to use the structures.
- The type of materials and substrate used in the structure, and the establishment of native vegetation at each end of the underpass for cover, are other factors that affect use of underpasses by animals.

Source: *Photograph by Akanksha Saxena.*

Pipe culverts

These are typically round pipes of relatively small diameter (<1.5 m), made of smooth steel, corrugated metal, or concrete. Although their primary purpose is to convey water under roads or railways, a variety of wild animals has been observed using them as passageways: they are often used by small mammals, reptiles and amphibians. They have also been used as fish passages.

Design considerations:

- Single or multiple pipes should be placed at an appropriate spot.
- Native vegetation should be established on both sides of the culvert to provide cover.

Source: *Photograph by Public works department, Government of the Netherlands.*

Modified culverts (culverts with furniture)

Additional features such as walkways or planks should be installed on the interior walls of the underpass, to encourage small and medium-sized mammals to use culverts built on natural drainage sites.

Similarly, in pipe culverts, guard rails or wooden planks may be installed to facilitate movement of small mammals and reptiles through the culvert.

Furniture can and should be added to all types of crossing structures.

Source: *Photograph from Clevenger and Huijser 2011.*

Fish passages

Bridges and arch structures across waterways can facilitate fish movement if the following site and design considerations are incorporated:

- Avoid locating bridge piers or foundations within the main waterway channel to avoid the formation of large-scale turbulence or the erosion of the bed and banks of the waterway.
- Locate bridge abutments well away from the channel banks.

Culverts can also serve as successful fish passages if they are sufficiently large and installed flat to allow the natural movement of bed load to form a stable bed inside the culvert.

Source: *https://www.fws.gov/leavenworthfisheriescomplex/MidColumbiaF&WCO/HabitatRestorProj.cfm.*

Fences

Fences are best used in combination with properly placed wildlife crossing structures; they direct animals away from roads or railways and towards these structures. Fencing has been clearly demonstrated to make crossing structures much more efficient and effective.

Different fence designs can be used for small or large mammals, amphibians and reptiles.

Design considerations:

- Fencing may be erected along the entire length of the linear infrastructure or only along sections known to present a risk to wild animals or livestock. Decisions on continuous or partial fencing will depend on land-use patterns (e.g. private land, forest land).
- Both sides of the road or railway should be fenced. Fences should be symmetrical and not staggered.
- Breaks in the fences should have wildlife warning systems, warning signs or cattle guards/gates to avoid animal mortality.
- The height, material and mesh size of the fence should be decided based on the target species.

Source: *Fence for turtle: http://lakejacksonecopassage.org/turtlesatfencelarge.jpg.*
Fence for Reptile: Public Works Department, Government of the Netherlands.

CANOPY BRIDGE FOR HOOLOCK GIBBONS

Hoollongapar Gibbon Wildlife Sanctuary, situated in Jorhat district covers an area of 20.98 sq. km. of tropical rain forest in upper Assam. This sanctuary holds the distinction of harbouring 7 primate species including the western hoolock gibbon (*Hoolock hoolock*), the only completely arboreal ape in India. A railway track, which was laid out in 1919, passes through the sanctuary and fragments the habitat into two. The Assam Forest Department with the help of the NF (Northeast Frontier) Railways, constructed a canopy bridge in October 2015 across the railway track to facilitate movement of gibbons and other primate species (Figure 6.3). The canopy bridge is in the form of an iron bridge, 10.5 m in height and 9.5 m in width, straddling the railway track. Iron ropes have been tied on both sides of the green-coloured bridge and fixed to trees on either side of the track to serve as approach way to the bridge. This bridge constructed at a cost of Rupees 0.83 million (approx USD 12,000), is perhaps the country's first crossing structure to mitigate impacts of a railway track on arboreal species and its habitat.

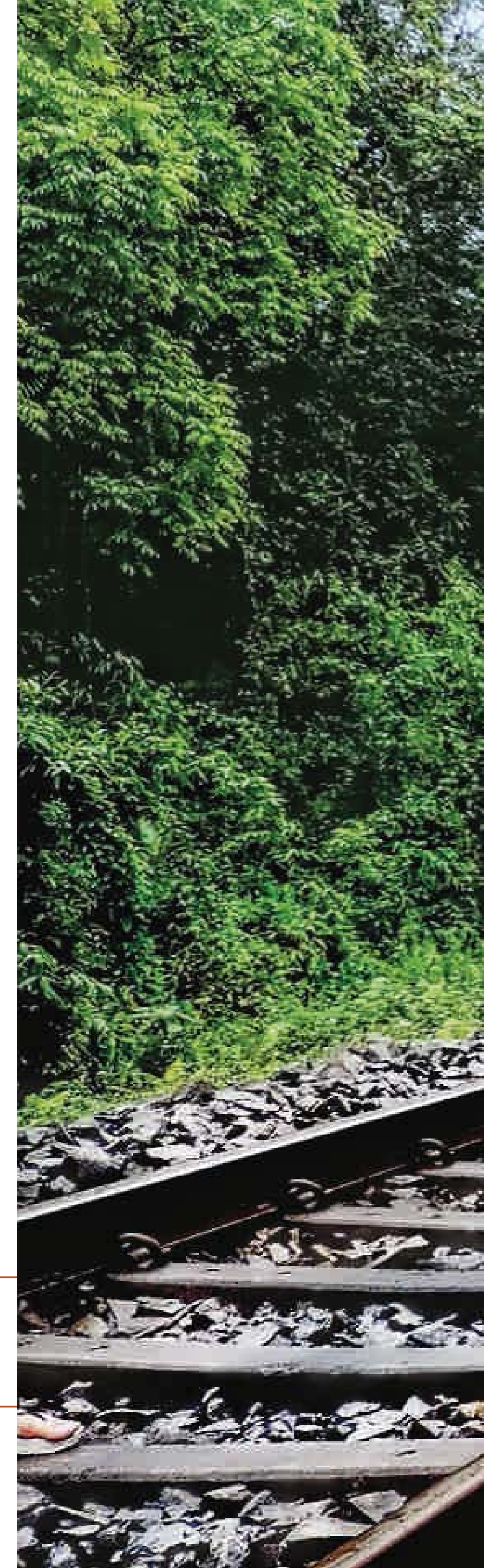


Figure 6.3: A canopy bridge (right) constructed on the railway line passing through the habitat of the western hoolock gibbon *(Hoolock hoolock)* (above).

Source: *Photograph by Vijay Cavale (hoolock gibbon) and Sonali Ghosh (canopy bridge).*

373

NON-STRUCTURAL OPTIONS

The following non-structural approaches provide additional measures for restoring wildlife connectivity across linear infrastructure and helping to improve the permeability of affected habitat.

Canopy connectivity:

The width of the linear clearing is kept sufficiently small to allow the tree canopy to remain continuous above the clearing (Figure 6.4). Where the tree canopy is not continuous, the clearing width is kept small enough to allow gliders (and other flying species) to traverse the clearing safely.

Figure 6.4. Maintaining canopy connectivity is a form of non-structural mitigation. ***Source:*** *Adapted from QLD Transport and Main Roads 2010.*

Habitat Management:

Vegetation or other habitat features (e.g. rocks, fallen timber) are strategically placed, planted or allowed to regrow so that animals are directed to preferred crossing locations. At these locations, animals cross the road or railway line without the aid of any structures (i.e. similar to a pedestrian crossing).

Corridor plantings:

Strips of vegetation are planted on either side of the linear clearing to provide attractive corridors for animal movement.

Elevating the linear infrastructure:

The road or rail is elevated above the vegetation to minimise clearing (limiting it to area required for bridge piers or pylons) and allow natural vegetation to grow under the infrastructure.

Local traffic management:

Devices to reduce noise, speed or volume of traffic, or convey early warning of risks, are used to manage traffic. They may include noise attenuation walls, road closures, lighting and signage.

Table 6.2 presents and evaluates the engineering (structural) and non-structural options for mitigating impacts on wildlife.

Table 6.2. Relative importance of different types of strategies and measures for mitigating the impacts of roads and railways on different functional groups of wild animals.

KEY	Minimum Requirement	Adequate	Best	Not applicable

MITIGATION MEASURES	Large carnivores	Large herbivores	Medium-sized mammals	Small mammals	Amphibians	Reptiles	Birds
Roadside forest habitat management							
Maintain natural habitat	Adequate	Best	Best	Best	Best	Adequate	Adequate
Minimise human activity	Best	Adequate	Best	Best	Adequate	Adequate	Adequate
Maintain canopy connectivity	Not applicable	Not applicable	Adequate	Adequate	Not applicable	Minimum Requirement	Best
Establish and maintain vegetation along roadway	Adequate	Adequate	Adequate	Best	Adequate	Adequate	Adequate
Structure type							
Pipe culvert	Not applicable	Not applicable	Not applicable	Adequate	Best	Best	Not applicable
Box culvert	Adequate	Minimum Requirement	Adequate	Best	Adequate	Adequate	Not applicable

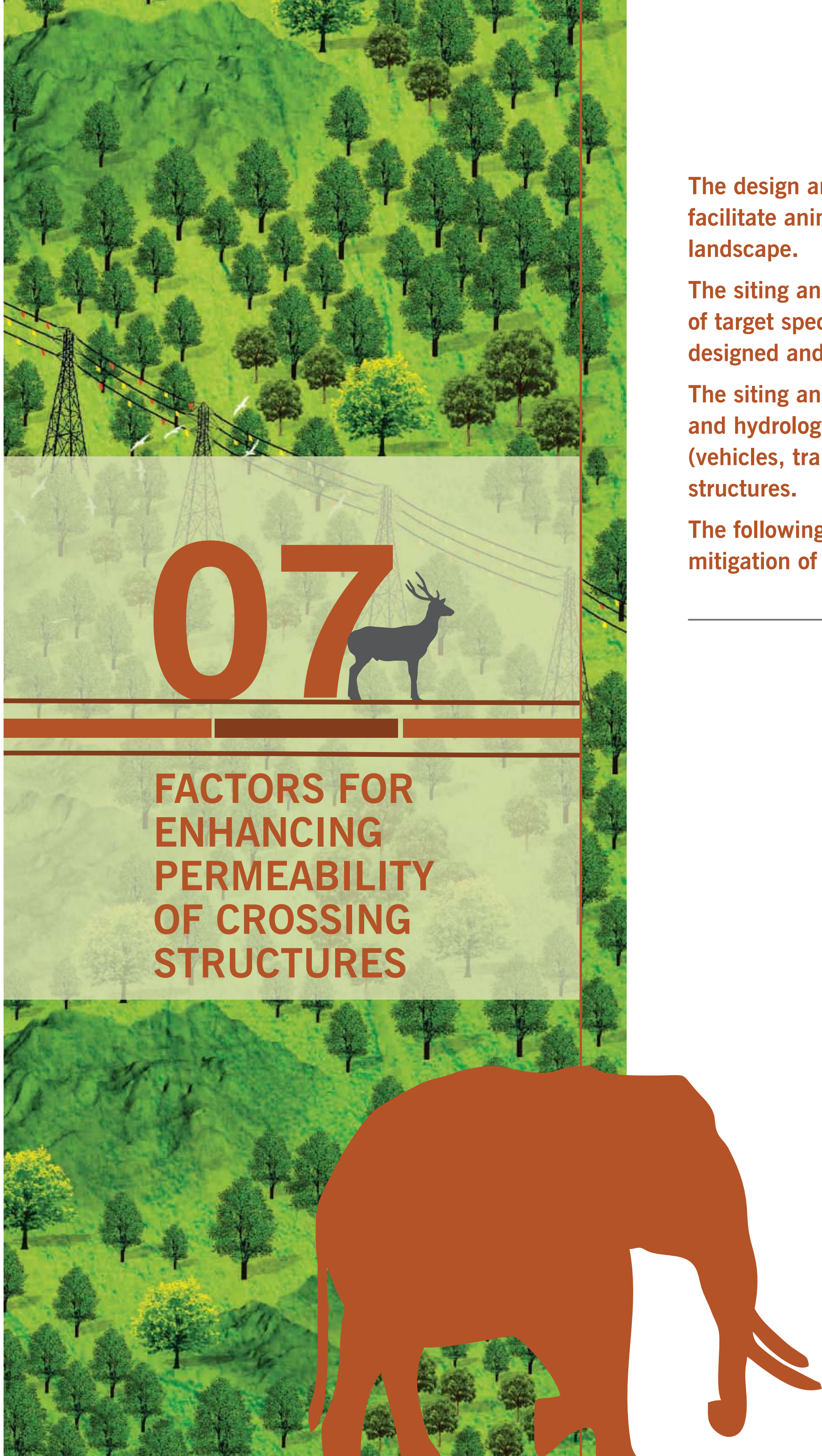
MITIGATION MEASURES	WILDLIFE FUNCTIONAL GROUPS						
	Large carnivores	Large herbivores	Medium-sized mammals	Small mammals	Amphibians	Reptiles	Birds
Canopy bridges/glider poles							
Bridge underpass							
Overpass							
Structure design standards							
Minimum openness ratio							
Field of view							
Opening cover							
Minimum height							
Natural substrate bottom							
Structure modification (furniture)							
Natural lighting							
Natural temperature							
Moisture							
Frequency of placement							
Accessibility							

MITIGATION MEASURES	WILDLIFE FUNCTIONAL GROUPS						
	Large carnivores	Large herbivores	Medium-sized mammals	Small mammals	Amphibians	Reptiles	Birds
Additional enhancement measures							
Fencing/funnelling							
Warning signs							
Animal detection systems							
Retrofitting of existing structures							
Road design in structure proximity							
Light pollution mitigation							
Traffic noise mitigation							
Other							
Maintenance							
Monitoring							

Wildlife functional groups	General animals considered (specific to India)
Large carnivores	Tiger, leopard, wolf, wild dog
Large herbivores	Elephant, gaur, rhino
Medium-sized mammals	Sambar, spotted deer, wild boar, bear
Small mammals	Hare, civets, mongoose, mouse and similar sized animals
Amphibians	Toads, frogs, salamanders
Reptiles	Snakes, lizards, turtles, tortoises, crocodilians
Birds	Great Indian bustard, eagles, vultures, munia, dove

References:

Department of Transport and Main Roads. 2010. Fauna-sensitive road design manual, Volume 2. Government of Queensland, Australia.



07 FACTORS FOR ENHANCING PERMEABILITY OF CROSSING STRUCTURES

The design and number of structures to improve the permeability of road and rail corridors must facilitate animal movement across these corridors and maintain habitat connectivity across the landscape.

The siting and design of animal passages must consider the specific requirements and behaviour of target species; where communities of animals may be affected, passages will need to be designed and managed to accommodate multiple species with different needs.

The siting and design must also consider site-specific variables such as vegetation, topography and hydrology. The types and levels of disturbance must be taken into account too: traffic (vehicles, trains) noise and vibrations may discourage wild animals from using crossing structures.

The following sections focus on the design of underpasses as the predominant structural form of mitigation of impacts of roads and railways on wildlife.

DESIGNING AN UNDERPASS

A crossing structure will only be effective if it is accessible and acceptable to the species that will potentially utilise it: its design and size can greatly influence its use.

The body size of the animal and its behaviour (e.g. solitary or group living, diurnal or nocturnal) will influence the design of the structure. In general, the bigger these structures, the more they are used (Goosem 2001). Where there is little or no research available to determine the appropriate dimensions of a crossing structure for a specific species— particularly if that animal is threatened or rare — the design should err on the side of caution and cater for relatively large animals.

Structures with greatest use have heights at least equal to their width, and openings that allow unobstructed view of habitat (Goosem & Weston 2002). Reed (in Watson & Klingel 2000) recommends that underpasses have an 'openness ratio' or index of at least 2.0 to be effective (openness ratio is calculated by dividing the cross-sectional area of the underpass by the crossing distance; i.e. opening height x span length divided by width of the road) as explained in Figure 7.1.

The use of underpasses, for example, is negatively correlated with crossing length and positively correlated with openness index (Clevenger & Waltho 2000).

Key Message

Use of underpasses by animals is influenced by its Openness Ratio.

$$\text{Openness ratio} = \frac{\text{height of the opening X width of the structure}}{\text{length of the underpass}}$$

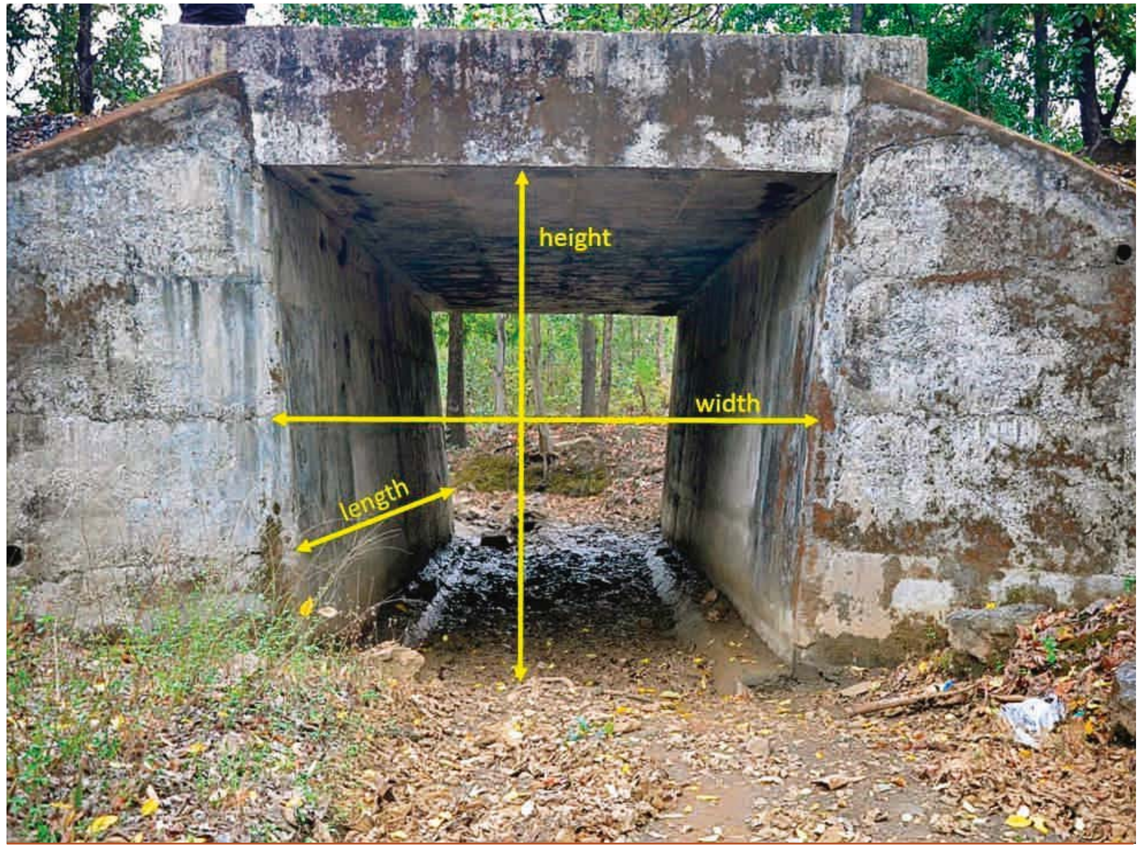


Figure 7.1. Dimensions of an underpass determining its openness.
Source: *Photograph by Akanksha Saxena.*

LOCATING WILDLIFE CROSSINGS

The location of wildlife crossings is critical. Wildlife crossing structures should allow for natural movement of animals and thus be constructed at locations where the possibility of animals using them is maximum. The general location of wildlife crossings can be decided by ascertaining pathways of animal movement and observations or evidence of habitat use along the road or rail corridor. In most situations, however, exact placement is required: wildlife crossings should be located precisely where animals want to approach a road or railway, or where they have historically done so. Often, animals choose areas to cross where there is a specific terrain feature, vegetation or, in the case of roads, a reduction in the number reduction in the number of lanes. Ridges, valley bottoms, streams and river courses greatly influence the movement of animals across the landscapes.

The following points should be kept in mind when determining the location of crossing structures:

- Surveys alongside the linear infrastructure should be carried out by suitably qualified people to assess use of the habitat by animals and identify areas used as crossing zones.
- Wildlife professionals, ecologists and locals familiar with the landscape and its animals should be consulted to help undertake faunal surveys.
- Forest cover and habitat maps of the area should be used: they are helpful in narrowing down areas likely to be used by animals.
- Unique local conditions such as natural drainage lines and forest edges are indicative of probable crossing zones, but their use will depend on the particular behavioural traits of animal species.
- Various methods may be used to determine patterns of animal movement (pathways or trails). They include radio telemetry, sign surveys, camera trapping, capture-mark-recapture approaches, track beds and the mapping of historic crossing zones.
- Historic data (observational data or from radio-tagged individuals) of animal crossing zones should be explored when available.
- Although hotspots of road kills are indicative of areas of animal use, they overestimate the extent of the animal crossing zones. They should therefore be used only as a last resort and an auxiliary source of information.

SPACING OF WILDLIFE CROSSINGS

Terrain, habitat type, levels of human activity, climate and species behaviour *per se* are some of the factors that influence wildlife movements and ecological flows. For this reason, the spacing of wildlife crossings on a given section of road or railway will depend largely on the variability of landscape, terrain, densities of animal populations, the prevalence of critical wildlife habitat intersecting the transport corridor, and the requirements of different species for habitat connectivity. Other factors that must be considered while locating animal crossings are animal home range sizes, migration patterns and the goals of mitigation. A range of types and sizes of wildlife crossing should be provided at frequent intervals along the road or railway. It may be appropriate to install several structures in one location to reduce competition between individuals, predator attraction, travel time to a safe crossing and habituation time (Barnes 2007), as well as increase connectivity incrementally (Jaeger 2007).

PLEASE NOTE

It is dangerous to assume that there is no need for building crossing structures if no animals are seen crossing the road or are not found killed. Animal evidence may not be available as the population may have been virtually wiped out because of frequent road kills.

PLANNING THE APPROACH TO A WILDLIFE CROSSING

The approach to an animal crossing is a crucial factor in determining its use. Approaches should mimic the routes and places where animals are most comfortable crossing a transport corridor. Structures should be designed to enable animals to view the horizon from a distance and see habitat on the opposite side of the corridor. Road cuts, steep drop-offs and cliffs may dissuade animals from making a successful crossing. Structures should be designed as flat and straight as the terrain permits: crossings with a steep grade reduce the openness of structures, and 'dog-leg' designs or staggered crossings prevent animals from seeing the receiving habitat. Appropriate use of vegetation (trees, shrubs and grasses) can play a significant role in enhancing the naturalness of an engineered structure.

MAKING THE APPEARANCE OF WILDLIFE CROSSINGS ATTRACTIVE

The more naturally a wildlife crossing fits into the surrounding area, the more likely it will be that animals will use it.

USING SUITABLE SUBSTRATES

Finding a suitable substrate or bottom material is one of the biggest challenges in designing wildlife crossings. The bottom of structures should, as far as possible, have similar substrates to that which would occur naturally in the absence of the structure.

Table 7.1. 'Good Practice' guidance in the form of Do's and Don'ts for avoiding and regulating the impacts of linear infrastructure projects.

Project phase	Do's	Don'ts
Planning and design phase	1. Organise a good team of professionals to review technical, financial and environmental/ecological aspects of the project. 2. Include an ecologist/wildlife expert on the team if the linear development would be routed through forested sections and natural landscapes. 3. Avoid aligning roads and railway line along or through sensitive habitats (wildlife movement corridors, flight paths of birds, areas of high biodiversity values, specialised habitats e.g. pools, dens, roosting sites, caves etc.). 4. Identify feasible alternatives of alignment to review the merits of different sites to arrive at the 'least impact' options. 5. Conduct a rigorous assessment of impacts on key wild species of animals and plants and habitats to integrate any special considerations in design features and structures. 6. Plan appropriate designs that facilitate animal movements 7. Include estimates of costs for constructing mitigation structures in the financial proposal to avoid cost overrun. 8. Prepare a schedule for implementation of mitigation measures, and institutional responsibilities for mitigation measures.	1. Do not undermine the importance of inter-agency coordination 2. Do not avoid consultation with wildlife experts and conservation agencies to understand challenges for wildlife that may come in way of environmental decision-making 3. Do not avoid field based surveys for generating primary information for impact assessment reports as a weak EIA would lead to subsequent delays in the implementation of the project 4. Do not split sections of the same road, rail or pipeline passing through different land use or states as separate projects for ease of implementation as this may pose difficulties in assessing the landscape level impacts on wildlife habitats and species with large home ranges 5. Do not plan mitigation structures around a single species but around all species of conservation importance in a landscape 6. Do not suggest mitigation measures without considering local ecology. Measures suitable for implementation in one landscape may not work in another site with different ecological conditions
Construction phase	1. Recommend construction schedule to avoid breeding/migration season of important species. 2. Take care to avoid direct impacts to land, water and habitats of wild animals due to labour camps, storage sheds and parking lots. 3. Initiate construction of mitigation structures along with road/rail upgradation projects so that damage/loss during this phase are minimised. Install sufficient drainage works under all access roads to avoid flooding land and damaging streams. 4. Protect top soil and implement measures to control soil erosion. 5. Avoid/minimise removal of natural vegetation. 6. Take measures to prevent animal injuries and mortality during earthwork, clearing of vegetation, and managing pools and streams. 7. Enforce good behaviour by construction workers to prevent illegal hunting, fishing and pilferage of resources. 8. Restore cleared areas wherever possible	1. Do not add to direct and physical impacts by careless material management and inducing avoidable disturbance 2. Do not violate conditions and specifications agreed upon as part of mitigation. 3. Do not dump/stack construction material inside sensitive habitats. 4. Do not dispose debris and other excavated material near water bodies and in valley bottoms. 5. Do not wash vehicles or change lubricants in waterways or wetlands.
Operation and monitoring	1. Conduct independent regular site inspections to ensure compliance with all EMP provisions, particularly in sensitive areas. 2. Implement an evidence-based system of collection, collation and analysis of data to assess efficacy of mitigation measures. Use audio-visual tools for generating more convincing evidence.	1. Do not forget to draw a schedule for maintenance of crossing structures such as drains and culverts to ensure their functionality. 2. Do not justify lack of manpower and financial resources to neglect/avoid monitoring.

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08 MITIGATION MEASURES FOR CONNECTING LANDSCAPES AND SPECIES

LANDSCAPE-SPECIFIC MEASURES

Landscape connectivity is the degree to which habitats across the landscape are connected, facilitating wildlife movement and other ecological flows.

The following aspects and concepts need to be considered when locating and designing linear infrastructure and deciding on appropriate measures to mitigate impacts:

1) The concept of 'minimum viable population', which sets – and respects – a lower limit on the population size or numbers of individuals of a species (including their genetic diversity) to make sure that species will survive in the long term.
2) Source-sink dynamics of the landscape, which identifies the critical elements and quality of different ecosystems and habitats on which the persistence of wildlife depends, and describes how variation in habitat quality may affect the population growth and decline of organisms.
3) Metapopulation structure, which considers the geography of, and relationship between, different populations of the same species, to ensure the persistence of that species.
4) The 'Allee effect' with respect to the behavioural ecology of the species, habitat matrix and its porosity to the taxa (corridors for movement). This effect considers the correlation between population size or density, and the mean fitness of individual animals of a population or species, recognising that fitness tends to decline in smaller populations.
5) Mitigation measures should be designed and implemented to meet the collective needs of all target taxa and biodiversity values of the landscape; designing for the biggest or most demanding species will often ensure that the needs of other species would simultaneously be met. However, in certain cases, additional measures may be required for particular taxa or functional groups to provide for specific needs: e.g. structures designed for elephants will serve the purpose for most terrestrial mammalian species but may not be effective for strictly arboreal taxa, or for reptiles and amphibians; special mitigation measures will still be needed for them.

General rules for maintaining habitat connectivity across the landscape:

The general guidelines set out below to maintain connectivity across an identified species corridor are based on species ecology, such as home range and habitat use pattern, species communities across different landscapes and other ecological information.

i. If the width of the corridor through forest habitat is 1 km or less, the construction of flyovers should be undertaken in such a way that the entire stretch of forest remains connected.

ii. If the width of the corridor is 1-2 km, one underpass of 750 m should be provided across the landscape. The exact location of the underpass should be based on topographic features of the area and information about customary animal crossing zones. This 750 m stretch of elevated road could also be divided into two parts of minimum 300 m each, located within that corridor. Their location would depend upon the terrain, characteristics of the particular species and its movement patterns.

iii. If the width of the corridor is 3 km or more, or if the forest landscape is to be dissected by either a new road or the upgrading of an existing road, 300 m underpasses are suggested within every km stretch of the road. The exact location of the underpass should be based on topographic features, crossing zones, and the particular ecological requirements of the affected species.

iv. Other than maintaining connectivity for larger mammalian species, for amphibians or reptiles across the landscape, small pipe culverts or bridges should be constructed in every 100 m stretch of road.

Table 8.1 summarises and Figure 8.1 illustrates the above points.

Table 8.1. Placement of crossing structures across animal movement corridors of varying widths.

Landscape characteristic	Design measures for maintaining connectivity
Connectivity across 1 km species corridor	Entire 1 km stretch to be connected
Connectivity across 1-2 km species corridor	750 m underpass either as one structure or two 300 m each depending upon terrain and other conditions are suggested
Connectivity across 3 km species corridor or across the forest landscape to be divided by either a new road or upgrading of existing road	300 m underpasses are suggested at every km of the road
For smaller species such as amphibians and reptiles	Small pipe culverts or bridges at every 100 m stretch of the road are suggested

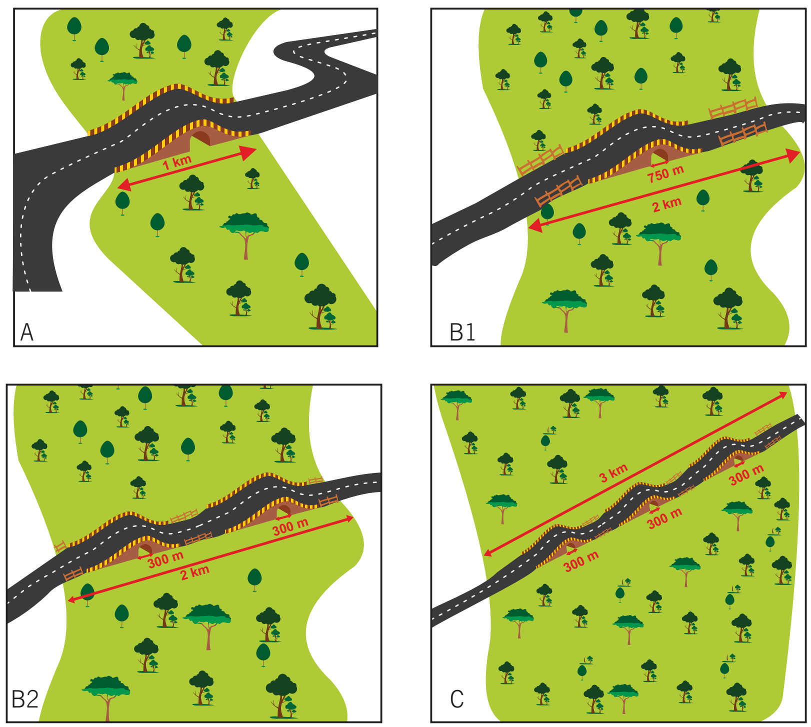


Figure 8.1. Underpass specifications suggested for different lengths of wildlife corridors: A) 1 km flyover for 1 km wide corridor; B1) one 750 m underpass, or B2) two underpasses of 300 m each for 2 km wide corridor; and C) 3 underpasses of 300 m each for a 3 km wide corridor.

SPECIES-SPECIFIC MEASURES

It is important to consider, and design wildlife crossings and animal passages to cater for, all of the species using the area affected by linear infrastructure, to improve the efficiency and effectiveness of mitigation solutions.

The following section focuses on the use of underpasses as a principal measure to mitigate negative impacts of roads and railways on terrestrial mammals. However, it is useful to note that these underpasses would also be used by other animal taxa.

Underpasses for terrestrial mammals

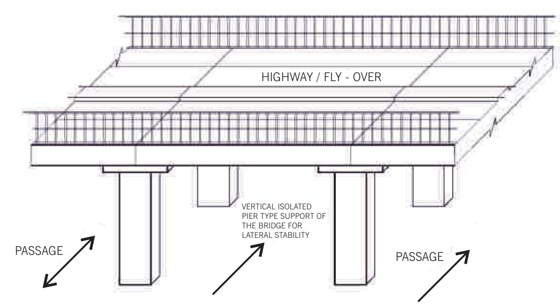
The following minimum design requirements of underpasses for specific terrestrial mammal species are based on the effectiveness of underpasses for mule deer, which have a shoulder height of 106 cm (Reed et al. 1975; Reed et al. 1979; Reed 1981; Ward 1982; Olbrich 1984; Reed & Ward 1987; Foster & Humphrey 1995; Putnam 1997).

- For chital, with a shoulder height of up to 75 cm, an openness index of 0.52 (metric) is needed.
- For sambar, with a shoulder height up to 160 cm, an openness index of 1.12 (metric) is needed.
- For gaur, shoulder height up to 175 cm, an openness index of 1.22 (metric) is needed.

Figure 8.2 shows the required underpass height in relation to animal size. In landscapes where sambar, gaur and tiger are the largest animals present, a minimum underpass height of 5 m would be acceptable if the viaduct were 300 m long and the span of the underpass were 28–30 m. For any other underpass with a viaduct of less than 300 m, and in landscapes where elephant and rhino are the largest animals in the community, the minimum height of the underpass should be 6-8 m to provide an openness ratio that could provide an optimum passage for these animals.

While approaching the underpass, the animal should preferably be able to view the horizon across the underpass in order to perceive any risks and opportunities on that side. Although a structure 5 m high and passage with a viaduct length of 300 m should be able to provide this view, a 7 m high passage would provide a more liberal view created by a higher openness ratio.

The design of the walls and the piers of an underpass can significantly improve the acceptability of passage structure by animals. Isolated piers are more favourable than wall-type piers: wall-type piers reduce lateral visibility and increase tunnel effects, especially for species that move in groups, such as chital. The inclusion of a cross beam at the top of isolated piers further improves their acceptability. Figure 8.3 shows line drawings and constructed animal underpasses with wall type and isolated piers.



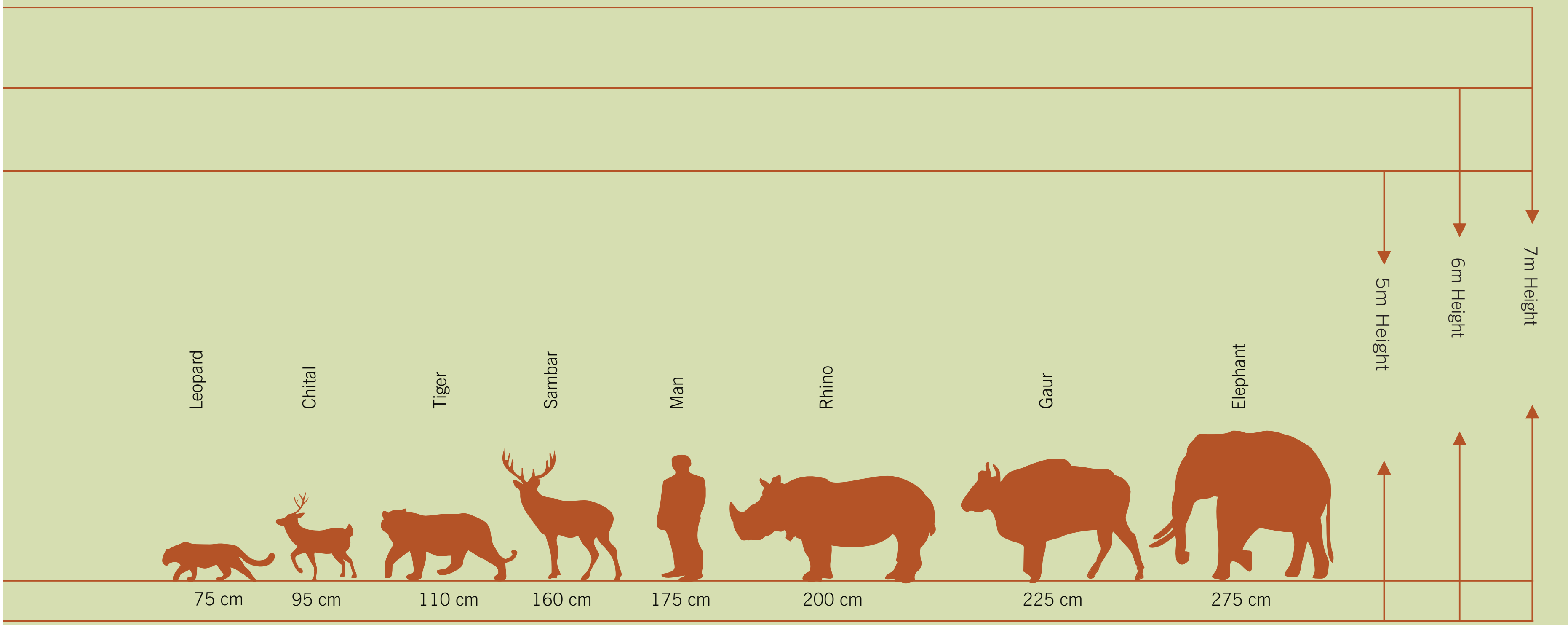


Figure 8.2. Underpass heights as they should relate to animals.

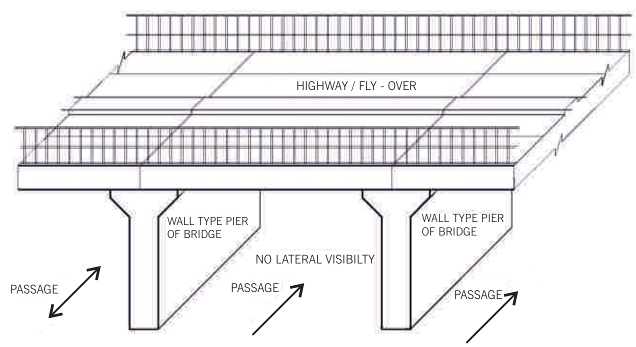


Figure 8.3. Diagrammatic representation of isolated and wall type piers. ***Source:*** *Adapted from Singh et al. 2010. Illustration by Niharika Saxena.*

MITIGATION MEASURES FOR DIFFERENT LANDSCAPES

TIGER LANDSCAPES

Both underpasses and overpasses (passageways) are potential engineering solutions for mitigating the impacts of linear infrastructure in tiger landscapes. The following designs and norms for these structures should serve as the minimum requirements for mitigation in such landscapes where elephants do not occur. In landscapes where elephants are present, the design of mitigation structures would generally also meet the needs of tigers and most other biota.

Underpasses

A minimum span of 30 m with a height of 5 m and a width of 5-8 m would work for most species in tiger landscapes. The 30 m span refers to clear open passageways – often these underpasses would have support pillars for the infrastructure and they should be excluded from the span measurement.

In critical tiger corridors as well as core areas of tiger reserves— if linear infrastructure is permitted at all— mitigation measures need to be especially stringent: the span needs to be a minimum of 50 m with the same dimensions of height (5 m) and width (5-8 m).

Overpasses

After accounting for structural construction requirements, the minimum passage width of an overpass needs to exceed 30 m. The overpass should not have a steep incline to the infrastructure crossing: slopes over 25 degrees should be avoided. Thus the length of the overpass is site specific and needs to be adjusted according to the lay of the land.

Density of mitigation structures

Besides the dimensions of the underpasses and overpasses, the density or numbers of such structures per unit length of the infrastructure is a crucial consideration for mitigating impacts. A passageway of over 50 m per 1 km length of infrastructure in forested habitats and over 100 m per 1 km length of infrastructure in critical tiger corridors would ensure that habitat connectivity is maintained and fragmentation is avoided.

It is important that wild animal movement is channelled to the passageway for crossing the infrastructure by using appropriate funnelling structures, either natural or artificial. At times it may be necessary, except at the underpasses and overpasses, to fence off the road or railway when passing through wildlife habitat. This fence may be essential to avoid mortality of wildlife, prevent accidents and ensure the safety of humans. Where fences are not required or are not feasible along the entire length of the infrastructure corridor, specific mitigation measures will still be required in the vicinity of topographic features that are known to trap wildlife on roads or railways: e.g. features like railway embankments need to be flattened as they act as traps for wildlife blinded in the headlamps of approaching trains.

Visual Barriers

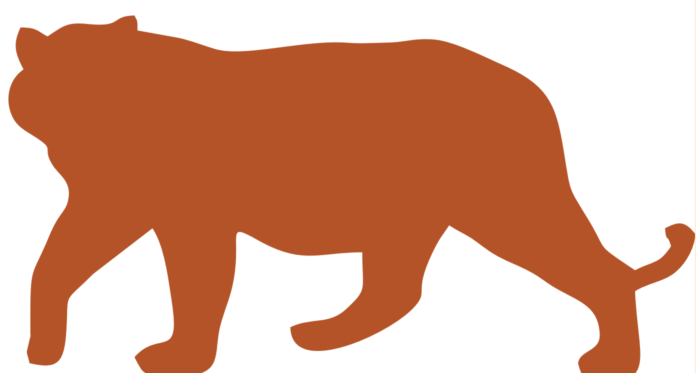
Visual barriers along the sides of the infrastructure need to be installed in such a manner that the traffic (vehicles/trains) is not visible from a distance or up close from the wild animal crossings. Care should be taken that vehicular lights do not escape the visual barrier at night as these visual clues could deter nocturnal species from using the underpass. Visual barriers can be camouflaged and enhanced by planting tall vegetation along the edges of the engineered structure.

Sound barriers

Both underpasses and overpasses need to be fortified with sound barriers to prevent any disturbance to wildlife that could potentially use these structures for passage across the infrastructure. Details of the design and construction of sound barriers are provided in chapter 11. The installation of appropriate sound and visual barriers cannot be over emphasized: without them, investments in constructing underpasses and overpasses can go to waste, as wildlife may never use them.

Olfaction and other sensory enhancers

Target wild animals can be encouraged to use the overpass or underpass by enhancing its porosity to wildlife through enrichment. These enrichments consist of a) use of appropriate substrate like soil, leaf litter, gravel, herbaceous vegetation b) attractants like food plants, carrion, pheromones, dung of conspecifics and scats in the case of carnivores like tigers. These enrichments require inputs from professional wildlife biologists and, if not appropriately used, can also act as deterrents to wildlife passage. Use of these enrichment approaches must be accompanied by rigorous evaluation and testing.



ELEPHANT LANDSCAPES

Roads and railways impact elephants in multiple ways. Loss and fragmentation of elephant habitat is the most severe problem arising from linear infrastructure development: it alters the elephant's home range and, consequently, may lead to an escalation of human-elephant conflict where these animals are forced into new areas. In addition, it may lead to elephant populations becoming isolated, resulting in a loss of their genetic diversity. To aggravate these impacts, elephants trapped in isolated areas rapidly destroy their own habitats.

Poorly planned roads and railway lines in elephant landscapes result in loss of both elephant and human life due to accidents. However, these critical problems can be addressed by appropriate mitigation measures. The principal mitigation measures proposed to minimise the impact of linear infrastructure in elephant landscapes are set out below.

Elevated linear infrastructure

Raising the linear infrastructure (road and railway line) on pillars above the ground is the best solution in elephant landscapes. A major consideration while elevating the linear infrastructure is height: the height of the pillars should be at minimum 8-10 m (thrice the height of an adult bull elephant) above ground, so as to provide safe passage for elephants. In the event that the costs of elevating infrastructure would be prohibitively expensive, other measures covered below should be considered.

Underpasses

The height of the underpass, to allow elephant movement, should be the major consideration. A minimum span of 50 m with a height of 6-8 m and a width of 10-12 m is desirable for movement of elephants.

The selection of sites for elephant underpasses should be carefully planned before road or railway design is finalised. Elephants tend to use fairly regular paths/trails and drainage lines in the forest. Such trails and drainage lines need to be identified by specialists trained specifically for this task (i.e. not untrained staff), following a thorough survey of the area. Underpasses should be located where the linear infrastructure corridor intersects with these paths/trails and drainage lines. Girder bridges are one of the best forms of underpass that can be provided for elephants' passage. Physical barriers should be erected along the remaining length of roads or railways in order to funnel elephant movement through these underpasses.

Overpasses

Construction of overpasses in flat terrain is not desirable in elephant landscapes. Overpasses can be considered as a mitigation measure only when the linear infrastructure passes through a stretch with steep terrain on both sides: the steep terrain on both sides of the road or railway can be connected with an overpass of at least 10-12 m in width.

Creating level crossings (for railway tracks)

The presence of embankments to make the track level, and even ballast (1 or 2 feet) in flat areas, makes it difficult for elephants to get off the track quickly when a train approaches. Level-crossing type approaches including ramps are advisable in places where elephant trails regularly cross railway tracks. The identification of locations for these types of level crossings requires well-trained teams who understand elephant movement and have the ability to evaluate elephant paths. However, level crossings should not be considered as a stand-alone option: this form of mitigation is not a replacement for elevated tracks, underpasses and overpasses. Level crossings should be created in addition to the above mentioned structures, because they are less safe than the latter.

Density of mitigation structures:

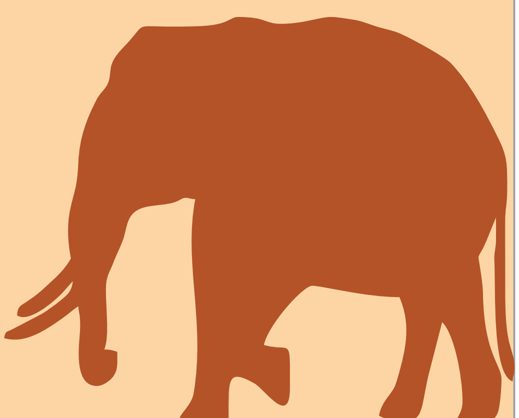
The density and numbers of mitigation structures is an important consideration for addressing the impacts of linear infrastructure in elephant landscapes. If elevating the linear infrastructure above the ground on pillars is not possible due to prohibitive costs, at least 100 m of passageways per 1 km length of linear infrastructure in elephant landscapes would ensure habitat connectivity.

Visual barriers

Visual barriers as proposed in tiger landscapes are applicable for elephant landscapes.

Sound barriers

Since elephants are sensitive to sound, all mitigation measures such as elevated structures, underpasses and overpasses need to be fortified with sound barriers. Details of the design and construction of sound barriers are provided in chapter 11.

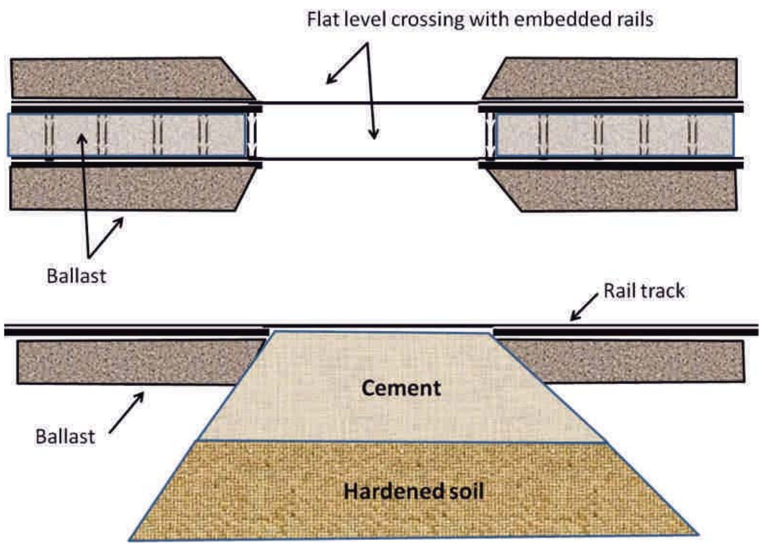


SPECIAL MEASURES FOR LAYING RAILWAY LINES IN ELEPHANT LANDSCAPES

Points to be considered when designing measures to mitigate the impacts of railways in elephant landscapes include the following:

1. Trains cannot stop abruptly. For example, a train travelling at 50 km/h will cover another 300 m before coming to a halt. Thus warning systems that detect animals at a short distance would be of no use.

2. Trains cannot brake hard on curves as they would topple over. Similarly, it is not possible for trains navigating a gradient or slope to stop; they need to maintain a particular speed to overcome the gradient.



These points should be considered when deciding on the type of warning and detection systems. Manpower needs, installation and maintenance costs, and the feasibility and reliability of such systems in different weather conditions are other factors that need consideration.

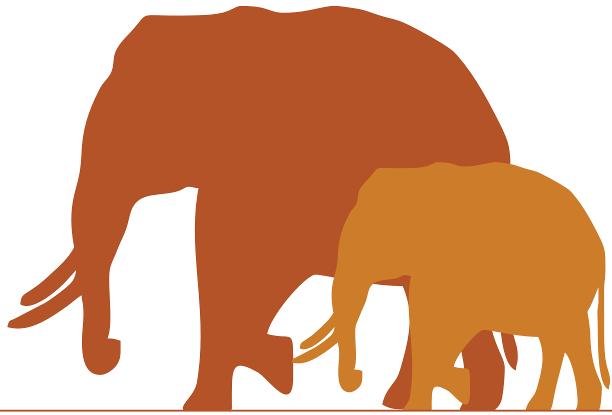


Figure 8.4. Level crossings for elephants. ***Source:*** *Illustration by Ajay Desai.*

In addition to underpasses and overpasses, the following measures should be considered for improving the safe movement of elephants across railway lines.

1. Wildlife biologists and forest personnel who have local knowledge of different types of elephant movement and migration, paths, resource needs (food and water), and behaviour, should be consulted.

2. At-grade level crossings for elephants (Figure 8.4) should be provided at regular intervals. These crossings should ideally have smooth slopes with the railway tracks embedded in the cement.

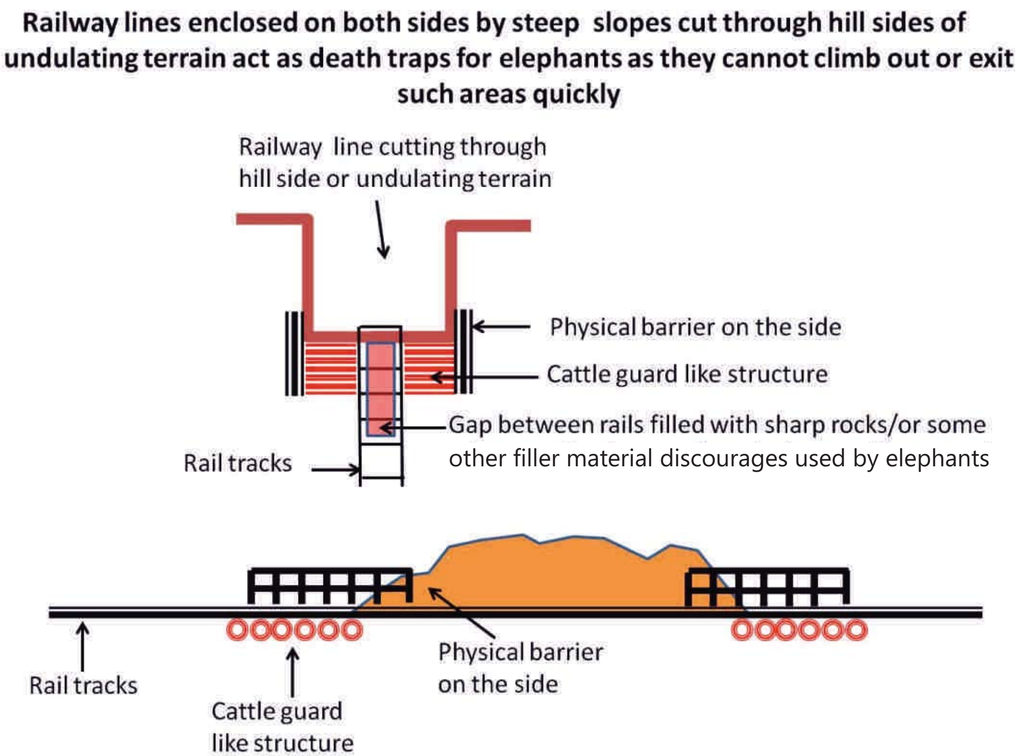
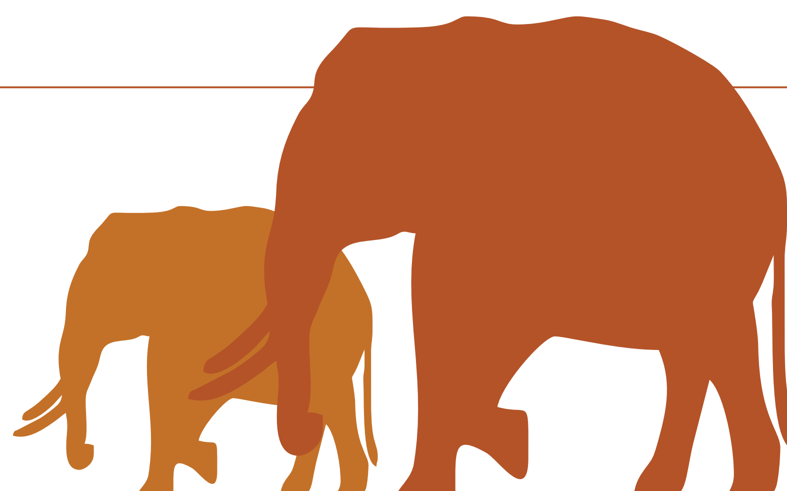


Figure 8.5. Physical barriers to discourage entry of elephants on railway tracks.

Source: *Illustration by Ajay Desai.*

3 To prevent elephants from being trapped in railway tracks between steep embankments, their entry into such areas should be discouraged by installing cattle proof barriers (Figure 8.5) or fences (rail tracks are most suitable for use as fence posts). These fences need to be reinforced as they can be easily damaged by elephants.



4 As it is risky for a train to stop on a curve, the presence of elephants in these terrains can be avoided by installing physical barriers on both sides of the curves (Figure 8.6)

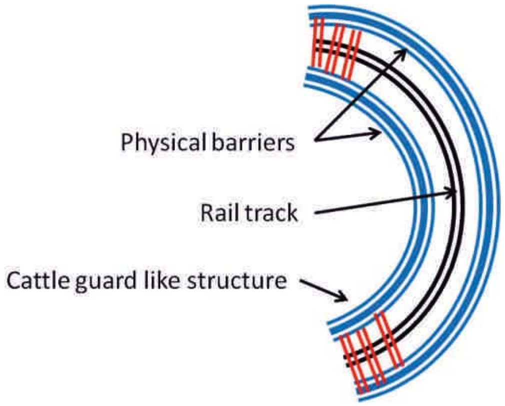


Figure 8.6. Fences or barriers installed to prevent elephants from getting onto the tracks near curves can help avoid both elephant and human fatalities.

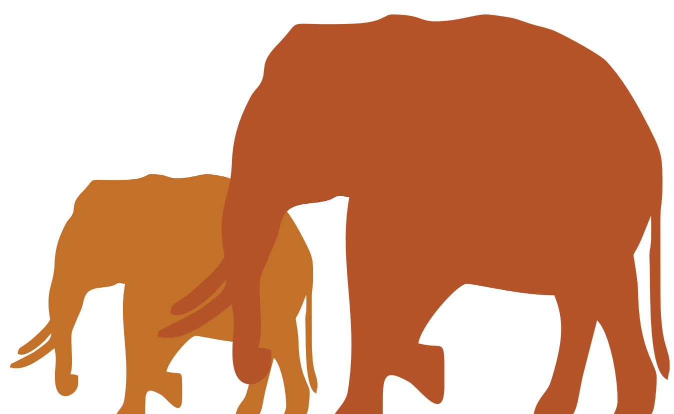
Source: *Illustration by Ajay Desai.*

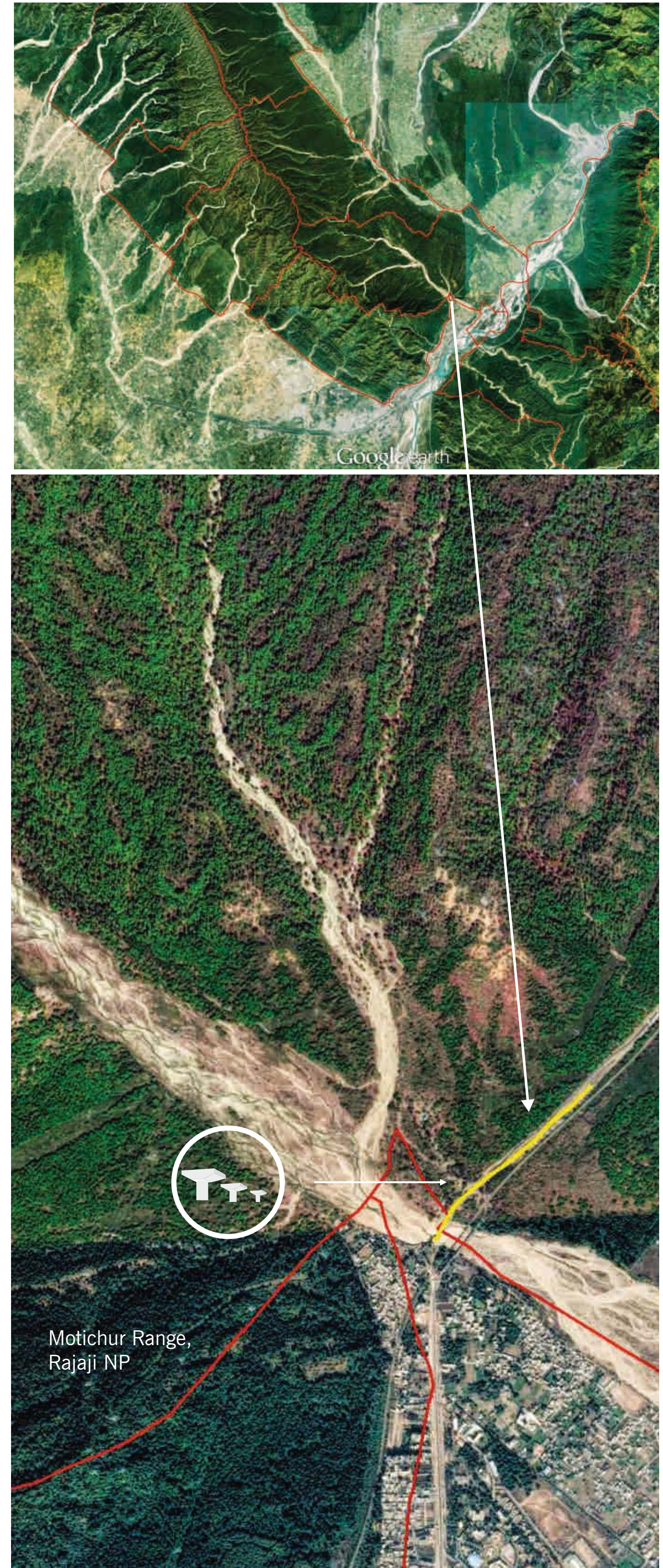
PLEASE NOTE

Delay in implementation of mitigation measures, especially those related to construction of underpasses, can negate the benefits of securing connected habitats (Box 8.1).

5 Barricading the major length of the track, and giving access to elephants at the required number of locations, is the optimum long-term mitigation measure. This is the only real solution for the proposed high-speed trains of the future: any train travelling at 150 km/h will not have the ability to stop, irrespective of how good the detectors may be. Moreover, having to stop for elephants is contrary to the notion of a high-speed train. Accidents involving elephants or other large mammals will be unacceptable from the human safety point of view. For all these reasons, complete isolation of the track must become the norm; it makes sense to follow this approach from the start.

This design approach requires railway tracks to become more effective barriers, but to retain sufficient porosity (required passages) to ensure that the daily and seasonal movements of elephants and other large mammals on regular paths can continue. The challenge will be constructing (and maintaining) the necessary barriers to *ad hoc* access to the tracks and getting the required number of passages constructed.





Box 8.1. Mitigation structures under construction for connecting habitats of large mammals in Rajaji Tiger Reserve, Uttarakhand.

Chilla-Motichur corridor forms a vital link for movement of elephant and tiger between eastern and western parts of Rajaji National Park, (now a notified Tiger Reserve). The population of elephants and tigers, west of Ganga river, represents the northwestern limit of their distribution ranges. The habitat connectivity between Chilla and Motichur ranges of Rajaji National Park is severely impaired, ever since the land between Rishikesh and Haridwar has been subjected to enormous changes over the last 50 years. The factors that have significantly contributed to the declining connectivity between the eastern and western parts of Rajaji National Park include the villages and settlements; functional railway track; a busy highway cutting across this corridor; army establishment and the Chilla power channel. Based on sound scientific evidence regarding elephant movement in the area, construction of three flyovers was proposed: 1) between Chilla and Motichur (736 m); 2) at Laltapur (500 m) and 3) at Teen Pani (400 m). The construction of these flyovers was initiated by NHAI. However, due to unforeseen reasons the completion of three flyovers has been delayed. As a result, the goal of providing ‘permeability’ across the highway for facilitating the movement of wild animals could not be achieved till date. Good practice demands that when such crossing structures are planned, these should be constructed per agreed schedule and with the minimum on-site disturbance that should be enforced through contractual clauses.

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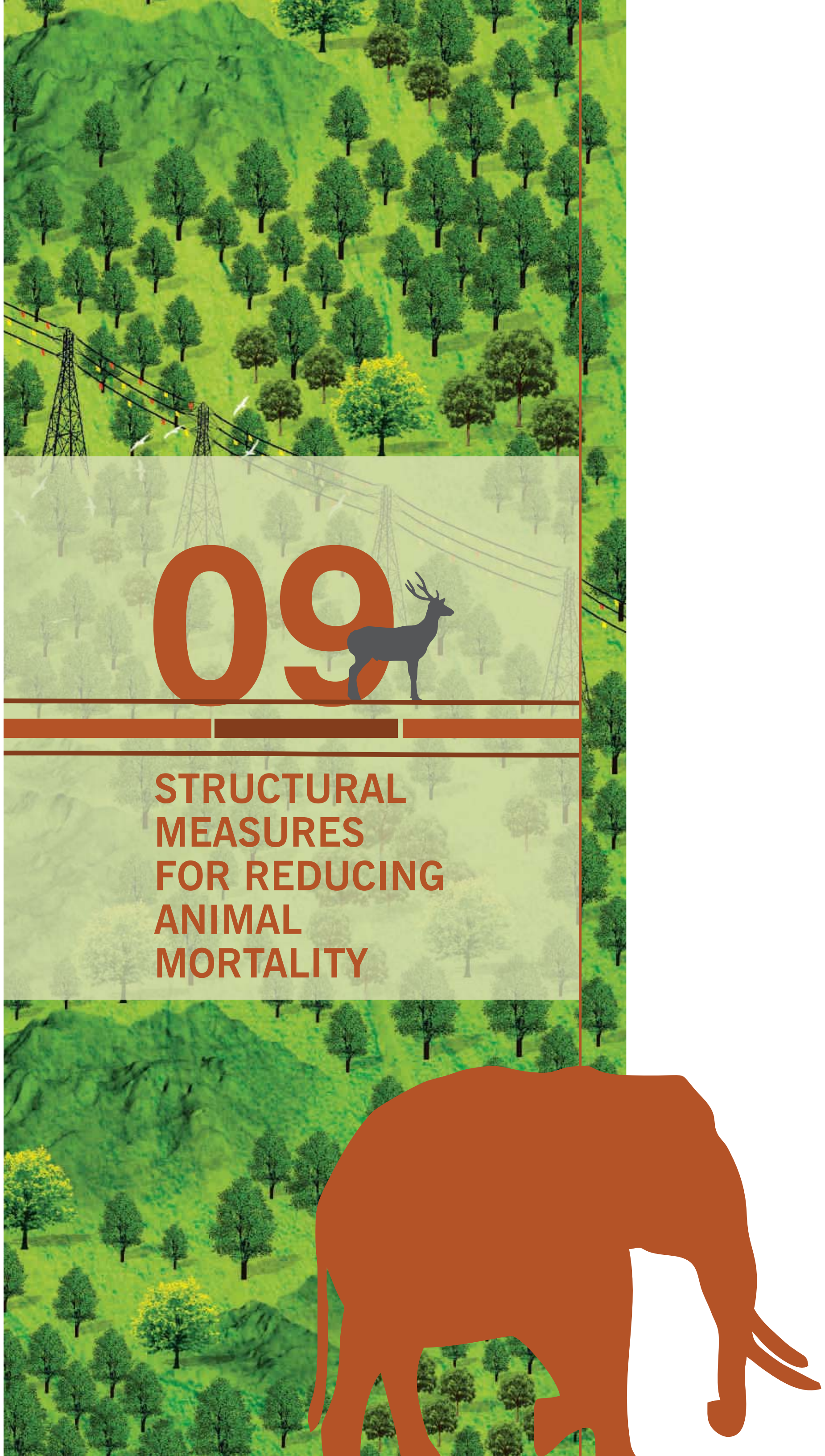


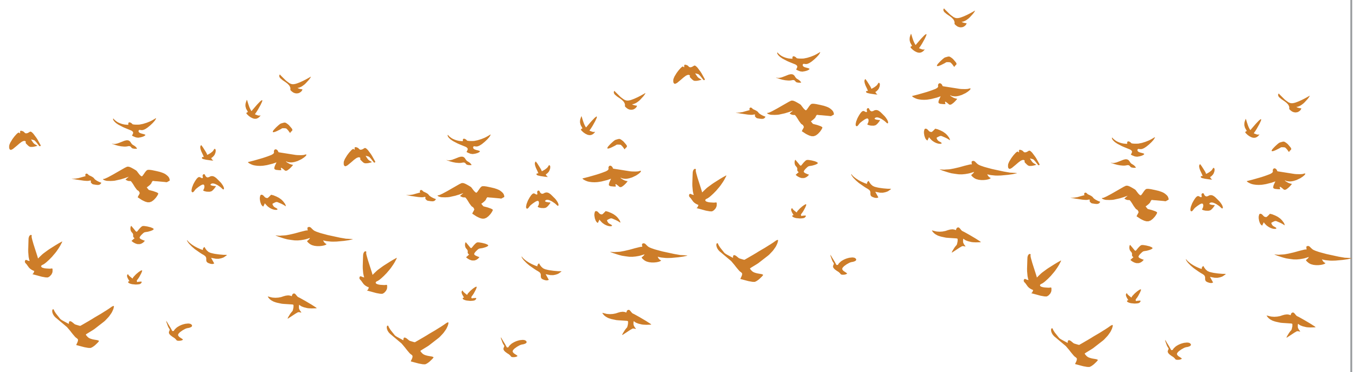
09 STRUCTURAL MEASURES FOR REDUCING ANIMAL MORTALITY

Mitigation measures to reduce deaths due to transportation infrastructure involve a combination of approaches: erecting fences and walls to exclude wild animals, constructing structures such as overpasses and underpasses to allow animals to cross a road or railway corridor safely, and erecting signage and warning systems. The integration of such features in road and rail projects can be effective for a variety of wildlife, provided that the specific requirements of all the different taxa at risk are considered in their design.

The location and design of safe crossings for terrestrial mammals is an important way of reducing their mortality on roads and railways; guidelines for designing appropriate structures are provided in Chapters 6 and 7. This section thus focuses on measures to reduce deaths of other animal taxa due to railways and roads.

Some studies have reported movement rates as the single greatest factor influencing the risk of road mortality. Birds that typically fly short distances (e.g. from one tree to the next) may struggle to fly across a large open space, making them vulnerable to collision. Reptiles like snakes and turtles, which sometimes bask on the warm asphalt of the road to regulate their body temperatures, are at greater risk of being run over by speeding traffic.

MEASURES FOR REDUCING BIRD HITS



The adverse impact of roads and associated vehicular traffic on birds can be minimized through their careful design, controlling the disturbance they cause, and reducing the availability of resources that attract birds next to roads.

1 Planning the timing of road construction and maintenance

Vehicle collisions with birds are likely to be more pronounced during the breeding season and migration period. They can be minimised by avoiding undertaking road construction and maintenance activities during these time periods: in India, the breeding season for most birds generally starts in early spring in lower altitudes and may continue until late in the rainy season in some areas and for particular species.

2 Avoidance of impacts on important bird habitats

Roads should be located away from water bodies, rivers and streams, to avoid or minimise the risks of vehicular collision and mortality to rare, threatened and migratory species of birds using these habitats.

3 Flight diversion

Birds with rapid and direct flight can be diverted to fly high over the traffic zone by erecting suitable roadside structures: fences, poles, soil berms above road level and solid walls with suitable improvisation, can help divert birds away from a roadway. Research and careful planning is needed before deciding on the most appropriate structure to use: particular structures may not be effective for all bird species and may pose a risk of collision for some species.

4 Managing roadside habitat to reduce its attractiveness for birds

Creating and maintaining vegetation should be a standard part of the prescription for roadside management: a 5 m-wide 'clear zone', with a 3 m-high clearance, devoid of trees and shrubs, is necessary to prevent reptiles and rodents become prey for birds patrolling for food (Figure 9.1). Planting of trees with non-edible fruits, and species that inhibit undergrowth along the roadside would be effective in reducing the use of roadside habitat and verges by most birds. To reduce mortality in canopy-dwelling birds, it may be helpful to plant tree species next to roads that tend to grow tall and have dense foliage. Plant species providing food and nesting opportunities for birds should be avoided along roadsides.

5 Wildlife crossing structures

Bridges, underpasses and overpasses, designed as passageways for other wild animals, can be used by some short-flighted birds (e.g. peafowl, quails, partridges and francolins, which cannot cross over roads in a single flight or avoid crossing traffic corridors), provided that these structures are sufficiently large and use suitable substrate.

6 Making roads less attractive to birds

Road surfaces and roadside habitats are an attractive source of food for birds, offering, e.g. spilled grains, road kills, seeds and fruit. Careful planning and management of roadsides can reduce their attractiveness to granivorous birds such as sparrows, munias, finches and doves, and scavenging birds such as black kite, vultures and crows. Carcasses of road kills should be removed as soon as detected. Lighting along roads may attract insects, which in turn attract birds like owls and nightjars. Use of appropriate lighting systems for illumination of roadways can reduce attraction for birds: artificial lights should generally be discouraged; and reflective posts should be used instead.

Figure 9.1. Conceptual plan of a road and managed roadside habitat to reduce bird hits.

II MITIGATION MEASURES SPECIFIC TO REPTILES AND AMPHIBIANS

Background

Herpetofaunal (reptile and amphibian) road kill is often a function of species-specific ecological and life-history traits, behaviour, and movement patterns (Forman et al. 2003; Andrews & Gibbons 2005). The dispersing and migratory behaviour of herpetofauna makes them particularly vulnerable to the impacts associated with roads and railways. They move between spatially separated breeding and foraging sites, and often need to cross landscapes that are fragmented by roads and railway lines (Andrews et al. 2008). Their vulnerability is further increased by their relatively slow movement rates (Hels & Buchwald 2001) and by the fact that many species become immobile in response to approaching vehicles (Mazerolle et al. 2005).

Seasonal amphibian movement also makes them particularly susceptible to road mortality. Their life stages comprise juvenile dispersal and adult migration (Pittman et al. 2014). A decline in amphibian populations can also result when their breeding sites and land habitats are interrupted or fragmented by linear barriers like roads, railway lines, pipelines or powerlines.

Daily cycles in the thermal profiles of highways suggest that snakes that are active at night may be at particular risk, because the road is warmer than the surrounding grassland early in the evening (Shine et al. 2004) and thus may be thermally attractive to snakes at this time. Basking or thermoregulatory behaviour thus prolongs their exposure to traffic and increases the likelihood of collisions (Rosen & Lowe 1994).

Turtles are known to cover long distances seasonally, and persistent road mortality may cause a serious bottleneck in the affected population: adult turtles need considerable time to mature.

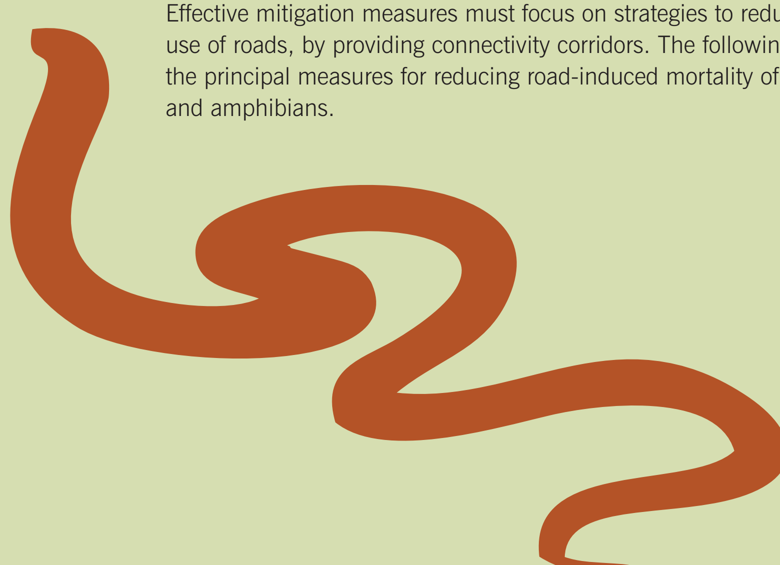
Mitigation

Roads are built to be long-lasting structures; mitigation measures should also be durable and long lasting.

Wetlands, forests and rocky habitats on either side of road are likely to be key areas in which mitigation measures for impacts on herpetofauna are required.

In order to design appropriate and species-specific mitigation measures, it is necessary to determine which species are at risk: an assessment of species composition (threatened species if any), relative abundance and habitat association along the road stretch must be made. Visual encounter survey, road cruising (night driving method), tracking animal trail or signs (such as python drag marks), radio telemetry, mark-recapture studies using VIE (Visible Implant Elastomer) or PIT (Passive Integrated Transponder) tags (Heyer et al. 1994) are the most common methods to identify zones of animal activity. It is important to determine and map the 'fatality hotspot' zones of movement along road stretches, to pinpoint optimum locations for mounting mitigation structures: detailed monitoring of amphibian road kill for at least three years has been suggested as an appropriate time interval in this respect (Grossi et al. 2001).

Effective mitigation measures must focus on strategies to reduce the use of roads, by providing connectivity corridors. The following are the principal measures for reducing road-induced mortality of reptiles and amphibians.



1 Providing passages to retain habitat connectivity

Movement of herpetofauna across linear infrastructure is often facilitated by drainage pipes, box culverts and minor bridges which often act as drainage structures associated with road construction. These 'non-wildlife engineered' passages (Forman et al. 2003) exist by default, and are not constructed with the objective of facilitating wildlife movement. However, they can provide crucial connectivity to maintain the meta-population dynamics if their location corresponds with locations suitable for animal movement.

For passages to be functional and optimally used, they must be placed within the natural migration and dispersal routes of target amphibian or reptile species (Figure 9.2 and 9.3).

Drift fencing or cemented crash barriers may be used to prevent animals from reaching the road and direct amphibians or reptiles to a safe passageway (e.g. turtles to a tunnel entrance).

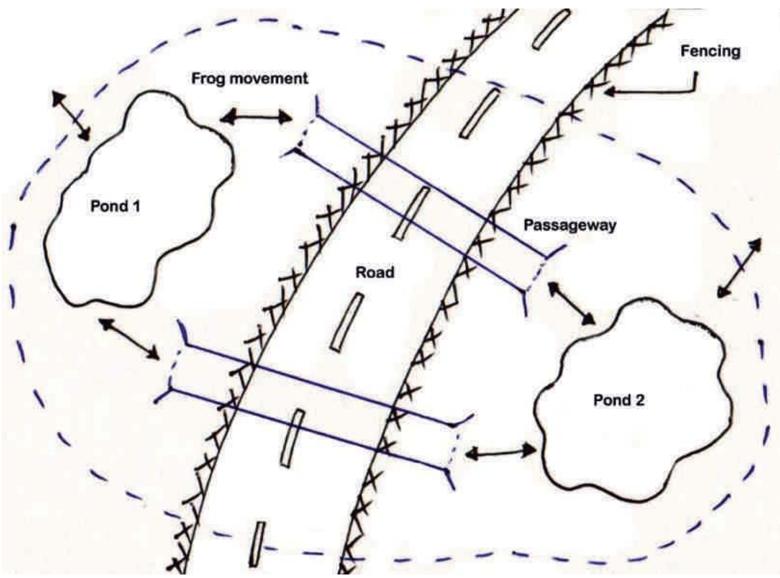


Figure 9.2. Passageway for connectivity of breeding habitat for amphibians and turtles.
Source: *Adapted from Anon. 2001. Illustration by Dimpi Patel.*

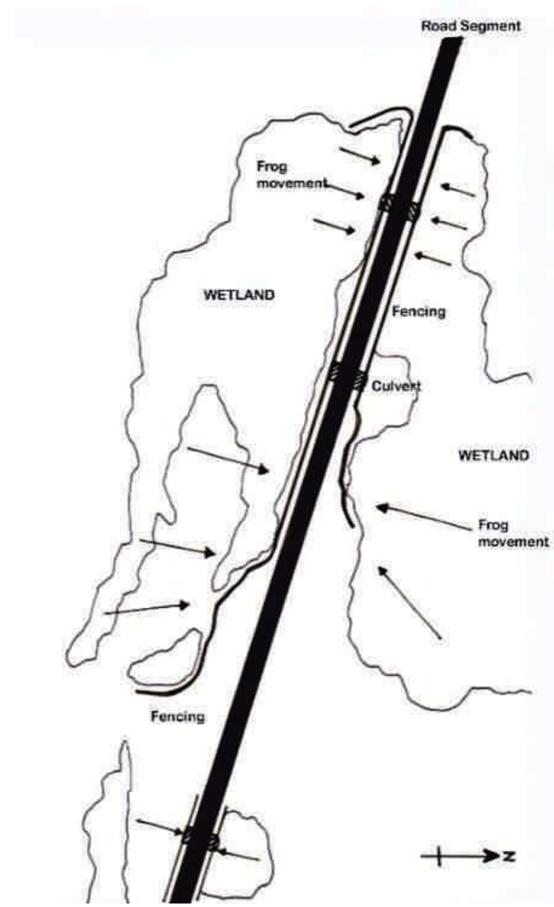


Figure 9.3. Schematic representation of the use of fencing and culverts to provide safe passage for amphibians and aquatic reptiles.
Source: *Adapted from Aresco 2005. Illustration by Dimpi Patel.*

Small passages of 20-25 m in length should have a diameter of at least 100 cm. Tunnels of 50 m length need to have a diameter of at least 200 cm (also see Forman et al. 2003).

Reptiles particularly cross more frequently through circular structures, while rectangular or square-shaped structures are preferred by amphibians. Frogs often prefer square-shaped tunnels that are buried close to the ground surface (Figure. 9.4).

Box culverts of dimension 2x2 m or 2x3 m are widely used above waterways in highway construction in India. These structures can provide passageways for reptiles and frogs connecting their habitat. However, they should be designed with risen 'dry ledges' of at least 50 cm width on each side of the central watercourse to facilitate animal movement.

If roads bisect amphibian habitat and migration routes, specially designed underpasses need to be provided.

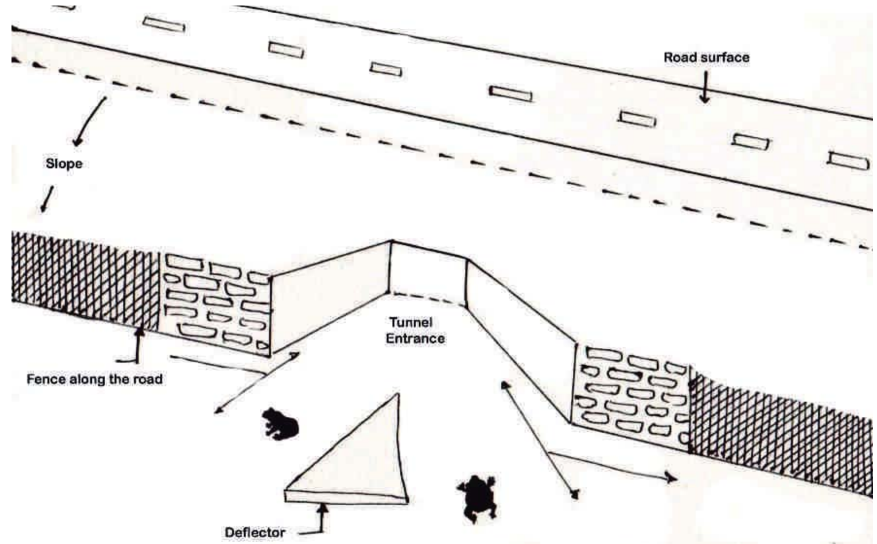


Figure 9.4. Herpetofaunal underpass with deflector.
Source: *Adapted from Anon. 2001. Illustration by Dimpi Patel.*

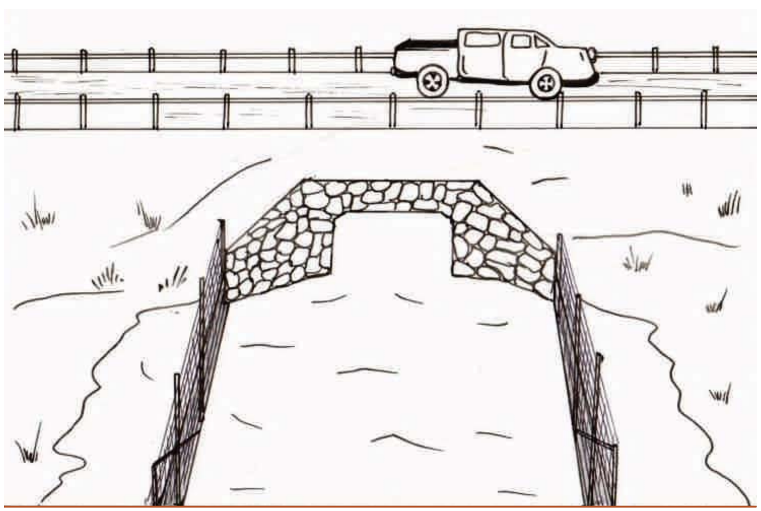


Figure 9.5. A fenced waterway to guide aquatic reptiles and amphibians through the underpass.
Source: *Adapted from Gilbert et al. 2015. Illustration by Dimpi Patel.*

Traditional culverts and minor bridges (built on ditches, streams and rivers) can be modified to facilitate safe movement of amphibians under the highway. The position and size (length and diameter) of these structures, and the angle that they are approached by amphibians, are critical factors determining their success. If placed across peak activity zones, these passageways can help reduce impacts on habitat fragmentation significantly.

Lack of light within tunnels may deter usage by amphibians (Jackson & Tyning 1989; Krikowski 1989). For this reason, larger tunnels should be designed to provide sufficient light to encourage their use (Puky 2003) by maximising the diameter-to-length ratio of passageways to maximise light penetration and airflow.

Tunnels fitted with metal grates on the top (i.e. on road surface) may act as effective small passages for amphibians. Metal grates may be installed to facilitate light and air penetration; gaps on the metal grates would help amphibians to drop down into the passage.

In dry areas, an engineering solution to maintain moisture levels in the passageways needs to be found. Where an underpass falls on a waterway or wetland, provision should be made to fence the sides of the water channel to direct animals to the safe passage (Figure. 9.5).

Passageways should be designed to minimize environmental gradients. Amphibians are particularly sensitive to moisture condition and thus cement flooring of a passage may deter amphibian movement. Cement flooring is also likely to limit natural vegetation growth and may be unsuitable for cryptic animals.

Passageways must provide an unbroken connection between the linked habitats: there should not be gaps in the fencing of passages, and fencing or barriers should be made of durable material.

2

Fencing to guide movement of amphibians

The aim of fencing is to prevent mortality and deter herpetofaunal movement on to roads by directing them to safe crossing points or passageways (Figure 9.6). If fencing can be erected along sufficient road lengths along 'fatality hotspots' and is properly designed, installed and maintained, it can significantly reduce road mortality (Malt 2012).

Fencing should cover all areas where the road intersects amphibian habitat and movement routes. It should ideally be located between two underpasses so as to guide animals to safe passageways.

The angle of fencing is an important aspect: if installed parallel to the road, a fence may exclude animals from the road but not direct them effectively towards passageways. An ideal design may be a zig-zag pattern, as described by Jackson and Tyning (1989). This design is likely to direct animals towards passageways at all points of contact, while simultaneously excluding animals. It is important to check if there are any holes or gaps remaining along the fence, particularly at culvert-fencing junctions, as this may reduce the effectiveness of the fencing.

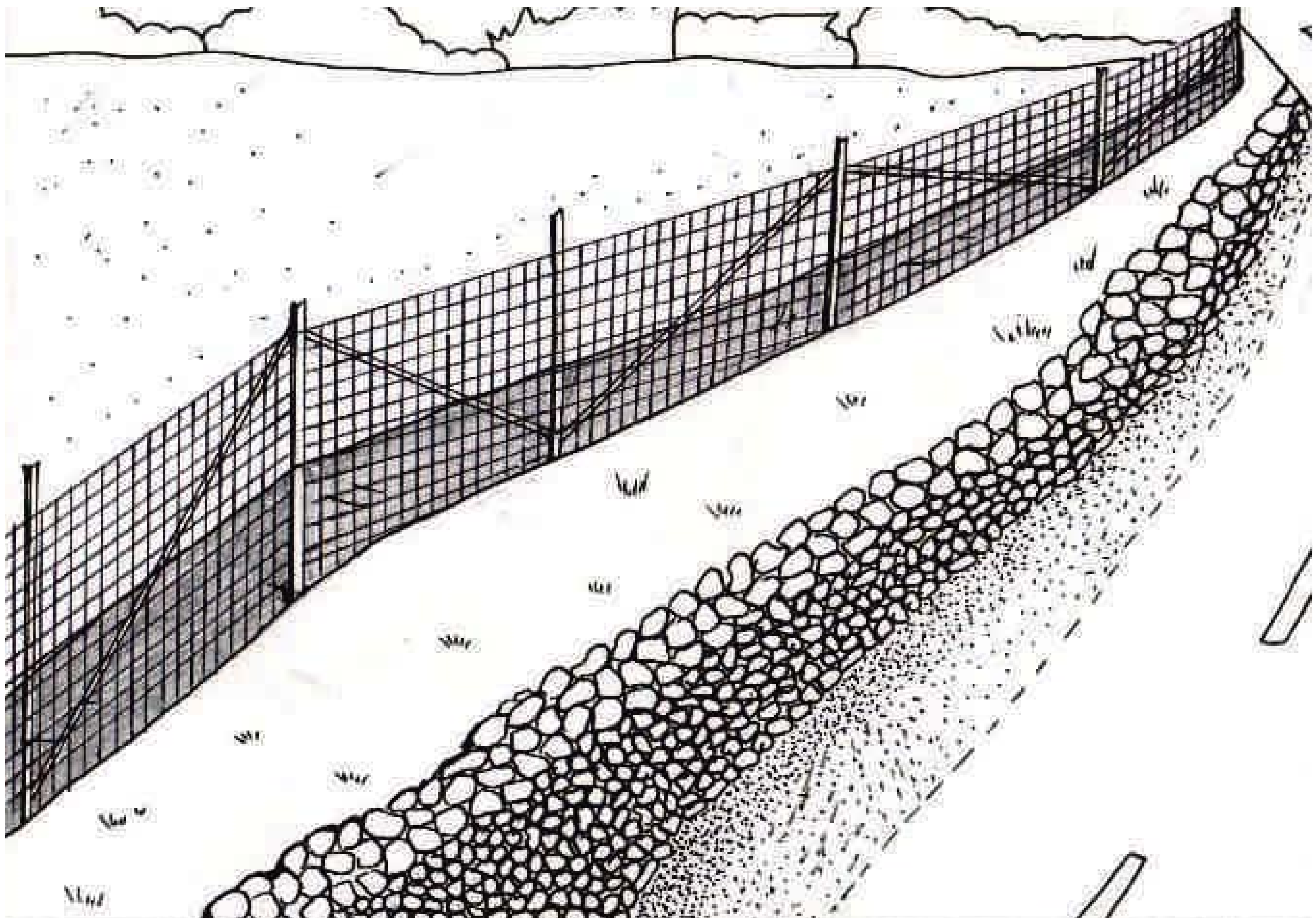


Figure 9.6. Fencing along roadside habitat to prevent herpetofauna from getting on to the roadway and to guide them to use the passageway.

Source: *Adapted from Gilbert et al. 2015. Illustration by Dimpi Patel.*

Figure 9.7. An outward lip in the wall for directing animals, especially snakes, towards underpasses.
Source: *http://www.lakejacksonturtles.org/ppe3.jpg*

A 1 m-high reinforced cement concrete (RCC) wall, having an outward lip of at least 50 cm (Figure 9.7), may be constructed along two sides of the road to prevent animals from accessing it and direct them to use passageways. This RCC structure may also act as crash barrier for vehicles and would help prevent pollutants and litter from entering adjacent natural habitat (e.g. forests and streams of protected areas). If the road is built in a high-rainfall area, a small opening at the base of such structure covered with iron mesh should be provided every 10-20 m along the road to permit drainage.

Most fences act as a one-way barrier: the movement of amphibians is only prohibited in a single direction. The top of the fence should thus curve away from the highway, in order to prevent tree frogs from climbing over (Puky 2003). Fences should be at least 50 cm high. However, in case of fencing for both reptiles and amphibians it needs to be at least 80 cm high above ground and 20 cm below ground.

3 Measures to reduce impacts on breeding success of amphibians

Protection of breeding sites of amphibians is of the utmost importance in the planning of linear developments, especially transportation corridors. Specific measures to protect the breeding sites of amphibians that fall within highway or railway corridors are given below.

i. The availability of amphibian breeding areas (e.g. streams, ponds, lakes, wetlands) along the proposed corridor must be mapped using GIS (Figure 9.2).

ii. Roads and railway lines should be located at a distance of at least 1 km away from amphibian breeding sites: although limited data is available on amphibian movement, most native species are likely to move less than a kilometre during dispersal or migration.

iii. Construction of new amphibian breeding sites or ponds, or restoration of habitat in previously used but degraded breeding sites, could be valuable mitigation measures which help to link populations.

iv. Pond design should take into account measures to assist in the long term management of amphibians. Studies should be undertaken to determine the number, size and type of breeding sites that will be needed to provide effective mitigation.

v. The design of breeding pond may vary according to the particular biological requirements of targeted species or amphibian assemblages. The exact size and shape of breeding ponds should be designed in consultation with amphibian experts.

vi. If new breeding ponds are located close to the road, care should be taken to separate their catchment from the road drainage system, to avoid pollution.

vii. Management of breeding ponds may include the removal of extensive growths of aquatic vegetation and the removal of predatory fish.

Traffic noise is known to interfere with noise perception in amphibians (Parris et al. 2009). If a road is planned to pass through a forest, especially in the Western Ghats or Northeast India, mitigation measures should include the construction of noise barriers along the length of forested sections of road. The barriers should be made of synthetic fibre of height 1.5 m, and may also be constructed on the rigid crash barrier on either side of the highway. Guidance on the design of noise attenuation measures is provided in Chapter 11.

4 Measures to reduce use of road surfaces by snakes for thermoregulation

Thermoregulation has been found to be the primary factor influencing the number of snakes on roads or the time spent on the road surface (Brattstrom 1965; Moore 1978; Sullivan 1981; Bernardino & Dalrymple 1992; Ashley & Robinson 1996). Pragatheesh and Rajvanshi (2013) thus recommend placing strips of different surfaces that may be attractive to thermoregulating snakes next to the road in areas known to have high mortality (Figure 9.8), and testing their effectiveness in diverting snakes from the road surface. Results and practical application of these trials should significantly reduce the mortality of snakes of high conservation importance, including the Indian rock python and Russell's viper.

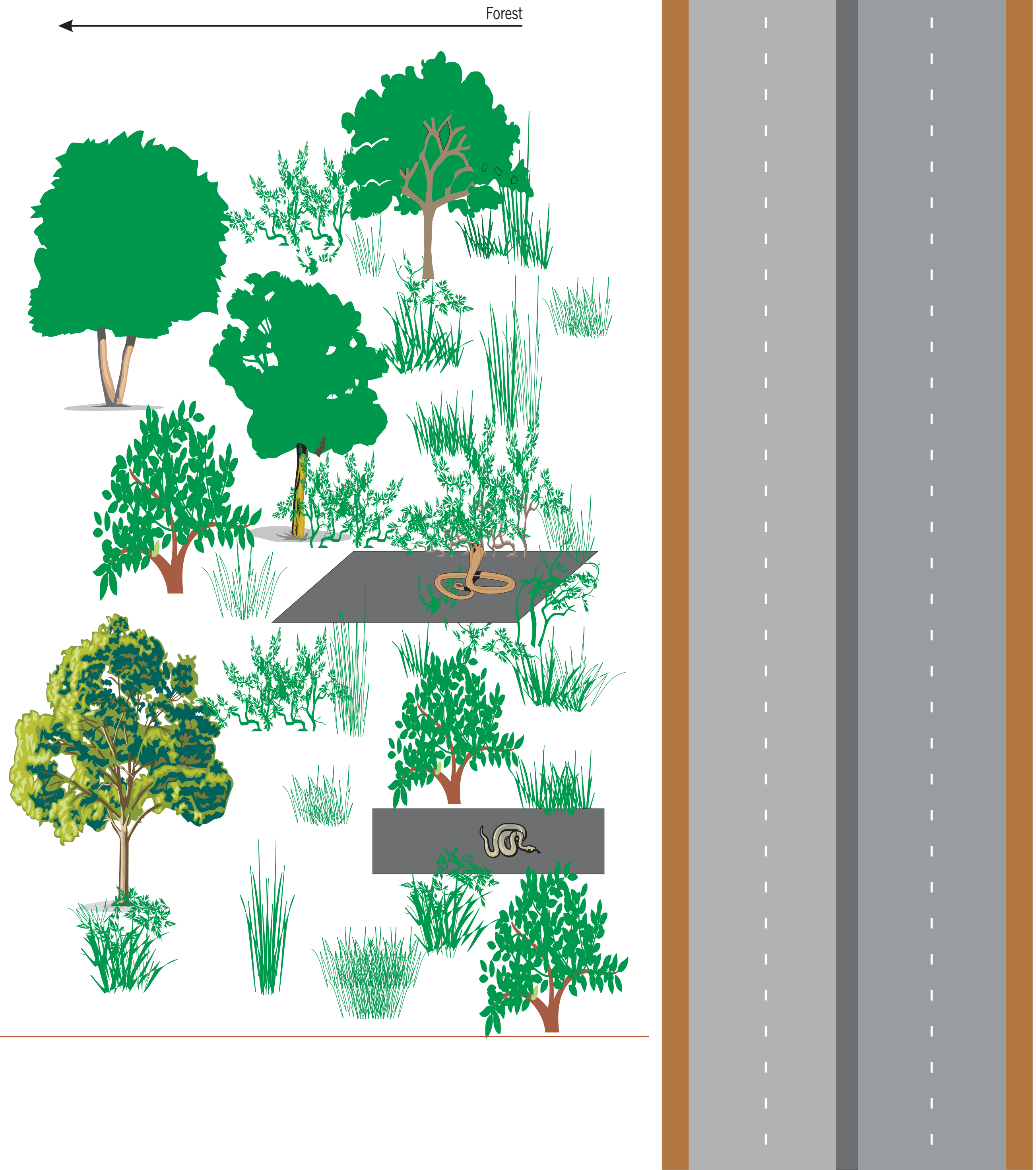
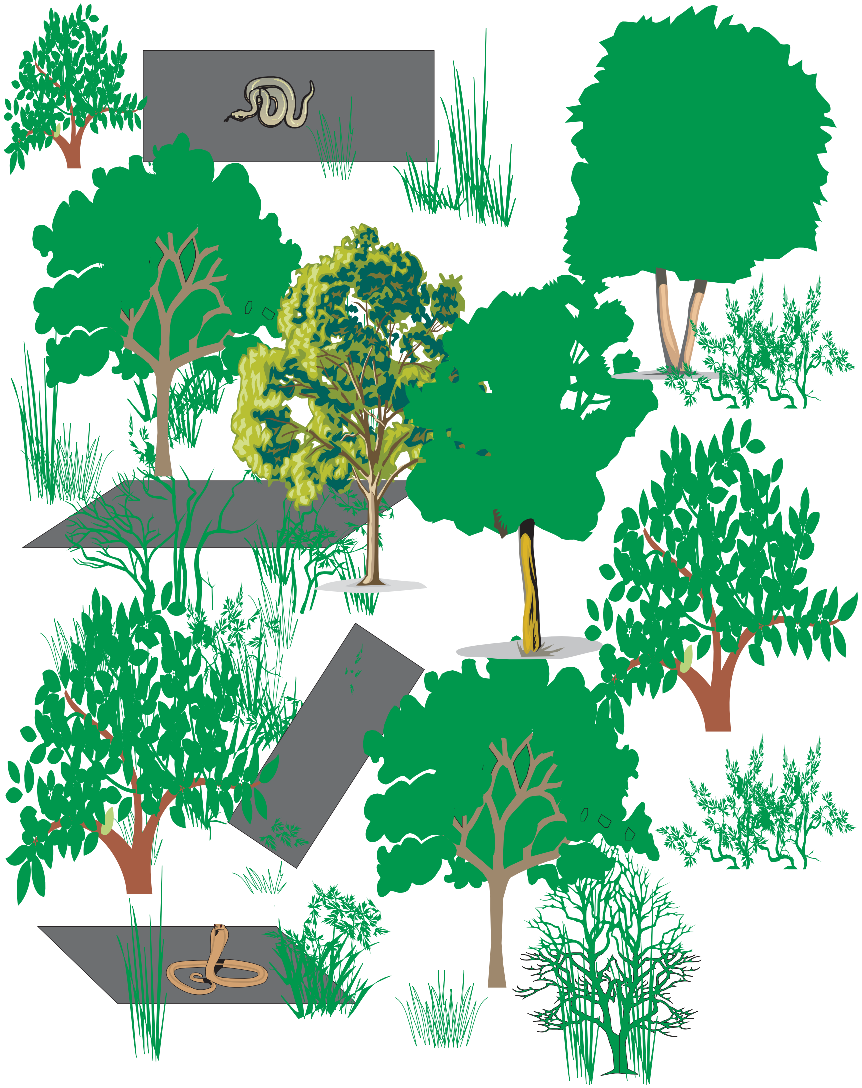


Figure 9.8. Creation of alternative sites for thermoregulation of snakes.

Source: *Pragatheesh & Rajvanshi 2013.*

Forest



5 Measures to facilitate turtle movement across roads and railway lines

Turtles exemplify the types of species least able to disperse across roads and railway lines. Breeding female turtles are the most likely portion of the population to be killed by turtle-vehicle collisions (Langen 2011). These deaths are extremely detrimental to turtle populations and can, in some cases, cause a total collapse of a given population due to the loss of breeding-aged females and lack of recruitment.

Installation of temporary exclusion fencing to direct turtles and other small animals to an existing culvert can be an effective measure to prevent turtle mortality and facilitate their safe passage across roads and railway lines to seasonally available habitat. Fencing should be carefully designed, located, installed, and maintained to reduce turtle mortality rates. The West Japan Railway Company recently installed turtle passages to enable native turtles to cross the railway lines safely (Figure 9.9). Prior to their installation, the turtles would get injured or die after getting stuck between railway tracks. The presence of turtles on the tracks could also endanger the safety of people in trains.

Figure 9.9. Turtle crossings installed across railway tracks by Japan Railways (left). Turtle stuck between railway tracks (right).

Source: http://www.independent.co.uk/news/world/asia/japanese-rail-workers-build-special-tunnels-to-save-turtles-from-train-deaths-a6757466.html

III RETROFITTING OF EXISTING STRUCTURES TO FUNCTION AS WILDLIFE CROSSING STRUCTURES

Existing structures such as bridges, culverts and other drainage structures can be modified to enable animals to use them for passage across highways. This modification is a cost-effective measure for mitigating impacts of highways or railways where no new mitigation structures are proposed. The following points should be kept in mind while retrofitting existing structures:

- Animals' responses to retrofitted structures may vary; some animals/taxa, for example elephants, may have special requirements that may not be fulfilled through retrofitting.
- For drainage structures that are inundated seasonally or perennially, shelves made of wood or boulders can be installed to allow movement of animals.
- If a structure is not already being used, the approach to the structure and nearby vegetation may be altered, and human-related disturbance may be reduced, to attract animals to it and encourage its use.
- Structures that are too old, long or curved, or have other negative issues such as too much disturbance or land ownership conflict, may not be considered suitable for retrofitting.
- Wildlife fencing could be installed near these structures to funnel animals towards these passages.
- Placement of natural elements such as boulders and logs would make the structure appear more natural to the target animals.

IV IMPLEMENTATION AND FOLLOW-UP OF MEASURES

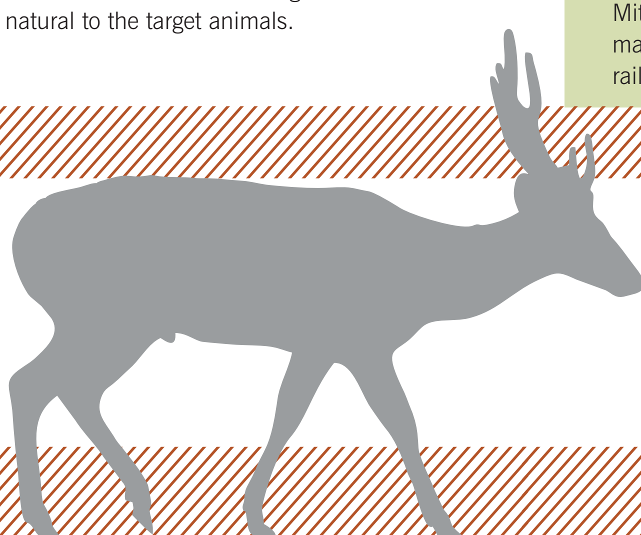
Rigorous and timely implementation of the mitigation measures described in previous sections, giving due consideration to the design specifications and particular features required, is crucial for minimizing the impacts of roads and railways on wildlife. Scientists, wildlife managers and engineers should all be involved in supervising the execution of mitigation measures during construction, to ensure that the design and structures proposed in the plan are faithfully implemented.

Gilbert et al. (2015) underline the importance of assessing the effectiveness of mitigation measures that have been implemented, and adjusting them to improve their performance and/or replicating effective measure in other areas to minimise animal mortality. Four follow-up methods are commonly used:

1. 'Before and after impact control' studies to examine change in animal abundance on roads and railways.
2. Use of radio telemetry to examine animal movements around roads and railways.
3. Evaluation of the willingness of animals to utilize passageways.
4. Monitoring of passages using remote cameras and mark-recapture studies. Camera traps may also be used to check the utilisation of passageways by wild animals during the operational phase of a project.

Mitigation measures found to be effective in reducing animal mortality may be replicated in other areas to minimise the impact of vehicular or rail traffic on wildlife.

Key Message



Where existing highway and railway lines pose significant ecological impacts, attempts to retrofit drainage culverts and bridges should be attempted to improve permeability to animals (Ruediger & Jacobson 2013).

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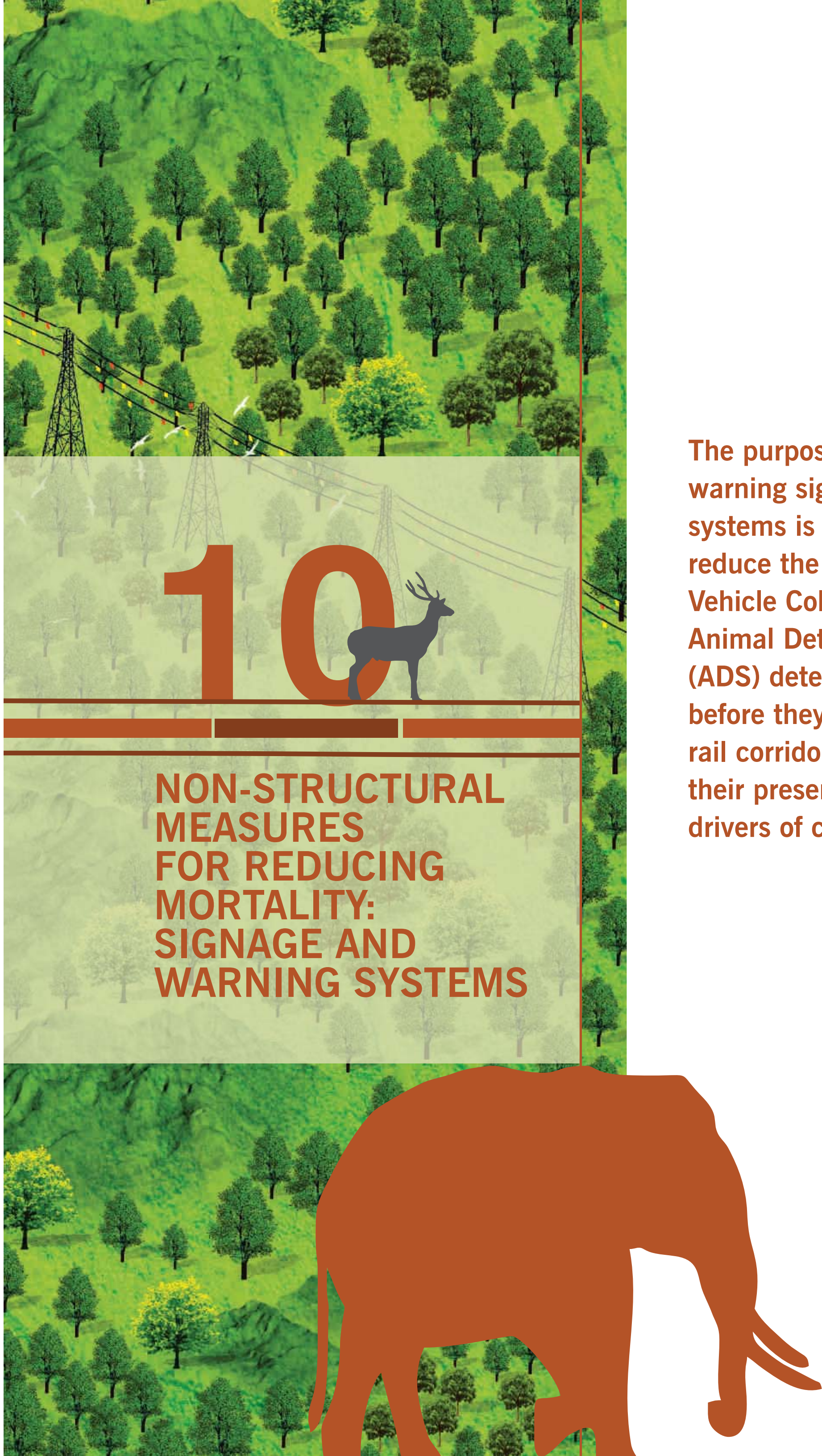


10

NON-STRUCTURAL MEASURES FOR REDUCING MORTALITY: SIGNAGE AND WARNING SYSTEMS

The purpose of animal warning signs and detection systems is to prevent or reduce the number of Animal-Vehicle Collisions (AVCs). Animal Detection Systems (ADS) detect large animals before they enter the road or rail corridor to alert drivers of their presence and warn drivers of collision risk.

SIGNAGE

Signs warning of wildlife are put up along stretches of roads or railway lines where animals are known to occur or use local habitat, to caution drivers about the potential presence of animals. Such signs are already in use on railway lines through Mahananda Wildlife Sanctuary in West Bengal and Rajaji National Park in Uttarakhand in India, and several roads passing through PAs in India. (It is important to note that only signs that are place and time specific may be effective (Huijser et al. 2015.))

All warning signs can be grouped into five categories (Mastro et al. 2008).

1 **Caution signs**

Simple caution signs are commonly used to alert drivers to the presence of wildlife crossing zones. In India, the most common caution signs near railway lines are simple warning signs with silhouettes of the animal that may be using the crossing, sometimes together with a prescribed speed limit or written message (Figure 10.1 and Figure 10.2).

Figure 10.1. Warning signs put up for train drivers near elephant crossing zones in Gulma near the Mahananda Wildlife Sanctuary, West Bengal and Motichur in Rajaji National Park, Uttarakhand.

Source: *Photographs by Shreya Dasgupta and Akanksha Saxena.*

Figure 10.2. Simple caution signs to alert drivers of animal-movement areas to reduce animal vehicle collisions (AVCs) in NH 6 and 7 in India.

Source: *Photographs by Akanksha Saxena.*

2 Enhanced caution signs

Many caution signs are enhanced by adding words like 'Deer Xing' or illuminated with reflective tape, in addition to silhouettes of animals (Figure 10.3).

Although multiple studies have noted that caution signs and enhanced caution signs are so common that motorists tend to ignore them, surveys also show that most motorists (76%) said that caution signs increased their alertness (Stout et al. 1993).

Figure 10.3. Enhanced caution signs can be placed in high AVC areas; e.g. signs placed along the highway passing through the Kaziranga National Park, Assam, India.

Source: *Photographs by A. Pragatheesh.*

Figure 10.4. Temporary signs to reduce road kills of migratory species, amphibians and reptiles.

Source: sustainabilitysoapbox.com; Andrea Bulfinch, for Ipswich Chronicle (https://frogmatters.wordpress.com/2008/03/)

3 Temporary wildlife warning signs

These signs may be put up to warn drivers of wildlife presence during specific times of the day or year: e.g. during animal migration or active and/or breeding periods of amphibians and reptiles (Figure 10.4).

4 Dynamic message signs

These electronic signs can be used to alert motorists of the presence of wild animals, or in areas of high AVCs (Figure 10.5). These signs are most effective at night when most AVCs occur.

Figure 10.5. Electronic message signs.

Source: *www.theindychannel.com*

5 Posters and billboards

Posters and roadside billboards are put up on highways as part of programmes and campaigns to reduce animal mortalities due to collisions with vehicles (Figure 10.6). They also help to generate awareness of this issue among the public.

Figure 10.6. Poster created by the Department of the Interior National Park Service, US.

Source: *Photograph by John Wagner.*

Factors influencing the effectiveness of these signs are listed below:

- Animal detection systems are best installed at locations that have a history of AVCs, especially involving large mammals such as elephant, rhinoceros or gaur and where animals are known to pass frequently: daily or seasonally.
- The distance between signs and the frequency of these signs should be decided according to the occurrence of AVCs in particular stretches of roads: the higher the incidence of AVCs, the greater the signage.
- Roadside vegetation should be cleared, especially near curves and embankments, to make the signs visible to motorists and train drivers.
- The size, shape, colour and material (reflective, non-reflective) of signs should be chosen to make the signs most effective.
- Signs that highlight the conservation importance of the site through which the transportation corridor passes, such as World Heritage Site or National Park (e.g. the signs on National Highway 37 bordering the Kaziranga National Park, Figure 10.7), can help garner support for reducing traffic speed and increased awareness of drivers, thereby helping to protect several threatened species.

Figure 10.7. Animal crossing signs on National Highway 37 passing through Kaziranga National Park, Assam, India, a UNESCO World Heritage Site (Natural).

Source: *Photographs by A. Pragatheesh.*

WARNING SYSTEMS

Animal detection systems are roadside wildlife detection systems that use radar and lasers to flash warning signs to alert motorists, preventing collisions between wild animals and motorists. They may be of different types, as described in Figure 10.8.

Animal-Detection Systems

Area-cover systems:
Detect large animals within a certain range of a sensor

Break-the-beam systems:
Detect large animals when their bodies block or reduce a beam of radio signals from transmitter to receiver

Other systems:
Systems dependent on radio-collared animals, receivers placed in Right of Way, seismic sensors for large animals

Active systems:
Detect animals by measuring reflected signals (e.g. microwave radar)

Passive systems:
Detect animals only by receiving signals (e.g. passive infra red & video detection)

Figure 10.8. Types of animal-detection systems (ADS) available today.

Source: *Adapted from Huijser et al. 2008.*

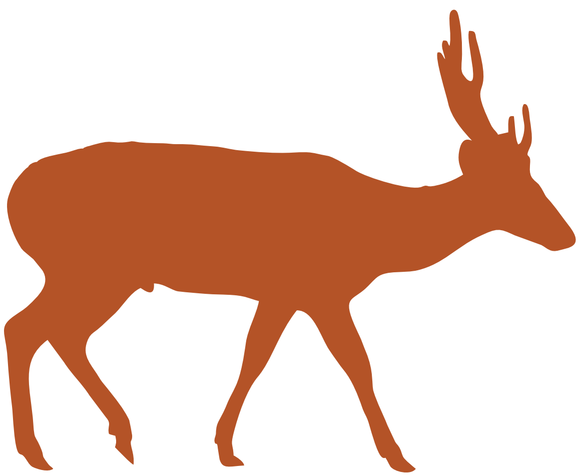
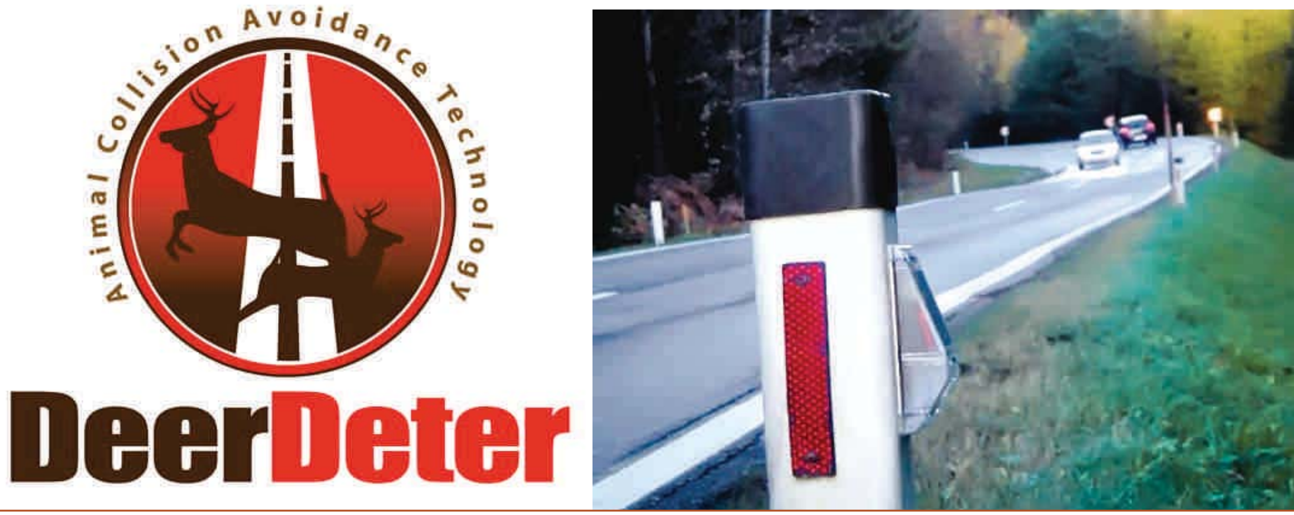


Figure 10.9. An area-cover ADS to detect large mammals on both sides of the pole (left); and an infrared break-the-beam ADS (right).

Source: *Photographs by Marcel Huijser.*



Animal-activated warning systems have proved to be very successful in reducing AVCs on roads of North American and European countries (Figure10.9).

The opto-acoustic deterrent (Figure 10.10) is another example of an ADS. It is activated by vehicle headlights and emits optical light-emitting diode flash and sound signals to alert animals.

Figure 10.10. Animal detection and alert systems like these are prevalent in European and North American countries.

Source: *Jafa Technologies Inc.*

Radar systems to detect animals on railway tracks with auto-brake systems have been proposed by some agencies. Use of Unmanned Aerial Vehicles (UAVs) to detect wildlife on railway tracks and give early warnings to trains has also been proposed to arrest wildlife mortality due to trains.

Thermal cameras mounted on railway engines are proposed to be used by the Sri Lankan Railways Department on trains routed through Jaffna, to detect animals up to 1 km away and avoid collisions (Anon. 2014).

In 2004, the Polish National Railway introduced UOZ-1, or 'key stimuli proxy' (Figure 10.11), a device emitting acoustic signals which create a fear factor in animals, deterring them from approaching the tracks. The gadget imitates naturally-occurring alarm calls or sounds, thus keeping animals away from the tracks without chasing them out of their habitat.

The usefulness of this device has recently been reviewed: it was found to have a material effect on wild animals (86% animals escaped) without any visible habituation of animals to the warning signals (Babinska-Werka et al. 2015).

Figure 10.11. The UOZ-1 device that emits acoustic signals to deter animals from approaching railway tracks.

Source: http://iene2014.iene.info

There are a number of animal-detection and early warning technologies and devices currently being developed or tested:

i) Sensor-based technology is currently being developed to monitor elephant movement along railway tracks; it is not yet ready for application. In July 2013, the MoEFCC permitted the scientists of the Indian Institute of Technology, Delhi, to field-test this technology in North Bengal. It consists of a series of heat- and motion-sensing devices that can be placed at different points along the railway tracks; they can detect body heat or the movement of animals that come close to the tracks. The information captured by the sensors will be relayed from one device to another in microseconds to alert the loco-driver and concerned authorities.

ii) The scientists of the Indian Institute of Science, Bengaluru, are also working on an early warning system that is sensor- and network-based, to prevent motorists or train drivers from running over wild animals on the roads or railway tracks passing through forests. This low-powered, compact device consists of two sensors installed on opposite sides of the road or the railway track with one of the sensors placed alongside a retro-reflector. If any object comes between the two sensors, the retro-reflector screen triggers the device to reveal the distance, height, speed and profile or shape of the object detected. The device would then issue early warnings to approaching motorists or train drivers to look out for wildlife, reduce speed and avert possible accidents.

iii) Mathur et al. (2014) have put forward an approach based on Wireless Sensor Networks: this approach aims to prevent elephant mortality due to trains and simultaneously to monitor the integrity of the rail track. It proposes the use of infrasonic sound for deterring the elephants from crossing the railway track. A novel, passive-node mobility mechanism would be used to provide input to the sensing nodes emitting infrasonic sound. Sensing devices would be placed in close proximity to areas of the track. Using a novel two-cycle communication and sensing check, the integrity of the rail track may also be evaluated and the result is communicated to the regional base station (RBS). This promising approach is subject to field evaluation and validation.

iv) OptaSense, in collaboration with Deutsche BahnNetz AG Europe's biggest rail provider, is testing 'Distributed Acoustic Sensing (DAS)' technology in various areas of operation, including animal detection. Although the system is already used in a range of other sectors, including oil and gas pipelines, the technique has not yet been tested on railways. OptaSense proposes to introduce the technology on the commercial market in 2015 if the trial proves to be a success (Gray 2015).

i. Advantages of Animal Detections Systems:

- ADSs allow for the free and safe movement of wild animals; they are less restrictive than wildlife fences or crossing structures.
- ADSs are relatively easy to install compared with other mitigation structures such as fences or crossing structures, and are likely to be less expensive than these other measures.

ii. Disadvantages of Animal Detections Systems:

- The ADSs available today detect only large animals effectively; small animals are hard to detect.
- Compared with wildlife crossing structures, ADSs do not ensure the safe passage of animals beyond a certain traffic volume in case of roads.
- Some types of ADSs detect animals only during the night; animals crossing roads and railway lines during the day may not be protected.
- Equipment associated with the system (e.g. posts and sensors) may pose a hazard to animals as well as vehicles that run off the road, may be accidentally destroyed, stolen or vandalised.
- ADSs will not eliminate AVCs. However, available data suggest that the effectiveness of ADSs is comparable with that of wildlife crossing structures together with wildlife fencing.
- The ADSs systems may not last as long as wildlife crossing structures and wildlife fences.

iii. Multiple factors influencing the effectiveness of ADSs:

- **Road characteristics.** ADSs are usually not effective on wide roads or on roads with roadside vegetation that impedes operation of the sensors. They are also not effective on high-speed roads as well as high-traffic roads.
- **Siting and spacing of the ADS.** The ADS should be located at a site where a relatively large number of AVCs have taken place in the past, or at locations where animals are known to cross a road or railway line (for daily movement or seasonal migration). The gap between two adjacent sensors should be determined according to the range of the sensors, location of wildlife fences and local conditions.
- The distance required by a train to halt is a major factor that should be taken into consideration before deciding on the type of ADS to be installed. Moreover, the topography of the area determines the minimum speed at which the train has to move; another factor that should be considered while planning the location of ADSs.
- The ADS site should allow for solar power or connection to a power source, and should have low risk of theft and vandalism.
- ADS systems are known to give 'false positives' or exaggerated signals: sensors may be triggered by falling leaves or by each and every individual of a herd of animals. Clearing all vegetation from the site of ADS installation would avoid 'false positives' caused by moving leaves.
- ADS sensors should not be placed on 'blind spots' such as near or on curves, or slopes.

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11 MEASURES FOR NOISE ATTENUATION

INTRODUCTION

Wild animals rely on sound for effective navigation, intra- and inter-specific communication, avoiding danger and finding food for survival. Excessive noise caused by engines and emission of exhaust, aerodynamic sources, tyre/pavement interactions and movement of trains have multiple effects on ecosystems. Roads and traffic alter the physical and acoustic environment of species and ecological communities, both during construction and when a road is open to traffic. While the construction-related noise produced during earthworks, pile driving and road surfacing is usually of limited duration, the traffic-induced noise persists over time.

Noise may interfere with the acoustic signals that are used by various species for navigation, maintaining or establishing contact with members of a family or larger social group. Signals convey many types of message, including distress or danger, the presence of food, and extent of territory (Fletcher & Busnel 1978). Noise may harm not only individual species, but it may also alter species' relationships, as in the case of song birds that depend on acoustics for defending territories, attracting mates, begging for food (by fledglings in a nest), and alarm calling (Slabbekoorn & Halfwerk 2009). Noise pollution is one of many factors contributing to the depletion of wildlife populations. Limited studies in India indicate a lower abundance and variability of birds in forests affected by air and noise pollution than in non-polluted forest in the same bio-geographic zone (Saha & Padhy 2011).

Laboratory experiments and field studies have suggested that wildlife are adversely impacted by noise pollution in the following four ways:

- Hearing loss, resulting from noise levels of 85 decibels dB(A) or greater.
- 'Masking', which is the inability to hear important environmental cues and animal signals because of other background noise (Warren et al. 2006).
- Non-auditory physiological effects, such as increased heart rate and respiration, and general stress reaction (Francis et.al. 2009).
- Behavioural effects, which vary greatly between species and according to the characteristics of the noise, resulting in, for example, abandonment of territory and failed reproduction (Barber et.al. 2009).

Although the generally accepted definition of 'excessive noise' is an increase of 10 dB(A) or greater, the sensitivity of different groups of wildlife varies. According to the US Department of Transportation, Federal Highway Administration (https://www.fhwa.dot.gov/), they can be summarised as:

- Mammals: < 10 Hz to 150 kHz ; sensitivity to -20 dB(A).
- Birds (more uniform than mammals): 100 Hz to 8-10 kHz; sensitivity at 0-10 dB(A).
- Reptiles (poorer than birds): 50 Hz to 2 kHz; sensitivity at 40-50 dB(A).
- Amphibians: 100 Hz to 2 kHz; sensitivity from 10-60 dB(A).

The Government of India, through the Noise Pollution Regulation and Control Rules (2000), prescribes ambient air quality standards. It directs State Governments to categorise areas into 'industrial', 'commercial', 'residential' or 'silence' areas or zones for the purpose of implementing noise standards for different areas (Table 11.1).

Table 11.1. Ambient Air Quality Standards in respect of noise.

Area code	Category of area zone	Limits in dB(A) Leq*	
		Day time	Night time
(A)	Industrial area	75	70
(B)	Commercial area	65	55
(C)	Residential area	55	45
(D)	Silence zone	50	40

Source: *(ref: S.O.123(E), [14/2/2000] - Noise Pollution (Regulation and Control) Rules, 2000; website : http://www.moef.nic.in/noise_pollution).*

Note :

1. Day time shall mean from 6.00 a.m. to 10.00 p.m.
2. Night time shall mean from 10.00 p.m. to 6.00 a.m.
3. 'Silence zone' is an area comprising not less than 100 m around hospitals, educational institutions, courts, religious places or any other area which is declared as such by the competent authority.
4. Mixed categories of areas may be declared as one of the four abovementioned categories by the competent authority.

*dB(A) Leq denotes the time weighted average of the level of sound in decibels on scale A which is relatable to human being.

A "decibel" is a unit in which noise is measured.

"A" in dB(A) Leq. denotes the frequency weighting in the measurement of noise and corresponds to frequency response characteristics of the human ear.

Leq: is an energy mean of the noise level over a specific period.

Noise pollution control and abatement is therefore a mandatory activity, especially when designing and planning a roadway project. Attenuation or reduction in noise due to vehicular traffic can be achieved by the use of noise barriers, limitation of vehicle speeds, alteration of roadway surface texture, limitation of heavy vehicles, use of traffic controls that smooth vehicle flow to reduce braking and acceleration, and tyre design. Costs of building in mitigation can be significantly reduced if the solutions are planned in the early scoping or planning stages of a roadway project. The following pages provide an introduction to noise attenuation structures, to act as a ready reference.

Noise may reduce the effectiveness of mitigation measures installed on roads to reduce the fragmentation and isolation of wildlife populations. It is therefore important to implement measures to reduce noise that has the potential to disturb human beings and wild animals.

NOISE ATTENUATION STRUCTURES OR NOISE BARRIERS

Noise barriers are the most commonly used form of noise abatement. On roads and highways, noise barriers (sometimes referred to as 'noise walls' or 'sound walls') are intended to block or reduce highway noise from reaching and affecting activities near the highway (Figure 11.1). They do this primarily by blocking the direct path that sound must travel between the source of sound on the highway and the receiver exposed to the sound. Effective noise barriers can reduce noise levels by 10 dB(A), cutting the loudness of traffic noise by half.

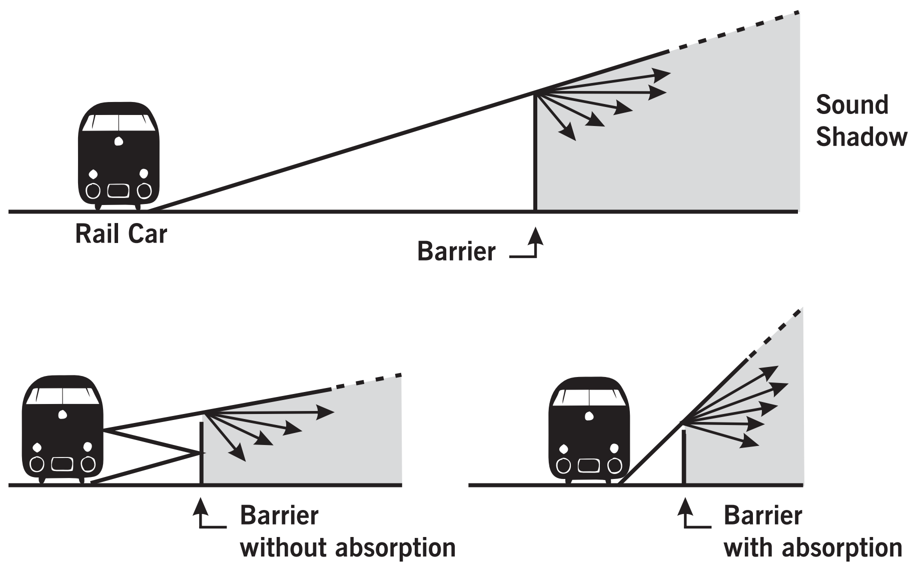


Figure 11.1. A pictorial depiction of artificial barriers and their role in noise attenuation.

Source: *Noise Barrier Design Hand Book; US Department of Transportation 1976.*

Factors Influencing Design of Noise barriers

Design of a noise barrier begins with the determination of its height and location relative to the roadway. These parameters are dictated by acoustical requirements, and are determined by the environmental engineer. Once these parameters have been determined, the structural design of the sound wall can proceed. The structural design of sound walls was principally controlled by the following factors: aesthetics, cost, maintenance, local influences and structural constraints. In addition to the structural factors mentioned above, several other factors influence the final design of sound walls. These include drainage, landscape, road access, vehicular impact, foundations, environmental impact, community impact, sight distance, right-of-way width and soil conditions.

TYPES OF NOISE BARRIERS

There are two basic types of noise barrier systems with associated special features, namely ground- or structure-mounted systems (Table 11.2, Figure 11.2 a-f):

- Ground-mounted systems are noise barriers embedded in or placed on top of the ground. They consist of noise berms, noise walls, or a combination of noise berms and walls.
- Structure-mounted systems are noise barriers incorporated within other structures, such as noise walls on bridges or on retaining walls.

When selecting the most effective noise barrier, the following factors should be considered:

i) Existing noise levels.

ii) Volume of road/highway traffic and associated noise level, or noise impact of a moving train.

iii) Sensitivity of different taxa to different noise levels.

iv) Design features that would be most appropriate to reduce the noise impacts on different taxa.

v) Feasibility and practicability of mounting noise abatement measures at the site (ground- or structure-mounted).

vi) Feasibility of abating traffic noise with traffic control measures.

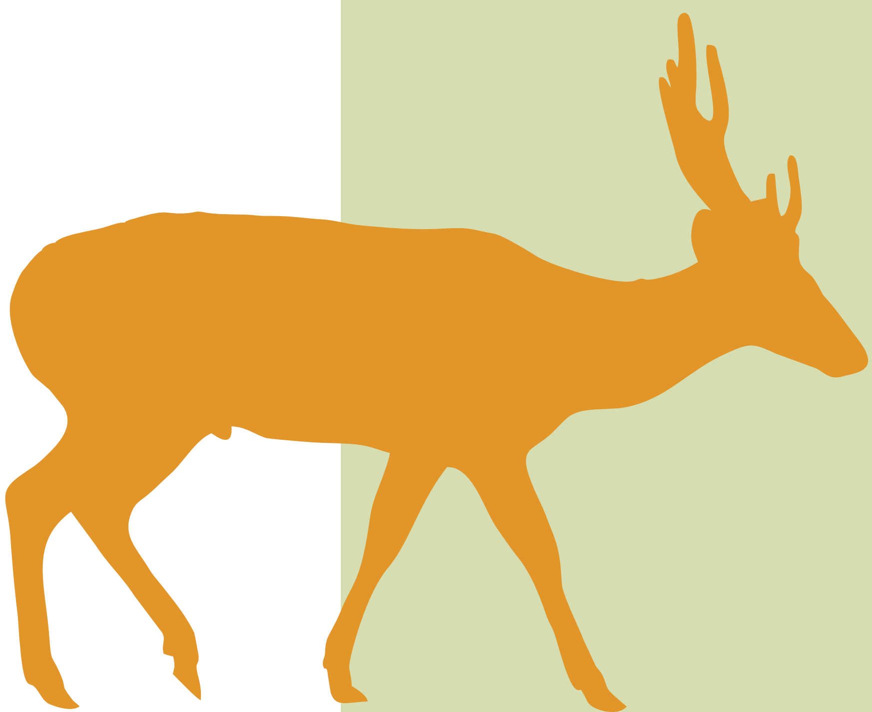


Table 11.2. Types of noise barriers commonly used in road projects.

Type	Construction details	Aesthetics	Drainage, utility and safety	Cost and maintenance
		Ground-mounted noise walls		
1.Noise berm	Constructed from natural earth materials such as soil, stone, rock, rubble, etc. in a natural, unsupported condition.	High appeal and natural	May obstruct natural drainage channels and cause localised flooding. Safe, although occupies more space than a wall-type barrier. Height may be a consideration in significantly reducing the noise levels.	Low costs, if raw material is available on site for construction and repairs.
2. Post and panel noise wall	Consists of noise barrier panels mounted between foundation-supported posts.	Colour and material for the pre-fabricated structures may be chosen to blend with the surrounding landscape	Side drains are usually provided. May have weight and size limitations.	Installation costs are higher than overall maintenance costs. Replacement of barrier elements may be required throughout the life of the noise barrier; availability of replacement parts becomes a critical issue.
3. Free-standing noise wall	Includes barriers which support themselves using 'zig-zag' configuration or compacted soil and a well-drained stone base, a plain cement-concrete levelling pad, or a continuous reinforced concrete footing. Includes three types: precast concrete, planted or 'bin' types, and stone crib.	Wider aesthetic appeal and variability, as can be adapted to suit various soil types and landscapes	Side drains are usually provided.	High installation costs.
4. Direct burial panel	Involves burying a portion of one end of the panel (either precast concrete or wood) directly into the ground with no other means of foundation support	A unique architectural design is obtained due to the 'tongue and groove' design (Inset to Figure 11.2(e)).	Differential settlement may not be even throughout the length of each panel, thus causing tilting and separating of the panels.	High installation costs
5. Cast-in-place concrete noise walls	Constructed at the project site, includes excavating for the footing, erecting form work, setting reinforcement steel, pouring concrete, surface finishing, and curing.	Less appealing as Surface textures obtained through raking, brushing, or stamping of concrete are not possible	Higher safety standards are achieved	High installation costs

Type	Construction details	Aesthetics	Drainage, utility and safety	Cost and maintenance
6. **Combination noise berm and noise wall systems.**	Consist of a portion of the barrier height obtained through use of an earth berm with the remainder of the required height achieved by placing a noise wall on top of the berm. The foundation, post, and panel considerations for these wall portions are similar to those of the original structures.	Limited aesthetic appeal	May obstruct natural drainage channels and cause localised flooding. Safe, although occupies more space than a wall-type barrier. Height may be a consideration in significantly reducing the noise levels.	High installation costs
Structure-mounted noise walls				
7. **Structure-mounted noise walls**	Noise walls used on structures, especially on bridges and retaining walls.	May block the 'view' although may be useful for privacy to settlement areas.	Normal safety standards are achieved if maintained properly.	Require additional costs of structural modifications on existing bridges and retaining walls. Overall considerations include maintenance, protection of traffic (both on and beneath bridge), accessibility to areas requiring modifications, bridge vibrations due to existing traffic, from construction operations, and potential environmental mitigation measures (e.g. related to painting beams or working over waterways or wetland areas).

Source: *Adapted from Simpson 1976.*

Figure 11.2. (a-f) Images for types of noise barriers commonly used in road and rail projects.
a. Noise berms.
Source: http://www.well.com/user/pk/waterfront/EastshoreStatePark/Berm.html

Top **-** (b) Post and panel noise wall.

Source: *http://www.geostructures.com/solutions/structures-walls/sound-walls.*

Right **-** (c) Free-standing noise wall.

Source: *http://www.a1highways.com.au/projects/services/sound-barrier-division/.*

Left Top - (d) Free-standing noise wall (2).

Source: *http://www.hsmlandscaping.ca/lawn_care_landscaping_retaining_walls.p.*

Top - (e) Direct burial panel with 'tongue and groove' design (inset).

Source: *http://www.gardenvisit.com/blog/2009/10/01/acoustic-noise-barriers-and -sustainable-landscape-architecture/.*
Inset: https://www.amazon.com/Freud-99-191-Paneling-Router-2-Inch/dp/B00004T7MK.

f. Cast-in-place concrete noise walls. *Source:* *http://precast.org/2014/09/integrated-sound-wall-system/.*

OTHER CONSIDERATIONS

i. Material types in noise barriers

Globally, there are no specific requirements or regulations related to the selection of material types in the construction of road- traffic noise barriers, although individual highway agencies select the material types to use when building their barriers (Anon. 2011). Highway agencies normally make this selection based on a number of factors such as aesthetics, durability, maintenance requirements, cost, public views, etc. The material chosen should be rigid and of sufficient density (approximately 1.8 kg/0.1 m^2 minimum) to provide a loss of 20 dB(A) greater than the expected reduction in the noise diffracted over the top of the barrier (Anon. 2011).

PLEASE NOTE

Do not build a noise wall of glass or see-through plastic as this may lead to collision of birds that may fly into them.

ii. Use of vegetation as a noise barrier

Vegetation, if it is high enough, wide enough, dense enough and opaque, may reduce highway traffic noise. Approximately 60 m width of dense vegetation can reduce noise by 10 dB(A); it is usually impossible, however, to plant enough vegetation along a road to achieve such reductions. It would be ideal to create noise buffers using a diversity of tree species, with a range of foliage shapes and sizes: a combination of shrubs and trees may be necessary to achieve this effect. Evergreen species that could provide a year-round buffer would be desirable.

iii. Height of a noise barrier

To produce at least 5 dB(A) reduction, a barrier must be tall enough (and long enough) to block the line of sight between a source and a receiver. If a barrier is too short, or if there are gaps between barriers, the noise can travel around the end of the barrier wall, reducing its effectiveness. Provided that sufficient barrier segments are installed, the noise barrier can achieve a 5 dB(A) reduction, even with gaps between segments. Computer-generated models should preferably be used to determine the optimum overall barrier dimensions.

iv. Noise barriers and neighbourhood planning

Project design engineers should be involved in decisions on the optimum locations of noise barriers: they should be asked for input regarding sight distance requirements, right-of-way issues, utility easements, and foundation requirements. Noise barriers should not cause any displacement or relocation of receivers. It is normally not cost-effective to build a noise barrier for a single receiver. Large gaps for driveways and alleys entering onto a roadway greatly reduce the effectiveness of a barrier. Access streets should not be closed to eliminate large gaps in a noise barrier and thereby enhance its effectiveness, unless requested and approved by local government officials. Associated responsibilities should be clearly spelled out in a written agreement prior to the final environmental clearance.

Traffic-noise analyses and any associated noise-abatement measures are not intended to be used to reshape or reconfigure existing neighbourhoods. Earth berms, although natural in appearance, may require a large plan area (right-of-way) to reach the height required to be effective.

v. Noise barriers on hilly, elevated, or depressed sites

Noise barriers are normally not effective for receivers on a hillside, overlooking the highway, or for receivers at heights above the top of the noise barrier. Depressed and elevated roadways normally result in somewhat lower noise levels (3–5 dB(A)), potentially eliminating the need for a noise barrier or requiring a lower barrier than would otherwise be the case.

vi. Effects of holes and surface texture

Small gaps and drainage holes (less than 3% of the total surface area) do not significantly reduce a noise barrier's overall acoustical effectiveness. The surface roughness of a barrier matters only if it is of the same order of magnitude as the wavelength of sound that the barrier is intended to attenuate. Because the wavelength of 100 Hz sound is around 3 m, ordinary surface roughness has little effect.

vii. Multiple-reflection issues

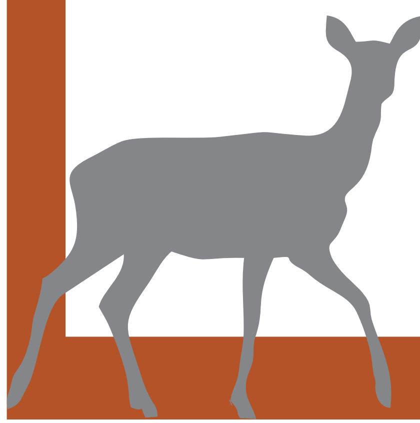
Multiple reflections of traffic noise between two parallel plane surfaces, such as noise barriers or retaining walls on both sides of a highway, can theoretically reduce the effectiveness of individual barriers and contribute to overall noise levels. During the preliminary design of noise barriers, the possible influence of parallel reflections should be checked.

viii. Effects of absorptive materials

Constructing barriers using sound-absorptive materials significantly reduces the noise level experienced by drivers on the roadway. It does not significantly reduce the noise level away from the highway, except when the highway has barriers on both sides.

PLEASE NOTE

Noise barriers may block the carriageway completely for the movement of animals across it. It must therefore be accompanied by the crossing corridors - the underpasses or eco-ducts.



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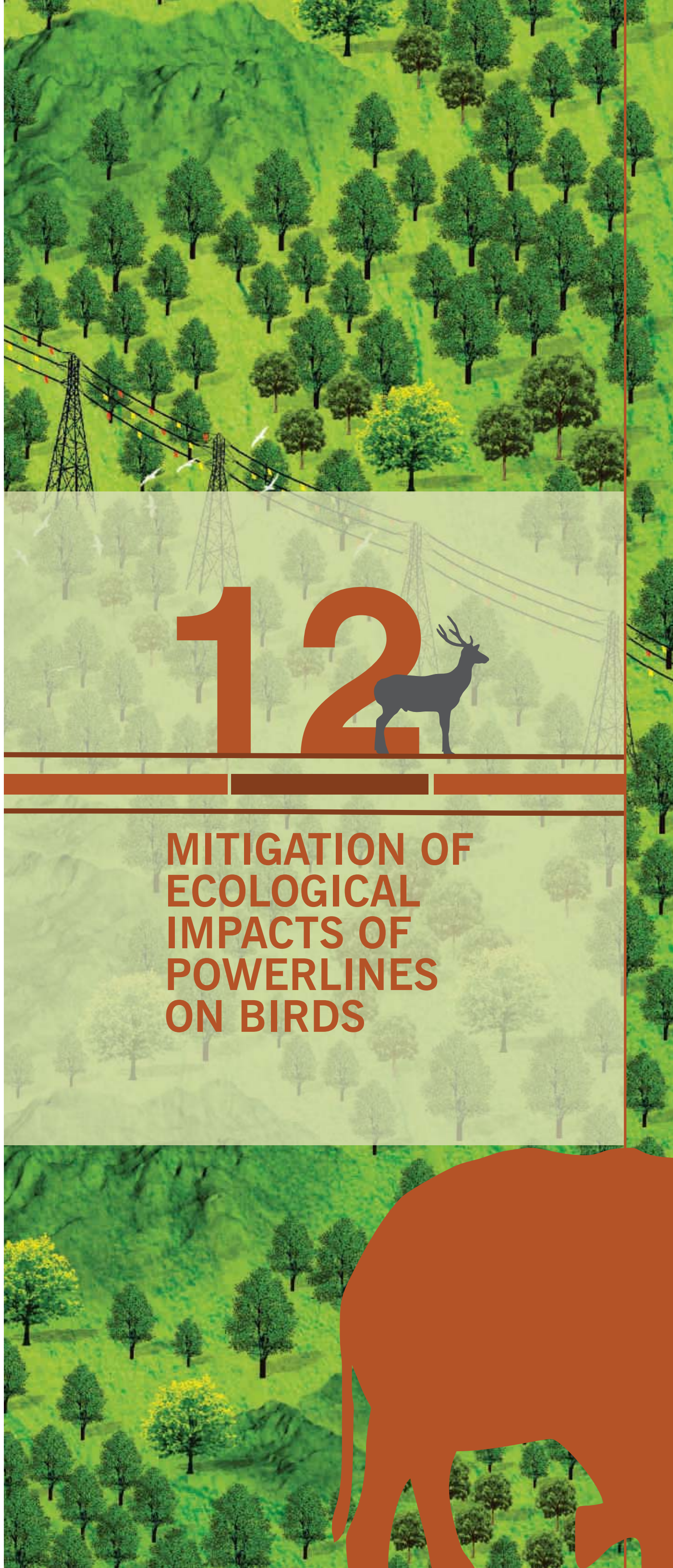
MITIGATION OF IMPACTS OF POWERLINES

PART III

The clearing of native vegetation in powerline corridors may affect the permeability of habitat for a wide range of wildlife. In addition, animals other than birds may be injured or killed as a result of collisions with or electrocution by powerlines. However, the main impacts of powerlines are undoubtedly on birds. This section presents mitigation option for addressing collision and electrocution impacts on avifauna.



12 MITIGATION OF ECOLOGICAL IMPACTS OF POWERLINES ON BIRDS

Electrocution of birds, and their collision with powerlines, is not only a topic of conservation concern but also an issue of serious economic and financial costs. Appropriate routing and structure of powerlines is said to reduce the risks of bird collision and electrocution by 50% or more (Prinsen et al. 2011).

Several guidelines have been suggested by different experts and agencies to minimise the impacts of powerlines on birds (Haas et al. 2005; APLIC 2006; Tucker & Treweek 2008; Prinsen et al. 2012). Based on these guidelines, the following steps are recommended:

> **PLEASE NOTE**
>
> Transmission lines are out of the purview of the list of projects requiring environmental clearance under the EIA Notification, 2006, and have been categorised as Category B2 projects. However, considering the magnitude of impacts of these structures on the environment and wildlife, particularly avifauna, they require environmental clearance if located within close proximity of/or within the 10 km boundary of Protected Areas, habitats for migratory birds and other sensitive sites (see Chapter 3).

1. Early planning and rigorous Environmental Impact Assessment (EIA) are two core requirements for reducing bird mortality due to powerlines, as well as minimising the risks of costly power outages. A nationwide strategy should be developed and supported to undertake the long-term planning of electricity grid networks as a priority. Planning should include the use of state-of-the-art bird protection equipment, and burying low-to medium-voltage powerlines below ground where feasible. In the Netherlands, burying these lines effectively removes the problem of bird electrocution. This prevention measure is also utilised in other European countries such as Belgium, United Kingdom, Germany, Denmark and Norway. EIA is an invaluable tool to inform decision-making, helping to ensure that powerlines are appropriately routed and designed.

2. Decisions on the routing of powerlines and shifting of transmission structures should be done collaboratively, involving the electricity supplier company, government bodies, conservation agencies, land owners and other interested and affected parties, culminating in one or more memoranda of understanding. In South Africa, for example, this practice has

been done by cooperation between the single utility company, Eskom, and a conservation NGO, the Endangered Wildlife Trust, and has helped resolve problems of bird electrocution and collisions, which was most effective (Prinsen et al. 2012).

3. As far as possible, bird collisions should be minimised by locating new transmission lines within existing power transmission corridors rather than by creating new corridors within prime bird habitats and across their migratory routes.
4. A database should be prepared that includes relevant information which must be taken into account in planning powerline corridors: location of protected area networks; important bird and wildlife habitat; presence of threatened bird species that are particularly vulnerable to collisions or electrocution, their flight routes between feeding, breeding and resting habitats; as well as information on migratory corridors.
5. A list of key conservation areas and species should be identified from this database to identify priorities for mitigation along different stretches of the powerline corridor: the routing of new powerlines should strive to avoid key areas and structures should incorporate the latest technology. Existing sections of powerline should be retrofitted with state-of-the-art technology or be re-routed away from key areas to reduce the risks of electrocution and collision.
6. A post-construction monitoring programme should be developed to check the efficiency of mitigation measures and enable further improvement.
7. Management of facilities and sites near powerlines that are known to attract birds—especially raptors, such as carcass and garbage dumps, can help minimise bird mortalities.

MODIFICATIONS TO POWERLINES TO MINIMIZE BIRD ELECTROCUTIONS

Measures to prevent bird electrocution are of paramount importance and are easier to achieve than measures to prevent collisions. Retrofitting existing powerlines is considered to be best practice to prevent bird electrocutions (APLIC 2006; Prinsen et al. 2012). The following measures should be used:

1. A power pole configuration should be designed to minimize avian electrocution risk by providing a separation between energized conductors or phases and grounded hardware larger than the wrist-to-wrist or head-to-foot distance of a bird (Figure 12.1).

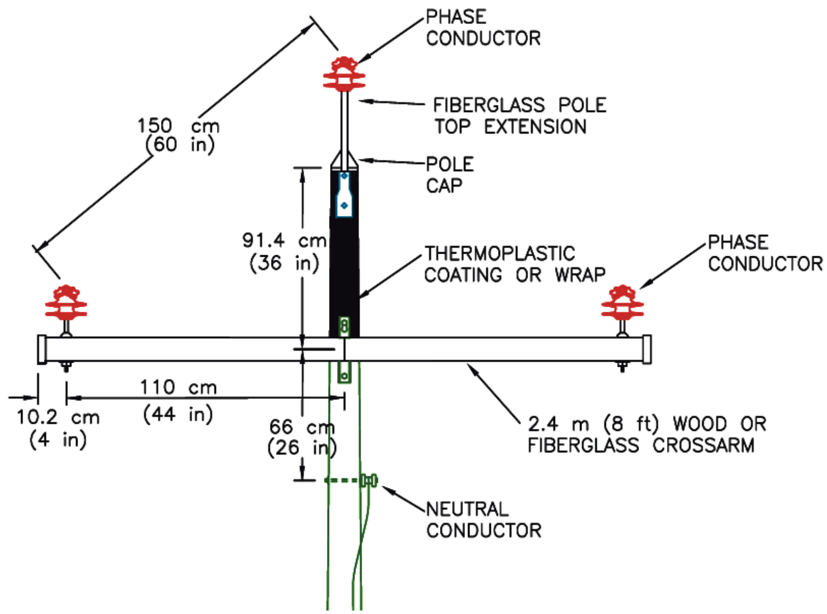


Figure 12.1. To prevent avian electrocutions, a minimum of 150 cm separation of phase wires horizontally and 110 cm separation between phase and grounded equipment on the cross-arms has been recommended.

Source: *APLIC 2006.*

2. Places where such separations are not possible, bare parts of poles like phase wire, insulators, jumper wires should be covered by a non-conductor insulated material (Figure 12.2).

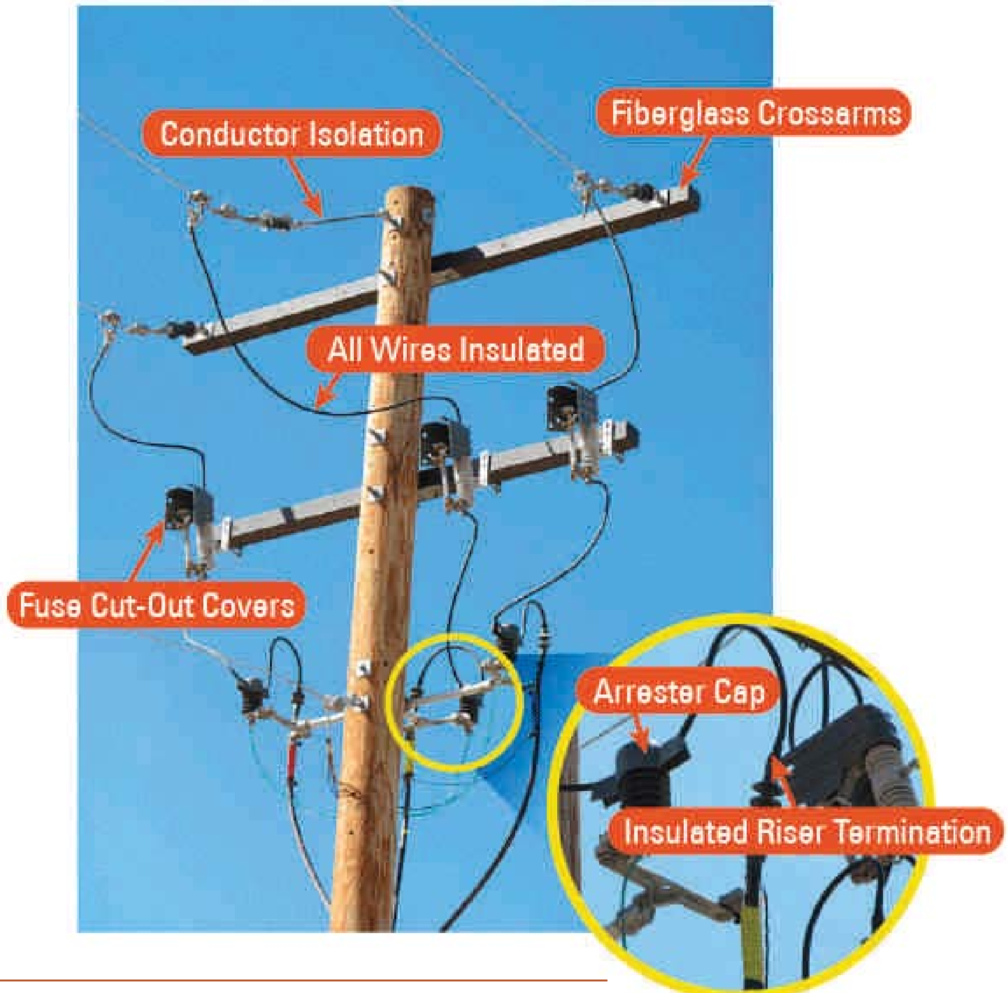


Figure 12.2. A power pole showing use of fibreglass cross arms, arrester caps and insulators on phase and jumper wires which prevent electrocution of birds.

Source: *http://www.anadarko.com.*

3. In the case when insulation of distribution lines is not possible, perch deterrent can be placed on the pole to prevent a bird from perching on it (Figure 12.3).

Figure 12.3. Perch deterrents are known to be effective in reducing raptor electrocutions in the USA.

Source: *Slater & Smith 2010.*

4. Installation of phase wires below the cross arms, using suspension insulators, can reduce electrocution risk.
5. Artificial bird perches or nesting platforms can be provided on the top of the power poles for birds in habitats that lack perching and nesting sites, thereby helping to prevent electrocution.

II DESIGN AND CONFIGURATION OF POWERLINES TO MINIMISE BIRD COLLISIONS

Measures to prevent or reduce bird collisions with powerlines are difficult. However, the risk of collisions can be minimised by re-routing powerlines away from key bird areas, attaching bird diverters to lines and burying the power cables underground in areas used intensively by birds (APLIC 2006; Prinsen et al. 2012).

1. Powerlines should not be located in Important Bird Areas (IBAs) such as water bodies and forested areas where large numbers of birds congregate. Where powerlines have already been erected in IBAs, re-routing or shifting those lines or by retrofitting mitigation measures can reduce bird collisions.
2. Potential collision risk can be reduced by keeping all key bird areas on the same side of the powerline corridor, providing a safe 'flyway' by minimising the need for birds to cross that corridor; i.e. where a bird's feeding, resting and/ or nesting sites are in close proximity, powerlines should avoid bisecting those areas (Figure 12.4).

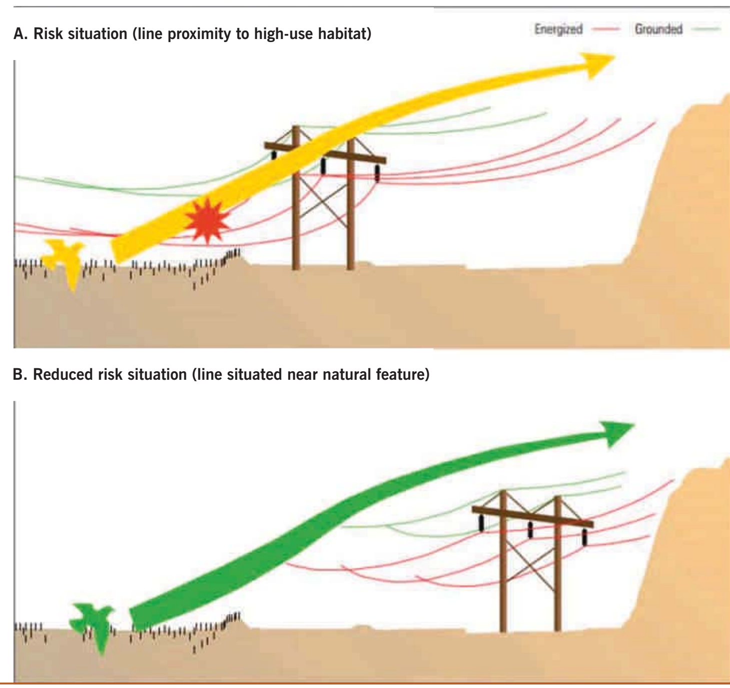


Figure 12.4. Image showing (A) the placement of power line corridors that are a threat to birds and (B) the placement that will reduce the risk of bird collision (after Thompson 1978).

Source: *APLIC 2012.*

3 Placement of multiple, vertical layers of conductor wires should be minimised. Alternatively, the conductor wires should be placed closer together, vertically, so as to enhance the visibility of an obstruction to birds.

4. New powerline corridors should be placed close to an existing corridor where feasible, so that birds already accustomed to the presence of powerlines in the area will be able to see the collective obstacle as well as have a better chance of avoiding the second powerline if it is of the same, or lower, height (Figure 12.5).

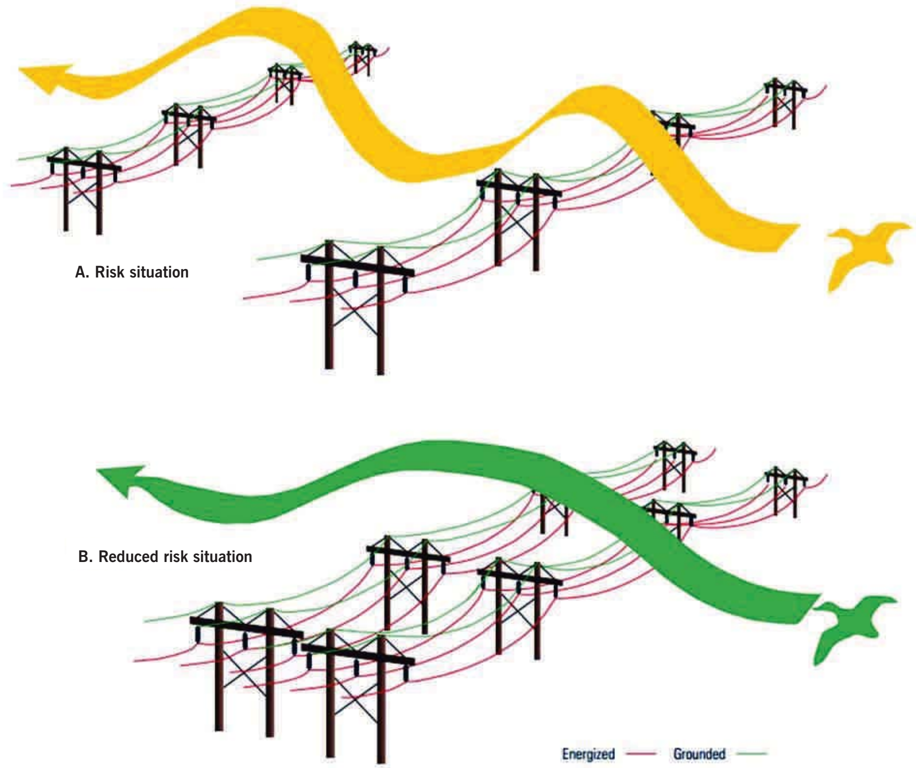


Figure 12.5. Recommended placement of multiple powerline corridors that will reduce the risk of bird collisions (after Thompson 1978).

Source: *APLIC 2012.*

4. Birds frequently collide with the earth wires installed at the top of transmission lines, as it is less visible and smaller in diameter (Figure 12.6). Removal of the earth wire has been reported to reduce bird collisions (Beaulaurier 1981; Brown et al. 1987). However this is rarely a viable option since the earth wires protect the powerline installation from lightning strikes. This is only possible in areas where there is very low lightning and to a limited extent (APLIC 2012).

Figure 12.6. A high voltage transmission line showing the conductor wire and the partially visible earth wire that birds frequently collide with.

5. Where the earth wires cannot be removed, using line marker devices should increase their visibility. Marker devices are available in several colours and are visible to birds from a long distance. Many types of marker devices are available, such as spheres, swinging plates, spiral vibration dampers, strips, flight diverters, bird flappers, ribbons, tapes, flags, and crossed bands (Figure 12.7).

Figure 12.7. Range of marker devices used on wires to improve their visibility to birds.

Source: *PR Tech website; http://pr-tech.com/shop/birdaway-bird-diverters/.*

6. Line markers should be as large as possible. The spacing between them should not be more than 5 to 10 m. Marker devices should be chosen to contrast as much as possible with the background colours (Figure 12.8), and, importantly, should be visible at night: most bird collisions are said to occur at night.

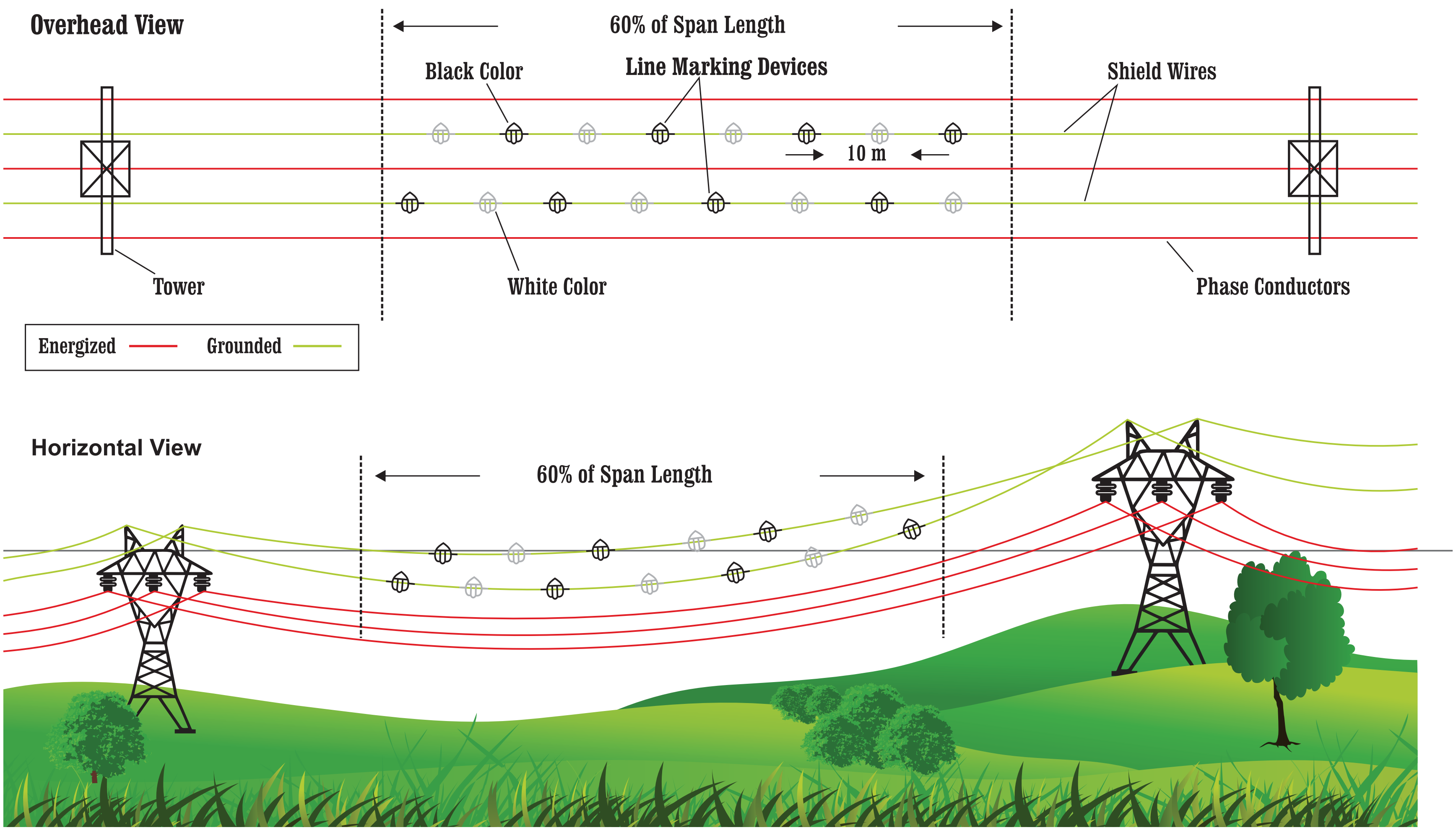


Figure 12.8. Design and configuration of markers to reduce bird collisions (after Eskom Transmission [South Africa] 2009).

Source: *APLIC 2012.*

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Tucker, G. and J. Treweek. 2008. Guidelines on how to avoid, minimise or mitigate the impact of infrastructure developments and related disturbance affecting water birds. AEWA Conservation Guidelines No. 11, AEWA Technical Series No. 26, Bonn, Germany.

AVAILABLE GUIDANCE

PART IV

Globally the body of knowledge and guidance on best practices adopted for mitigating impacts of linear infrastructure projects is fast accumulating. Best practice guidelines have been developed in many countries for different species and landscapes. This section provides a ready reckoner and quick glance at guidance available globally for adapting measures to mitigate impacts of such infrastructure.

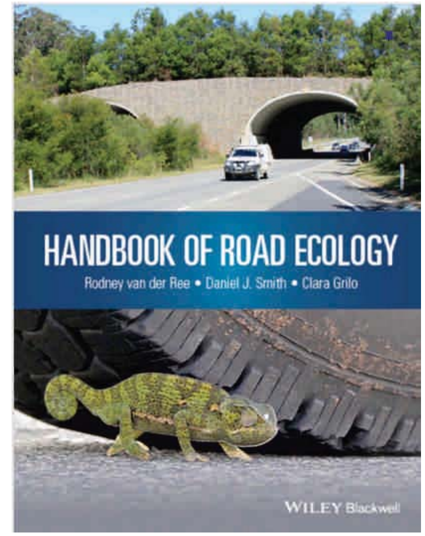
BOOKS

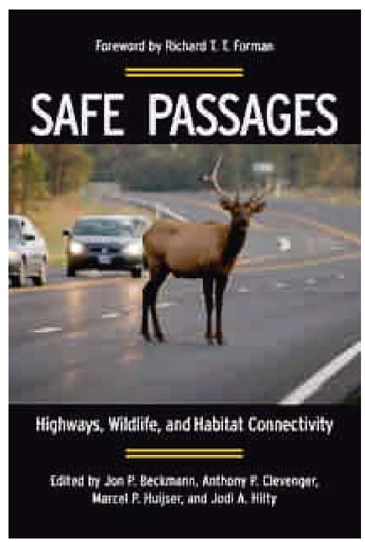
Handbook of Road Ecology.

-van der Ree, R., D. J. Smith and C. Grilo. 2015.

John Wiley & Sons, UK. p552. DOI: 10.1002/9781118568170.

This book brings together some of the leading researchers, academics, practitioners and transportation agency professionals from different parts of the world to contribute towards improving the ecological sustainability of linear infrastructure such as roads, rail and utility elements that dissect and fragment landscapes around the world. Chapter subjects include planning and design, construction, maintenance and management of linear infrastructure, monitoring and evaluation of impacts and effectiveness of mitigation measures, impacts and solutions for species groups and specific regions, with regional examples from Asia, South America and Africa.





Safe Passages: Highways, Wildlife, and Habitat Connectivity

- Beckmann, J. P., A. P. Clevenger, M. Huijser, and J. A. Hilty. 2010.

Island Press, Washington, D.C. p424. ISBN1597269670, 9781597269674.

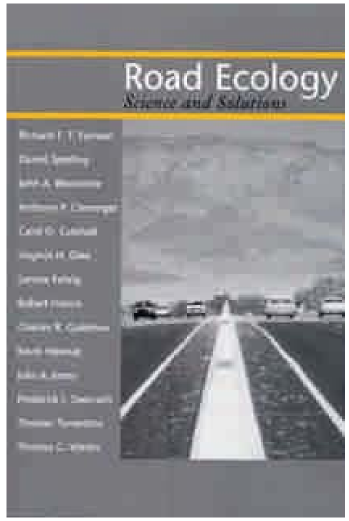
This book brings together the latest information on the emerging science of road ecology through detailed case studies spanning local site-specific interventions to state-wide planning for habitat connectivity, to national legislation. It deals with the importance of habitat connectivity in the context of roads and the current planning approaches and recent innovations aimed to mitigate road-related impacts.

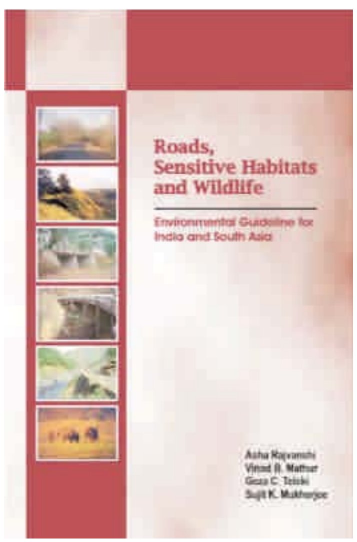
Road Ecology: Science and Solutions

-R. T. T. Forman et al., 2002.

Island Press, Washington, D.C. p481. ISBN 1559639334, 9781559639330.

In addition to laying the foundation of road ecology, the various chapters delve into the impacts of roads and transport infrastructure on vegetation, wildlife populations, water resources, aquatic ecosystems, wind, noise and atmosphere, and on the overall integrity of the landscape. The book also demonstrates, by example, the application of principles to mitigate ill-effects of roads on the environment.





Roads, Sensitive Habitats and Wildlife: Environmental Guideline for India and South Asia

- Rajvanshi, A., V. B. Mathur, G. C. Teleki and S. K. Mukherjee. 2001.

Wildlife Institute of India, Dehradun and Canadian Environmental Collaborative Ltd., Toronto. p215.

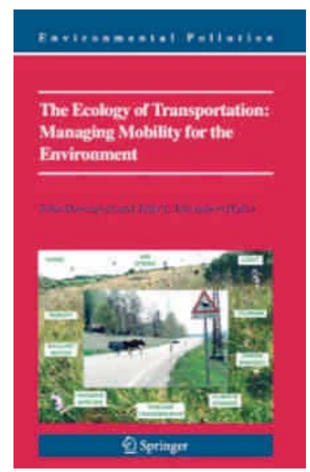
Apart from being one of the early comprehensive guides to the ecological impacts of roads in natural areas in India and South Asia, and their interactions, this book provides guidance on tools and methods to carry out environmental assessments of such projects. It also describes the prevalent institutional and legislative framework pertinent to road infrastructure. Case studies of roads and rails passing through sensitive areas in the Indian subcontinent are included, to drive home the importance of assessments of anticipated ecological impacts of such infrastructure on natural areas, and the need to formulate and adhere to solutions to these problems.

The Ecology of Transportation: Managing Mobility for the Environment

- Davenport, J. and J. L. Davenport. 2006.

Springer Science & Business Media, The Netherlands. p393. ISBN 1402045042, 9781402045042.

This book reviews ecological impacts of all forms of transport: road, rail, ship and air. The focus of the book ranges from identification of threats, amelioration of damaging effects, planning and design of transport systems, to minimisation of environmental degradation. With respect to terrestrial transportation systems *viz.*, road and rail, the book deals with mortality, habitat fragmentation and other impacts on wildlife such as the barrier effect. It also deals with methods to restore habitat connectivity across transport corridors by promoting strategic environmental assessments, ecological engineering and other sustainable transport designs.



GUIDANCE DOCUMENTS

Guidelines for Linear Infrastructure Intrusions in Natural Areas: Roads and Powerlines.
- National Board of Wildlife, Ministry of Environment and Forests, India. 2011.

http://envfor.nic.in/assets/FIRSTDraft%20guidelines%20roads%20and%20powerlines.pdf.

This document gives an "overall policy priority schema and framework of generic and specific guidelines for the creation, design, realignment, removal, restoration and maintenance and mitigation measures for roads and powerlines in defined natural areas of importance in the country".

Environmental Impact Assessment Guidance Manual for Highways.
- Administrative Staff College of India, Hyderabad. 2010.

Ministry of Environment and Forests, Government of India, New Delhi. http://envfor.nic.in/sites/default/files/highways-10_may_0.pdf.

This document consists of a chapter-wise description of how an EIA report for this sector should be structured. The manual is aimed to help a wide range of users such as the proponent, the environmental consultant, the regulatory authority and decision-makers, as well as the public and other stakeholders. In summary, it is a comprehensive guide on the environmental clearance process in the highways sector.

Wildlife Crossing Structures Handbook: Design and Evaluation in North America.
- Clevenger, A. P. and M. P. Huijser. 2011.

Report No. FHWA-CFL/TD-11-003. Western Transportation Institute, Bozeman, MT. http://roadecology.ucdavis.edu/files/content/projects/DOT-FHWA_Wildlife_Crossing_Structures_Handbook.pdf.

This handbook provides technical guidelines for the planning, design (for particular species or species groups in different landscapes) and evaluation of wildlife crossing structures and their associated measures (fencing, gates). It describes ways to increase the effectiveness of established designs, and can be used to design crossing structures for highway construction and road upgrading projects. Though intended for North American landscapes, the handbook provides detailed guidelines for impact identification, remediation, planning and placement of crossing structures, and other practical applications.

Banff Wildlife Crossings Project: Integrating Science and Education in Restoring Population Connectivity across Transportation Corridors.
- A. P. Clevenger, A. T. Ford and M. A. Sawaya. 2009.

Final report to Parks Canada Agency, Radium Hot Springs, British Columbia, Canada.p165.http://arc-solutions.org/wp-content/uploads/2012/03/Clevenger-et-al-2009-Banff-wildlife-crossings-project.pdf.

This publication highlights the success of science-based engineering solutions for creating crossing structures for the wildlife in the Banff National Park bisected by a major transportation corridor.

Guidelines on Mitigating the Impact of Linear Infrastructure and Related Disturbance on Mammals in Central Asia.
- Convention on Migratory Species (Wingard et al.). 2014.

UNEP/CMS/COP11/Doc.23.3.2. 11th Meeting of the Conference of the Parties. http://www.cms.int/sites/default/files/document/COP11_Doc_23_3_2_Infrastructure_Guidelines_Mammals_in_Central_Asia_E.pdf.

These guidelines delve into the legal frameworks available in Central Asian nations for mitigating the impacts of linear infrastructure on migratory species such as Asiatic and Tibetan wild ass, Tibetan gazelle, Argali etc. and the assessment, planning, design, mitigation principles, construction standards and monitoring and evaluation principles.

Review of Mitigation Measures Used to Deal with the Issue of Habitat Fragmentation by Major Linear Infrastructure.
- van der Ree, R., D. T. Clarkson, K. Holland, N. Gulle and M. Budden. 2008.

Report for Department of Environment, Water, Heritage and the Arts (DEWHA),Contract No. 025/2006, Published by DEWHA. https://www.environment.gov.au/system/files/resources/dbcf5e19-a1bc-4405-b497-fdcc7c05ab12/files/habitat-fragmentation.pdf.

In addition to information on the effects of linear infrastructure on wildlife and effectiveness of measures to mitigate habitat fragmentation, this guidance contains a review of cost-benefit analysis studies for these measures.

Identifying the Best Locations along Highways to Provide Safe Crossing Opportunities for Wildlife.
- Barnum, S. A. 2003. Colorado Department of Transportation Research.

Report No. CDOT-DTD-UCD-2003-9. http://arc-solutions.org/wp-content/uploads/2013/02/CDOT-DTD-UCD-2003-9-Barnum-20031.pdf.

This guidance summarises the ideal methods and techniques to identify crossing locations of wildlife for mitigation structures and other guidelines to create successful mitigation projects.

Interaction between Roadways and Wildlife Ecology: A Synthesis of Highway Practice.
- National Cooperative Highway Research Program. 2002.

Transportation Research Board of the National Academies, Washington D.C.http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_syn_305.pdf.

This guidance deals with topics such as the regulatory context in the transportation planning and development process, assessment and scale of impacts on wildlife ecology, analytical tools, and conservation measures and mitigation.

Design of Terrestrial Wildlife Crossing System: Nature Conservation Practice Note.
- Agriculture, Fisheries and Conservation Department, US, 2014.

Ref. AF GR CON 21/2. https://www.afcd.gov.hk/english/conservation/con_tech/files/NCPN_No.04_Wildlife_Underpass_Structures_v2006.pdf.

This is a technical guide for designing crossing structures for terrestrial wildlife. The note states that design considerations have been suggested from the ecological perspective and that the engineering requirements and practicability are to be determined on a case-by-case basis.

Ecology Guidelines for Transmission Projects: A Standard Approach to Ecological Assessment of High Voltage Transmission Projects.
- EirGrid. 2012.

EirGrid and Natura Environmental Consultants, Dublin, Ireland.

These guidelines developed by EirGrid (an independent electricity Transmission System Operator (TSO) based in Ireland) provide best practice guidance for ecological impact assessment for both flora and fauna in the planning and construction of high-voltage transmission projects.

Guidelines for Assessment of Ecological Impacts of National Roads Schemes.
- National Roads Authority, Ireland. 2009.

Ireland. http://www.tii.ie/technical-services/environment/planning/Guidelines-for-Assessment-of-Ecological-Impacts-of-National-Road-Schemes.pdf.

This document aims to provide guidance on the assessment of impacts on the natural environment during the planning and design of national road schemes.

Principles, Practices and Challenges for Green Infrastructure Projects in Latin America.
- Quintero, J. D. 2012.

Discussion paper no. IDB - DP – 250. Inter-American Development Bank. http://www19.iadb.org/intal/intalcdi/PE/2013/11428.pdf.

This document emphasises a multi-level approach to infrastructure development, in order to overcome the limitations of traditional project-by-project approaches. It promotes the development of smart, green infrastructure that would abate the long term impacts of habitat fragmentation and biodiversity loss caused by infrastructure in natural areas, with special reference to linear infrastructure.

Smart Green Infrastructure in Tiger Range Countries: A Multi-Level Approach.
- Quintero J., R. Roca,A. J. Morgan and A. Mathur. 2010.

Global Tiger Initiative, The World Bank, Washington, D.C. http://www.globaltigerinitiative.org/download/GTI-Smart-Green-Infrastructure-Technical-Paper.pdf.

Aimed at South and East Asian countries that have tiger populations, this document includes details of impacts of infrastructure development on tiger conservation landscapes, national and international policy options available to deal with infrastructure development, and cases of smart green infrastructure that have been developed in some of the tiger-range countries. The ultimate goal is to provide a sound basis for informed decision-making, and for infrastructure development plans to be integrated with national tiger conservation plans and policies.

Wildlife and Traffic: A European Handbook for Identifying Conflicts and Designing Solutions.
Iuell, B., et al. 2003.

European Co-operation in the Field of Scientific and Technical Research, Brussels.http://www.iene.info/wp-content/uploads/COST341_Handbook.pdf.

This manual describe the effects of infrastructure development on natural areas, especially with respect to fragmentation of natural areas. The handbook provides general advice on reducing the impacts of present, future and to-be-upgraded infrastructure. Guidance with respect to the assessment of such impacts, ecological compensation, and monitoring and evaluation of mitigation measures, is also provided.

Ecological Surveying Techniques for Protected Flora and Fauna during the Planning of National Road Schemes.
- National Roads Authority. 2009.

Ireland. http://www.tii.ie/technical-services/environment/planning/Ecological-Surveying-Techniques-for-Protected-Flora-and-Fauna-during-the-Planning-of-National-Road-Schemes.pdf.

This document provides comprehensive guidance for carrying out biological surveys for environmental assessments of road infrastructure. General guidelines for dealing with potential constraints, establishing baseline conditions and carrying out desk studies are provided. Group-specific guidelines, such as general surveying guidelines for plants, fungi, invertebrates, birds, reptiles, amphibians, mammals etc., are given, along with 'key cards' for common Irish species. These cards may be modified for Indian flora and fauna.

Safe Passage: A User's Guide to Developing Effective Highway Crossings for Carnivores and Other Wildlife.
- Reudiger, B. 2007.

Wildlife Consulting Resources, US. http://www.elkhornsloughctp.org/uploads/files/1182793716carnivoresafepassage.pdf.

This document provides a general account of the tools that can be used to plan connectivity projects: the different measures that can be taken to facilitate carnivore crossings, ranging from wildlife crossing signs for motorists to options of various crossing structures. Details of design considerations such as location, dimensions and species-specific considerations are also provided.

Wildlife Vehicle Collision Reduction Study: Best Practices Manual.
- Huijser, M. P. et al. 2008.

Report No.FHWA-HRT-08-034U.S. Department of Transportation. https://www.fhwa.dot.gov/publications/research/safety/08034/08034.pdf.

This report details the causes and impacts of wildlife-vehicle collisions, and explains the various mitigation options available to ensure the safe passage of animals and humans alike.

Roads in Rainforest: Best Practice Guidelines for Planning, Design and Management. Cairns, Queensland: Reef and Rainforest Research Centre Limited.
- Goosem, M. et al. 2010.

Australia. http://researchonline.jcu.edu.au/12113/1/goosem_guidelines.pdf.

These guidelines are aimed at planners, engineers and managers to inform them of the key ecological elements of rainforest environments that are unique, and thus require particular consideration when designing and constructing roads in these habitats.

Wildlife Crossings Guidance Manual.
- Meese, R. J., F. M. Shilling and J. F. Quinn. 2007.

Information Center for the Environment, Department of Environmental Science and Policy, University of California. Under contract to the California Department of Transportation, Environmental Division. http://roadecology.ucdavis.edu/files/content/projects/CA_Wildlife%20Crossings%20Guidance_Manual.pdf.

This manual presents case studies from California and elsewhere to illustrate guidance on tools to identify and assess wildlife crossings. It also includes a review of best practice and is aimed at enhancing efforts to evaluate and avoid, minimise or compensate for wildlife crossing conflicts.

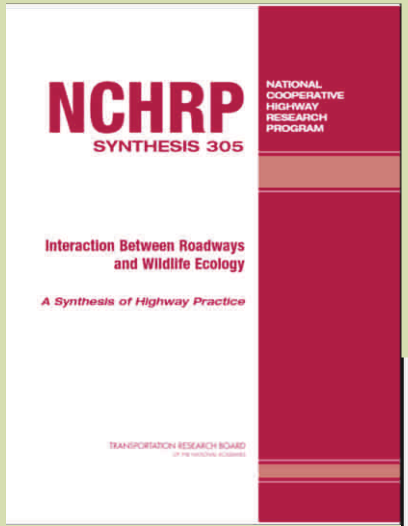
Best Practice Guidance for Biodiversity-inclusive Impact Assessment: A Manual for Practitioners and Reviewers in South Asia.
- Rajvanshi, A., V. B. Mathur and U. A. Iftikhar. 2012.

CBBIA-IAIA Guidance Series. Capacity Building in Biodiversity and Impact Assessment (CBBIA) Project, International Association for Impact Assessment (IAIA), North Dakota, U.S.A.

Prepared as part of the IAIA project on Capacity Building in Biodiversity and Impact Assessment, this manual provides best practice guidance with specific examples from five countries in South Asia and draws on the extensive experience of key experts in the field. The manual thus aims to provide practical information to assist planners and decision-makers in assessing the potential impacts of projects and policies on biodiversity, and the continued provision of ecosystem services.

Avian Protection Plan (APP) Guidelines.
- The Edison Electric Institute's Avian Power Line Interaction Committee (APLIC) and U.S. Fish and Wildlife Service (USFWS). 2005.
http://www.aplic.org/uploads/files/2634/APPguidelines_final-draft_Aprl2005.pdf.

This guidance document aims to help utilities devise an avian protection plan that would best fit their needs to reduce the operational and avian risks that result from avian interaction with electric utility facilities through guiding principles and examples.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A Synthesis of Highway Practice
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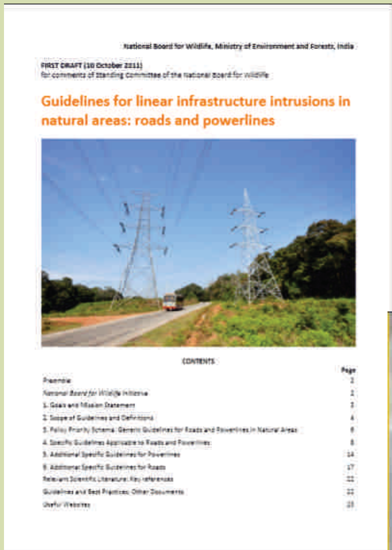
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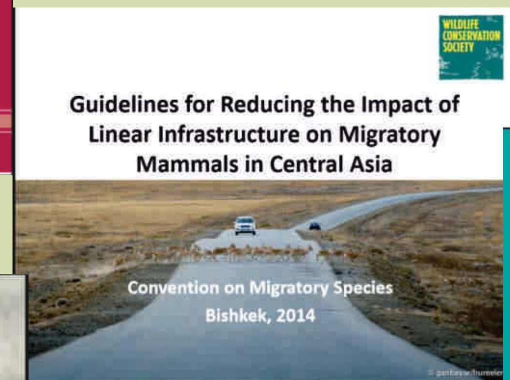
CONTENTS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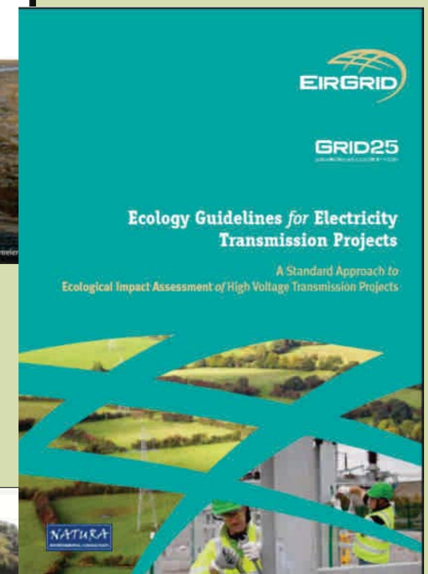
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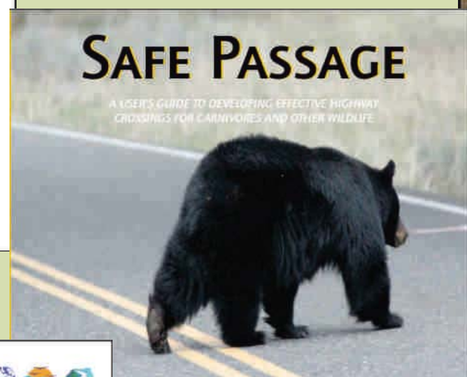
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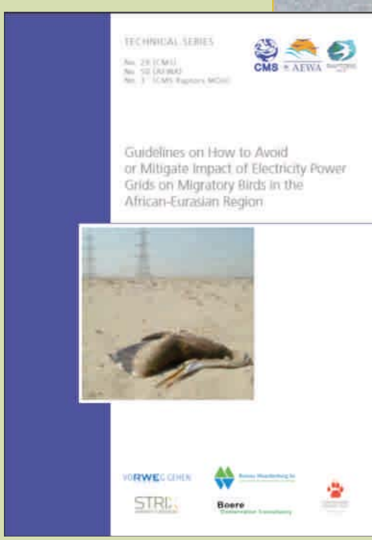
A USER'S GUIDE TO DEVELOPING EFFECTIVE HIGHWAY CROSSINGS FOR CARNIVORES AND OTHER WILDLIFE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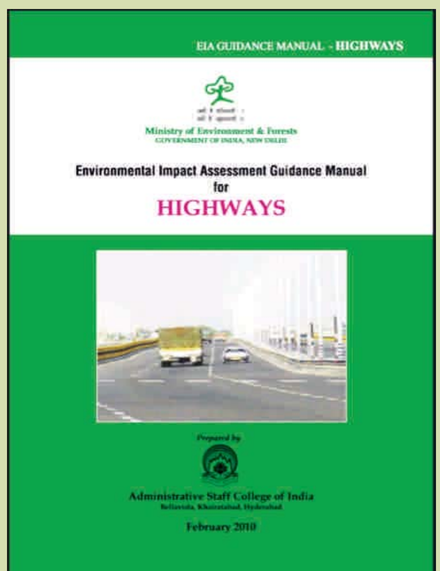
EIA GUIDANCE MANUAL - HIGHWAYS
Ministry of Environment & Forests
GOVERNMENT OF INDIA, NEW DELHI
Environmental Impact Assessment Guidance Manual for
HIGHWAYS
Prepared by
Administrative Staff College of India
February 2010


Australian Government
Final Report
REVIEW OF MITIGATION MEASURES USED TO DEAL WITH THE ISSUES OF HABITAT FRAGMENTATION
SMEC


Best practice guidance for biodiversity-inclusive impact assessment
A manual for practitioners and reviewers in South Asia
CBBIA - IAIA Guidance Series
Convention on the Conservation of Migratory Species of Wild Animals (CMS)
Guidelines for Addressing the Impact of Linear Infrastructure on Large Migratory Mammals in Central Asia
IDB
Principles, Practices, and Challenges for Green Infrastructure Projects in Latin America
Juan David Quintero
Inter-American Development Bank
VPS/ESG
DISCUSSION PAPER
No. IDB - DP - 250
November 2012
Juan D. Quintero
A Guide to Good Practices for Environmentally Friendly Roads
The Nature Conservancy
Latin America Conservation Council
Banff Wildlife Crossings Project: Integrating Science and Education in Restoring Population Connectivity Across Transportation Corridors
Prepared for:
Parks Canada Agency
Western Transportation Institute – Montana State University
Woodcock Foundation
Henry P. Kendall Foundation
Wilburforce Foundation
June 2009
Ecological Surveying Techniques for Protected Flora and Fauna during the Planning of National Road Schemes
NRA
Smart Green Infrastructure in Tiger Range Countries: A Multi-Level Approach
GTI Global Tiger Initiative
GTI-SGI Working Group
Suggested Practices for Avian Protection On Power Lines: The State of the Art in 2006
Report No. CDOT-DTD-UCD-2003-9
Final Report
IDENTIFYING THE BEST LOCATIONS ALONG HIGHWAYS TO PROVIDE SAFE CROSSING OPPORTUNITIES FOR WILDLIFE
Sarah A. Barnum
M.S., Wildlife Biology
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DOT
DEPARTMENT OF TRANSPORTATION
RESEARCH
August 2003
COLORADO DEPARTMENT OF TRANSPORTATION RESEARCH BRANCH

GLOSSARY OF ECOLOGICAL TERMS USED IN THE MANUAL

Abundance	The total number of species in a particular ecosystem
Age class	Individuals of a population in the same age range
Allee effect	The positive correlation between population density and individual fitness
Amphibian	Cold-blooded organisms that begin their lives in water and then adapt to live on land as adults
Animal trail	A path in the forest made by repetitive use or passage of animals
Arboreal	Meaning tree; related to animals that depend on trees to provide all or part of their life requirements
Auditory signal	A call or vocalisation for communication among animals
Barrier effect	The extent to which roads or other linear features prevent, or filter animal movement. The barrier effect can be quantified by species, populations and so on
Bask	Behaviour of exposing the body to the sun or warm surfaces to regulate body temperature exhibited by cold-blooded animals
Biodiversity	The variety of life at any given spatial scale including all the levels contained within, including genes, species, communities and ecosystems and their complex interactions
Biotic pressure	Pressures to an organism caused by other living organisms living in the same ecosystem and interacting with the affected organism
Bottleneck	Defined area (e.g. particularly narrow part of a habitat corridor) that, due to the presence of transport infrastructure or encroachment of other land use, has become a limiting factor to animal migration or dispersal
Breeding colony	A congregation of breeding individuals
Breeding	Reproduction
Buffer	Areas peripheral to a protected area where restrictions on resource use and special development measures are undertaken
Camera trapping	A method for capturing wild animals on film in absence of humans, the data is then used for ecological research
Canopy	Collection of above-ground individual plant crowns
Capture-mark-recapture	Method used in ecology to estimate population size, where animals are initially captured, marked in some way (e.g. leg band) and then re-sighted or re-captured at a later date. The ratio of marked versus unmarked individuals is used to estimate the size of the population
Carnivore:	Animal that feeds on meat of other animals
Carrying capacity	The maximum number of individuals of a given species that a given area's resources can sustain indefinitely without significantly depleting or degrading those resources
Connectivity	The degree to which a landscape facilitates or impedes movement among habitat patches. The concept of connectivity is used to describe

	how the spatial arrangement and quality of elements in the landscape affect the movement of organisms among habitat patches
Conspecific	Members of the same species
Core	Areas within protected areas free of all human activities, also referred to as 'inviolate' areas
Corridor	Components of the landscape that facilitate movement of organisms and continuation of ecological processes between areas of intact habitat
Crossing structure	A structure such as a pipe, culvert, bridge, underpass or overpass that provides a passageway for wildlife over or under a road/railway. Most traditional crossing structures are primarily intended to facilitate the flow of water
Crossing zones	Stretches of linear infrastructure frequently used by animals to cross from one side to the other
Cryptic	Organisms that avoid observation or detection by their prey or predators, through camouflage, mimicry or by being nocturnal
Critically Endangered	The most severe conservation status for wild populations on the IUCN's Red List
Culvert	Buried pipe or channel structure, that allows a watercourse and/ or road drainage to pass under a road or rail route
Density	Number of organisms of a species present within an area
Depredation	Raiding of crop fields by wild animals to eat crops
Diel cycle	A period of 24 hours
Dispersal	Ecological process that involves the movement of one or more individuals away from the population in which they were born to another location, or population, where they will settle and reproduce
Diurnal	Activity pattern where animals are active during the day
'Dog-leg' design	A course or way that turns at a sharp angle or has a sharp bend, especially a road or route that bends abruptly
Ecosystem service	Benefits such as goods and services, provided to society by ecosystems, for example production of food and water, control of climate and disease, nutrient cycles and pollination
Ecosystem	The community of living organisms (plants, animals, microbes) and non-living components of their environment (air, water, soil) interacting as a functional unit
Endangered	The second most severe conservation status for wild populations on the IUCN's Red List, after Critically Endangered
Endemic	An ecological state of a species being unique to a defined geographic location – either the particular country or a local area (narrow or local endemic)
Extinction	The end of organism or a group of organisms after the death of the last individual of the species
Fatality hotspot	Stretches along a road/railway line where maximum number of animal mortalities is concentrated

Faunal passage	Measure installed to enable animals to cross over or under a road, rail or canal passageway: without coming into contact with the traffic
'Flight or fight' response	A physiological response to a perceived harmful attack or threat to survival wherein the animal either fights or flees
Fire regime	Pattern, frequency and intensity of wildfires that prevail in an area
Foraging	Searching for wild food resources
Furniture	Logs, branches, rocks and other enrichment structures placed in wildlife crossing structures to provide shelter and/or protection from predators
Gene flow	The transfer of alleles or genes from one population to another
Genetic drift	Change in frequency of an allele in a population due to random sampling
Genetic viability	The ability of a population to have a realistic chance of avoiding the problems of inbreeding and persisting in the long term by having a certain amount of genetic diversity and a certain minimum number of members
Gliders	Animals that manage to travel through the air by gliding from great heights, or leaping from the depths.
Gliding	Mode of locomotion where an animal leaps or drops from high locations such as trees and covers great horizontal distances due to aerodynamic force to reach a landing surface (typically another tree)
Granivorous	Animals feeding on the seeds or grains of plants
Green infrastructure	Infrastructure that is designed and developed by considering conservation values and actions in concert with land development, growth management and built infrastructure planning
Habitat degradation	Process of change in the characteristics of an area that renders it functionally unable to support the species present
Habitat fragmentation	Process by which habitat loss results in the division of large, continuous habitats into smaller, more isolated remnants
Habitat matrix	A combination of 'non-habitat' and range of native habitat areas, or a portion of a landscape where habitat patches and corridors are embedded in a wider mix of land uses
Habitat	An area, usually consisting of predominantly native vegetation that is inhabited by a particular species
Herbaceous vegetation	Vegetation composed mostly of herbs (plants which have no persistent woody stem above ground)
Herpetofauna	The reptiles and amphibians of a particular region, habitat or geographical period
Home range	The area in which an animal lives and accesses for normal daily activities such as food gathering, obtaining shelter, mating and caring for offspring
Important Bird Area	An area recognised as being globally important habitat for the conservation of bird populations
Inbreeding depression	Reduced biological fitness in a given population as a result of inbreeding, or breeding of related individuals
Invasive species	Plants, animals or pathogens that are non-native to an ecosystem and whose introduction is likely to cause harm to, or oust, native species
Invertebrates	Animals that do not possess or develop a vertebral column; e.g. insects, snails, worms
IUCN Red List	A comprehensive inventory of the global conservation status of biological species
Landscape ecology	The study of the pattern and interaction between ecosystems within a region, and the way these interactions affect ecological processes
Landscape permeability	The quality of a landscape that allows organisms to move freely across it

Landscape	A heterogeneous land area composed of a cluster of interacting ecosystems that creates a specific, recognisable pattern
Leaf litter	Dead plant material such as leaves, twigs and barks that have fallen on the ground
Linear infrastructure	Structures such as roads, railway lines, power transmission lines and canals that cause linear breaks in an otherwise contiguous and connected landscape
Long-ranging species	Animals that tend to cover great distances
Mark-capture-recapture	A method commonly used in ecology to estimate a uniquely marked animal's population size. The 'mark' may be natural—like stripes in tigers, or human-made—like colour tags on birds
Mega-herbivore	A large, plant-eating animal (e.g. elephant)
Meta-population	Set of local populations of a species that are spatially separated within some larger area, but which interact at some level. Genetic diversity is maintained by the dispersal of individuals from one local population to another
Meta-population dynamics	The study of the interactions between meta-populations
Migration	Journey undertaken by some species in response to changing seasons or climatic events, such as rainfall
Migratory birds	Birds that exhibit regular seasonal movement, often north and south along a flyway, between breeding and wintering grounds
Minimum viable population	A lower bound on the population of a species such that it can survive in the wild
Mitigation	Action to avoid or prevent, reduce or minimise the severity of, or compensate for an adverse impact
Nest box	A man-made enclosure provided for animals such as birds and small mammals to nest in
Nest or roosting substrate	The base upon which a nest is built or on which birds rest and sleep, e.g. power poles, platforms, boxes and latticework in electricity masts
Nesting	Behaviour of animals such as birds to build nests near the breeding season
Nocturnal	Activity pattern of animals such as bats and fireflies that are active during the night
NTFP	Non-Timber Forest Products like fruits, flowers, leaves, seeds, gums, fibres, oils
Perch	Act of resting on elevated places such as trees or poles by birds
Pheromones	Hormones secreted by animals for communication and other signals
Physiology	Study of how organs and other systems of the body function
PIT tags	Passive Integrated Transponder is an electronic tag to track and detect animals
Poaching	Illegal hunting or killing of wild animals to obtain animal products
Population isolation	Seclusion of a group of organisms as a result of little genetic mixing with other organisms due to physical, geographical or other barriers
Population viability	The probability that a population will persist in the long term or within a given number of years, with given environmental conditions (or go extinct)
Population	Total of all individuals of a species living in a particular area that have the capability to interbreed. It represents a functional group of individuals that interbreed within a given, often arbitrarily chosen, area
Precautionary Principle	A principle to guide decision-making in the absence of scientific certainty, which states that precautionary measures should be taken when an activity may harm human health or the environment, and that measures should reflect precaution (i.e. be risk-averse). Typically, the proponent for an activity must prove that it will not cause harm

Predator	An animal that naturally preys on other animals
Prey	An animal that is hunted or killed by another for food
Protected area	A clearly defined geographical space recognised, dedicated and managed to achieve long-term conservation of nature
Radio telemetry	Involves monitoring radio signals sent from a device attached to an animal to track its movements
Rail or railway corridor	A linear tract of land (right-of-way) through which a railway passes. It includes the area of land immediately influenced by the railway in terms of noise, visual, hydrological and atmospheric impacts: typically an area 50 to 100 m from the edge of the road
Raptor	A bird of prey that hunts other animals
Rare	Species that are uncommon, scarce or infrequently encountered
Right-of-way	The entire width of the reserved strip of land on which the linear infrastructure is built.
Road Corridor	Linear surface used by vehicles plus any associated verges (usually vegetated). It includes the area of land immediately influenced by the road in terms of noise, visual, hydrological and atmospheric impacts: typically an area 50 to 100 m from the edge of the road
Road verge	The vegetated area adjacent to roads; generally located outside the road shoulder
Roadkill	Animals that have died as a result of collision with vehicles or trains
Rodents	Mammals of the order Rodentia characterised by a single pair of incisors in each of the upper and lower jaws
Roost	To settle or congregate for rest or sleep
Runoff	Flow of water on the earth's surface that occurs as a result of precipitation. Excessive runoff may lead to erosion of soil
Salt-lick	A place where animals go to lick essential mineral nutrients from a deposit of salts
Scat	Faeces of a carnivorous animal
Scavenger	An animal that feeds on dead organisms rather than—or in addition to—hunting live prey
Sign survey	Visual assessment and documentation of visual clues of animal presence and activity such as faeces and foot marks
Smart infrastructure	Comparable to 'green infrastructure', it refers to infrastructure that has been located and designed to foster sustainable development, taking into account biodiversity conservation issues along with other social, economic and health factors
Source-sink dynamics	A theoretical model used by ecologists to describe how variation in habitat quality may affect the population growth and decline of organisms
Species diversity	A measure of the diversity within an ecological community incorporating both species richness and evenness of species abundance
Species range	The geographical area where a particular species can be found during its lifetime and includes areas where individuals or communities may migrate or hibernate
Sustainable development	Development that meets the needs of the present without compromising the ability of future generations to meet their own needs
Target species	The species or group of species intended to benefit from proposed mitigation
Taxa	Taxon (pl. taxa) is a group of one or more populations of an organism or organisms considered by taxonomists to form a unit
Terrestrial	Pertaining to the land or earth

Territory	An area defended by an organism or a group of similar organisms for mating, nesting, roosting, feeding or breeding
Thermoregulation	Ability of an organism to maintain its internal temperature within certain boundaries, even when ambient environmental temperatures are different
Tiger reserve	A protected area considered significant for protecting tigers and their habitat
Track beds	An artificial surface of fine sand, plaster of Paris, or other fine material laid to track animal movement
Tunnelling effect	The effect by which animal movement through an underpass or tunnel is hampered due to a narrow or constricted view across the structure
UNESCO World Heritage Site	An area specifically designated under the United Nations Educational, Scientific and Cultural Organisation (UNESCO) Convention as being of special cultural significance
Ungulates	Animals with hooves (an enlarged toenail) e.g. sambar, spotted deer
Vertebrates	Animals with a vertebral column
VIE tags	Visible Implant Elastomer tags are biocompatible materials that are used to mark animals such as amphibians by injecting into the animal's tissue
Volant	Animals that are able to glide or fly
Water hole	A depression in the ground in which water can collect
Wetland	Lands that are transitional between terrestrial and aquatic systems where the water table is usually at or near the surface, or the land is periodically covered with shallow water. They generally contain plant communities that are adapted to periodic inundation
Wildlife community	An assemblage of plant and animal populations living in a particular habitat and interacting with each other
Wildlife conservation	Practice of protecting and managing wild plant and animal species and their habitats, to ensure their persistence in the long term
Wildlife overpass	Physical structure built over road or rail infrastructure in order to connect the habitats on either side. The surface is at least partly covered with soil or other natural material that allows the establishment of vegetation
Wildlife underpass	Physical structure situated underneath linear infrastructure in order to connect the habitats on either side. The surface is at least partly covered with soil or natural material that allows the establishment of vegetation
Wing span	The distance from one wing tip to the other

Animal groups	General animals considered (specific to India)
Large carnivores	Asiatic lion, Bengal tiger, common leopard
	Striped hyena, grey wolf, golden jackal, wild dog, sloth bear
Large herbivores	Asian elephant, gaur, greater one-horned rhinoceros
Medium-sized mammals	Ungulates: sambar, spotted deer, nilgai, wild boar
	Primates: rhesus macaque, northern plains langur
Small mammals	Jungle cat, leopard cat, common palm civet, ruddy mongoose
Amphibians	Toads, frogs, salamanders
Reptiles	Snakes, lizards, turtles, tortoises

PLATES

Large carnivores

Asiatic lion | Mohamed Zahir

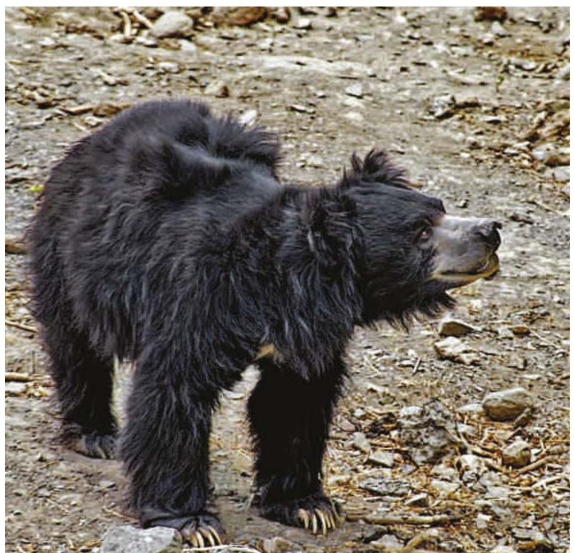
Common leopard | Srikaanth Sekar/Flickr

Bengal tiger | Paul Mannix
http://www.flickr.com/photos/paulmannix/464048079/sizes/l/in/set-72157600089897078/

Grey wolf | Bilal Habib

Striped hyena | Dr. Shamshad Alam, Department of Wildlife Sciences, Aligarh Muslim University

Golden jackal | CL Pramod
Own work, CC BY-SA 4.0, https://commons.wikimedia.org/w/index.php?curid=45840849



Sloth bear | Mohamed Zahir

Wild dog | Kalyan Varma http://en.wikipedia.org/wiki/Image:Wilddog_brt.jpg

Large herbivores

Asian elephant | http://www.flickr.com/photos/wribs/837038964/in/set-72157603351082588/

Greater one-horned rhinoceros | Mohamed Zahir

Gaur | Bilal Habib

Medium sized mammals: Ungulates:

Spotted deer
http://flickr.com/photos/97235261@N00/3494400556

Nilgai | en:Image:Nilgai female and baby.jpg, uploaded by en:User:Vyzasatya

Sambar | Joseph Lazer

Primates:

Langur | Mohamed Zahir

Rhesus macaque | Thomas Schoch http://www.retas.de/thomas/travel/india2007/index.html

Small mammals:

Ruddy mongoose | Kalyanvarma (Own work) [CC BY-SA 3.0 (httpcreativecommons.orglicensesby-sa3.0)], via Wikimedia Commons

Leopard cat | Der Irbis - http://de.wikipedia.org/wiki/Bild:Bengalkatze.jpg

Amphibians:

Common Asian toad | Abhijit Das

Indian bull frog | Abhijit Das

Reptiles:


Burmese rock python | Abhijit Das


Indian garden lizard | Abhijit Das


Indian black turtle | Abhijit Das


Pope's pit viper | Abhijit Das


Indian leaf turtle | Abhijit Das

Birds:

Lesser flamingo | Rupal Vaidya

Eastern imperial eagle | Rupal Vaidya

Common crane | Rupal Vaidya

These guidelines are an excellent resource that can be used to ensure the linear infrastructure that is built today is as environmentally friendly as possible. “Smart green infrastructure” has the potential to transform the way that infrastructure is planned, designed, constructed and managed, and these guidelines are a critical first step in that process. The guidelines address issues at all stages of a project, with particular emphasis on design options to reduce rates of collision between vehicles and wildlife and maintain the movement of wildlife across the infrastructure.

These are the first guidelines of this nature for south-east Asia and I am sure will be an important guiding document for the region.

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Australian Research Centre for Urban Ecology
Royal Botanic Gardens Victoria
University of Melbourne, Australia

This practice guidance gives detailed recommendations for the appropriate design of roads and railway lines, complemented with useful photographs and illustrations; apart from generic measures, special sections of the document are dedicated to the design of linear infrastructure in elephant and tiger habitats.

The guidance document is well written, the language is easy to understand, and the proposed mitigation measures should be both practicable and cost-effective to implement. Of particular importance, it makes reference to emerging technologies and approaches which may become mainstream in future, providing pointers to young planners and engineers.

It is hoped that these guidelines will become standard good practice to linear infrastructure planners, helping to ensure that through better location and design, as well as ongoing 'learning by doing', the future of India's wildlife will be ensured whilst simultaneously minimising health and safety risks to people.

Susie Brownlie
Independent Consultant
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