Thesis for the Degree of Master of Science in Environmental Science and Management

Assessment of the impacts of linear infrastructure on wildlife connectivity and to identify the mitigation measures to safeguard wildlife in Tiger Range Habitats of Nepal

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February, 2024

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Supervised by Asst. Prof. Praveen Kumar Regmi

A thesis submitted in partial fulfilment of the requirements for the degree of Master of Science in Environmental Science and Management

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DEDICATION

I would like to dedicate this thesis to my wife Ila Nepal who encouraged and motivated me to earn this degree while rearing our three kids. We have seen a lot of highs and lows in our life together where I started this Master's degree course when We already had two children the eldest one – Shuvansh, and Hrishikesh Dev Neupane. Later, during my third semester, We had our third child, a lady this time- Trishprisha. I could never have been so much motivated to earn this degree should you not have left your job and managed my life Ila. I am very much thankful to you, Buwa Ratnamani Nepal and Aama Piyush Nepal who selflessly supported me to earn this respectful degree.

DECLARATION

I hereby declare that this study entitled **Assessment of the impacts of linear infrastructure on wildlife connectivity and to identify the mitigation measures to safeguard wildlife in Tiger Range Habitats of Nepal** is based on my original research work. Related works on the topic by other researchers have been duly acknowledged. I owe all the liabilities relating to the accuracy and authenticity of the data and any other information included hereunder.

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LETTER OF RECOMMENDATION

This is to certify that this thesis entitled **Assessment of the impacts of linear infrastructure on wildlife connectivity and to identify the mitigation measures to safeguard wildlife in Tiger Range Habitats of Nepal** prepared and submitted by **Pramod Neupane**, in partial fulfillment of the requirements of the degree of Master of Science (M.Sc.) in Environmental Science and Management awarded by Pokhara University, has been completed under my/our supervision. I recommend the same for acceptance by Pokhara University.

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CERTIFICATE

This thesis entitled **Assessment of the impact of linear infrastructure on wildlife connectivity and to identify the mitigation measures to safeguard wildlife in Tiger Range Habitats of Nepal** prepared and submitted by **Pramod Neupane** has been examined by us and is accepted for the award of the degree of Master of Science (M.Sc.) in Environmental Science and Management by Pokhara University.

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LETTER OF APPROVAL

This Thesis submitted by Pramod Neupane entitled **The Impacts of Linear Infrastructure on Wildlife Connectivity and Probable Mitigation Measures to Safeguard Safe Dispersal of Wildlife in Tiger Range Habitats of Nepal** has been accepted for the partial fulfillment of Master of Science in Environmental Management from Pokhara University.

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ABBREVIATIONS

BaNP	Banke National Park
BBA	Biodiversity Baseline Assessment
BNP	Bardiya National Park
BZ	Buffer Zone
CFUG	Community Forest User Group
CNP	Chitwan National Park
DNPWC	Department of National Parks and Wildlife Conservation
DoFSC	Department of Forests and Soil Conservation
DoR	Department of Roads
DoRW	Department of Railways
DoWRI	Department of Water Resources and Irrigation
EN	Endangered, IUCN Red list Category of Faunal species
Ha	Hectare (equal to 10,000 square meters)
LPR	Living Planet Report – A flagship publication of WWF on planetary health
MoFE	Ministry of Forests and Environment
MoPIT	Ministry of Physical Infrastructure and Transport
NT	Nearly threatened, IUCN Red list Category of Faunal species
PA	Protected Area
PNP	Parsa National Park
SASEC	South Asia Sub-Regional Economic Cooperation
SAR	Search and Rescue
ShNP	Shuklaphanta National Park

TRH	Tiger Range Habitats
VU	Vulnerable, IUCN Red list Category of Faunal species
WFICD	Wildlife Friendly Infrastructure Construction Directives
WVC	Wildlife Vehicle Collision

ABSTRACT

Nepal is home to some of the world's most diverse and endangered wildlife, including the Bengal tiger, one horned rhinoceros, Asian Elephants, Snow Leopards and many other species. Nepal's conservation success has enabled it to gain major achievements in the conservation of floral and faunal biodiversity in Nepal, however the developmental demand of the nation is escalated like never before. The rapid development of linear infrastructure, such as roads, railways irrigation canals and transmission lines in the country's tiger range habitats especially at Chitwan-Parsa complex is threatening the survival and connectivity of these species. This study attempted to find out the impacts of Linear Infrastructure especially Roadways in Tiger Range Habitat (TRH) of Nepal starting from Parsa National Park to Shuktaphanta National Park(Parsa district to Kanchnapur district).The construction of such infrastructure can fragment habitat and disrupt the movement of wildlife, leading to reduced genetic exchange and increased vulnerability to extinction. Roadkill data from 5 tiger bearing PAs were collected and road kills hotspot analysis was done. The results of the analysis showed a concentrated scenario of road kills at particular patches within road sections contributing to the scenario of the need of wildlife friendly mitigation measures including wildlife overpass, underpass and their associated structures to minimize the impacts of highways on wildlife.

Therefore, it is important to understand the impacts of linear infrastructure on wildlife connectivity and to identify and implement effective mitigation measures to safeguard these species. This thesis is aimed at understanding the status of wildlife friendly infrastructure and predict the basic requirements of the sizes of crossing structures for safe passage of wildlife.

Keywords: *Linear Infrastructure, Wildlife Friendly Infrastructure, Wildlife Crossing Structure, Safe Passage*

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CHAPTER 1

1. INTRODUCTION

Linear infrastructure refers to the physical structures and networks that are designed in a linear (in a line for a long distance) or elongated manner to facilitate the movement of people, goods, energy, or information from one location to another. Linear infrastructure typically follows a specific path or corridor and includes various types of transportation and utility systems. These infrastructures play a crucial role in connecting regions, supporting economic activities, and enabling the functioning of modern societies.

The major stakes of linear infrastructure for Nepal which have higher impacts on Natural Resources Management are namely Roads and Highways, Railways, Irrigation Canals and Transmission lines. Each of these linear infrastructures are defined below;

1.1. HIGHWAYS: Networks of roadways that provide routes for vehicular transportation, connecting cities, towns, and rural areas are included in this section. On top of this, the major highways in Nepal – mainly East-West and North-South Highways which connects the most vibrant market centres as well as crosses through biodiversity rich areas and hotspots are included in this category. The total length of strategic highways is 14,913 km (Statistics of National Highway, DoR, 2020/21).

Mahendra Highway (1028 Km) is the oldest East-West highway in Nepal which was operational since 1980's and is the lifeline of the country's economic transformation. It is also a part of South Asia Sub-Regional Economic Cooperation (SASEC) which connects South Asian countries through highway link. Postal highway (1795 km), Nepal's oldest walking trail used by postmen to commute East to West also known as Hulaki Rajmarga connects Nepal's border cities in South with India. Proposed Madan Bhandari highway follows East-West trajectory and follows a parallel path to Mahendra highway connecting northern cities in the Churiya landscape. Pushpalal or Mid hill highway (1776 km) connects Nepal's mid-hills from East to West. There are 15 North-South highways that connects through China's border up North to the Indian border down South through various parts of the country.

1.2. RAILWAYS: Railway is a system of tracks and stations that allow for the movement of trains, transporting passengers and freight over long distances. The idea of introducing railways in Nepal was first proposed during the Rana regime in the early 20th century. In 1927, a preliminary survey for a railway line from Raxaul, India to Kathmandu was conducted. However, due to various challenges, including financial constraints and political instability, the project did not materialize.

The first railway service in Nepal was begun in 1927 AD with a length of 48 km between Amalekhagunj (Nepal) to Raxaul (India) which was closed in 1960 AD. A second railway service was begun in 1937 AD connecting Jayanagar in India to Janakpur and Bijalpura in Nepal with the length of 51 km.

As Railway service is reliable, less expensive and more comfortable than other modes of transportation, the development and expansion of our country's railway network, as well as connecting it to the railway networks of neighbouring countries is significant to our country's economic development. To achieve the goal, Nepal Government recognized the necessity to create a permanent organization structure to help in policy formulation, development and expansion of railway infrastructure and provide suggestions on railway services operation. Subsequently, Nepal Government established the Department of Railways (DoRW) under the Ministry of Physical Infrastructure and Transport (MoPIT) on 2068/03/01 (B.S).

Janakpur-Jaynagar Railway is the only currently operational railway route in Nepal. In 1937, a narrow-gauge railway line was constructed between Janakpur in Nepal and Jaynagar in India, spanning a distance of around 29 kilometers. The Janakpur-Jaynagar Railway served as a cross-border link, primarily for transportation of goods and passengers between Nepal and India.

The Fifteenth Five Year Plan’s mid-term review (FY 2076/77-78/79) has mentioned that among 69 km of Janakpur-Bardibas railway section, Janakpur-Kurtha section of 35 km has been completed. Kurtha-Bijalpura section will be finalized soon while as among 18 km Bathnaha-Biratnagar railway section, 10 km section has been completed. Likewise, Nepal’s flagship railway project of East-West Electrified railway (1056) km’s Detailed Project Report has been completed. Within the Bardibas-Nijgadh section of 70 km,

trackbed construction works has been completed for 52.5 km along with 5 bridges construction works has been accomplished. Similarly, the detailed studies for Birgunj-Kathmandu, Rasuwagadhi-Kathmandu, Kathmandu-Pokhara-Lumbini railway sections are under way. More details can be accessed here t.ly/s3xBk Page no. 102

1.3. IRRIGATION CANALS: Irrigation canals are man-made canals constructed for agriculture purpose in a large scale to irrigate water scarce areas. Irrigation canals have significantly contributed to increased agricultural productivity, enabling farmers to cultivate crops throughout the year, even in areas with limited rainfall. They have played a crucial role in food security and economic development in Nepal.

Despite there are multiple irrigation projects, four of them which are located within the Western TAL are of major importance to biodiversity conservation;

1.3.1. Mahakali Irrigation Project: Mahakali Irrigation Project, located in Kanchanpur district of Sudur Paschim Province. The total command area of Mahakali Irrigation Project through all its three phases is almost 45000 Ha. The project initiation year was 2006 while the expected project completion date is 2030. The total cost of the project is expected to be NPR 350 million. (Source: A brief introduction to National Pride Projects, NPC)

1.3.2. Rani Jamara Kulariya Irrigation Project (RJKIP): RJKIP is a multi-purpose irrigation project which utilizes the water from Karnali river in Chisapani to irrigate 38,300 Ha. of agricultural land in Kanchanpur district in Sudur Paschim province while producing 4.71 MW of electricity from the kinetic energy of water flowing through the canal. The revised estimate of the project cost is NRs 277 million which is already operational after 2023. The current irrigation capacity of RJKIP as per the existing masterplan is for 20,300 Ha. while the design and construction of the rest 18,000 Ha. is planned for the next stage of the project extension phase.

1.3.3. Babai Irrigation Project (BIP): BIP is Nepal's first irrigation project whose study was initiated since 1967. BIP irrigates 36,000 Ha. of agricultural land in Bardiya, Lumbini Province. While BIP is an operational project since long back, the revised date of planned completion of project activities is 2025. The revised cost of the project executed is estimated to be NRs 189.63 million.

Sikta Irrigation Project (SIP): SIP is located in Banke district in Lumbini Province which is expected to irrigate 42,766 Ha. of agriculture land. The revised estimated cost of construction of this project is NRs 250.2 million whereas the expected date of completion is 2027 AD.

Table 1: Irrigation Infrastructure Projects' Canals crossing through PAs and Wildlife Corridors in Western TAL

Irrigation Canals through PAs and Corridors				
S.N.	**Protected Areas**	**Length (Km)**	**Wildlife Corridors**	**Length (Km)**
1	Shuklaphanta NP	30	Karnali Corridor	18.89
2	Shuklaphanta BZ	95	Laljhadi Corridor	70.95
3	Bardia NP	3	Brahmadev Corridor	1.71
4	Bardia BZ	44	Khata Corridor	6.18
5	Banke NP	2.28	Kamdi Corridor	149.2
6	Banke BZ	8.68		
	Total PAS	**182.96**	**Total Corridors**	**246.93**
	Total Length (Km)	**429.89**		

1.4. TRANSMISSION LINES: Transmission lines, also known as power lines or electrical lines, are infrastructure systems used to transport electricity over long distances from power plants to distribution networks or directly to consumers. These lines consist of conductors, usually made of aluminium or copper, supported by towers or poles.

The purpose of Transmission lines is to transmit high-voltage electricity efficiently and reliably over long distances. They form the backbone of the electrical grid, connecting power generation sources, such as coal-fired power plants, hydroelectricity, wind farms, or solar power plants, to substations and distribution networks.

Transmission lines play a crucial role in delivering electricity to homes, businesses, and industries. They are an essential component of the electrical infrastructure, enabling the efficient and reliable transmission of power across long distances, facilitating regional grid integration, and supporting the growth of renewable energy sources.

Transmission lines operate at high voltages, typically ranging from 69 kilovolts (kV) to several hundreds of kilovolts, depending on the distance and power capacity required. Most common high voltage transmission lines in Nepal are 132kV, 220 kV and 400 kV. High-voltage transmission helps reduce energy losses during long-distance transmission, as lower currents are needed for a given amount of power. Transmission lines carry alternating current (AC) electricity. AC is preferred for long-distance transmission due to its ability to be easily stepped up or down in voltage using transformers. This facilitates efficient transmission over different voltage levels and reduces losses.

1.4.1. Overhead Lines: The most common type of transmission lines are overhead lines, where the conductors are mounted on towers or poles. These lines are visible as the familiar network of power lines running across landscapes. Overhead lines are cost-effective, easily expandable, and provide easy access for maintenance and repairs.

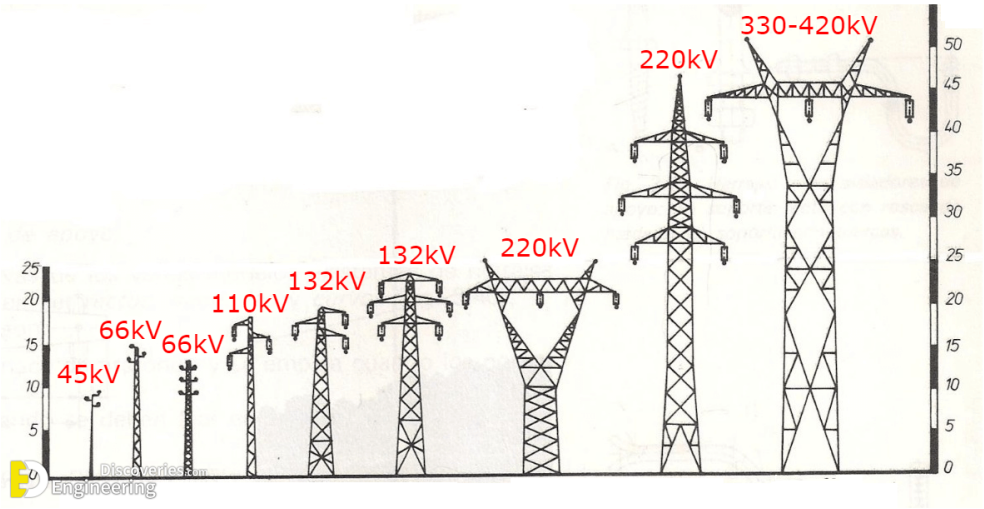

Figure 1: Types of typical transmission lines as per high voltage transmission requirements (Source: Civil Engineering discoveries t.ly/tT0hy)

1.4.2. Underground Lines: In some cases, transmission lines are installed underground, particularly in urban areas or environmentally sensitive locations. Underground cables are more expensive to install but offer advantages such as reduced visual impact, lower transmission losses, and reduced vulnerability to weather-related disruptions.

The construction and operation of transmission lines can have environmental impacts, such as habitat disruption, visual intrusion, hazard to migratory birds' species and

electromagnetic field emissions. Environmental assessments and mitigation measures are often undertaken to minimize these impacts and ensure compliance with regulations and best practices.

1.5. WILDLIFE HABITAT:

A habitat refers to the natural environment or specific place where a particular species of plant or animal lives and thrives. It is characterized by a combination of physical factors, such as climate, soil type, water availability, and vegetation, which collectively provide the necessary conditions for the species to survive, reproduce, and fulfil its ecological role.

Habitats can vary greatly in size, ranging from small microhabitats like the underside of a leaf to large-scale ecosystems like a tropical rainforest or a coral reef. Each habitat has its own unique set of characteristics and supports a specific community of organisms adapted to those conditions.

Habitats are essential for the survival and biodiversity of species. They provide resources such as food, water, shelter, and breeding sites, and they shape the distribution and abundance of organisms in an ecosystem. Protecting and conserving habitats is crucial for maintaining healthy ecosystems, preserving biodiversity, and ensuring the long-term survival of species.

Some common types of habitats include:

1.5.1. Terrestrial Habitats: These habitats occur on land and include forests, grasslands, deserts, tundra, wetlands, and more. Each terrestrial habitat has distinct features, such as temperature, precipitation, vegetation types, and soil characteristics, which influence the types of plants and animals that can thrive there.

1.5.2. Aquatic Habitats: Aquatic habitats encompass various bodies of water such as oceans, rivers, lakes, ponds, and wetlands. Aquatic habitats can be classified into marine (saltwater) or freshwater habitats. They vary in temperature, salinity, current flow, and nutrient levels, supporting a diverse range of aquatic organisms adapted to these conditions.

1.5.3. Coastal Habitats: Coastal habitats occur where land and sea meet, including beaches, estuaries, mangrove forests, salt marshes, and rocky shores. These habitats are

influenced by a combination of marine and terrestrial factors, such as tides, wave action, salinity, and coastal vegetation, creating unique and dynamic ecosystems that support a variety of plant and animal species.

1.5.4. Subterranean Habitats: Subterranean habitats refer to environments found beneath the ground, including caves, underground rivers, and soil ecosystems. These habitats are characterized by low light levels, high humidity, and specific soil conditions. Organisms adapted to these habitats often have specialized adaptations for surviving in darkness and limited resources.

1.5.5. Aerial Habitats: Aerial habitats are found in the air column above the Earth's surface and include habitats such as the canopy of forests, the airspace above grasslands, and the upper atmospheric layers. Aerial habitats are inhabited by birds, insects, bats, and other flying organisms that have adaptations for flight and survival in the air.

1.6. TIGER RANGE HABITATS OF NEPAL:

Nepal is home to several important tiger range habitats, primarily located in its southern lowland Terai region and extending into the surrounding hills and forests. These habitats provide critical support for the survival of the Bengal tiger (Panthera *tigris tigris*), which is the subspecies of tiger found in Nepal. Tigers' population is distributed over 5 National Parks and its periphery in the lower belt of Terai. The tiger population in these parks have shown a promising increase in the last decade complementing Nepal to meet the doubling tiger population target, an international commitment to the world back in 2009 in St. Petersburg, Russia among the tiger range countries.

The graph below shows the historic number of tiger populations in all 5 PAs which are the Tiger Range Habitats (TRH) of Nepal. All 5 PAs have shown a incremental trend of tiger numbers which is the result of combined efforts of multiple agencies including authorities, security forces, conservation partners, Community living in the fringes of the PAs among others.

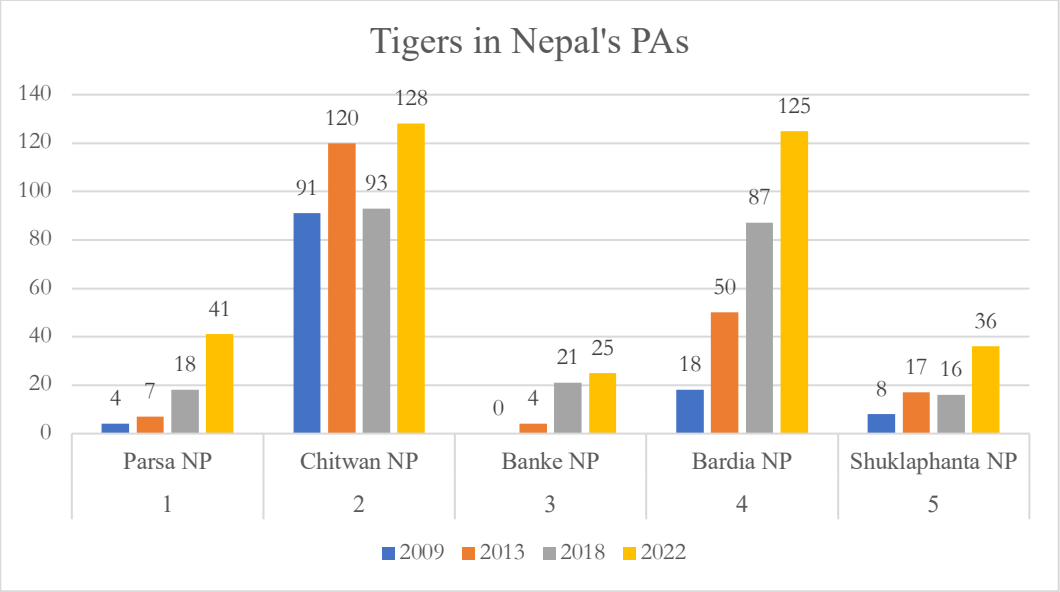

Figure 2: Tigers Population in Nepal in Tiger bearing PAs

{Source: Department of National Parks and Wildlife Conservation (DNPWC)}

1.6.1. Chitwan National Park (CNP): One of the most renowned tiger habitats in Nepal, Chitwan National Park is located in the subtropical lowlands of the Terai region. It is Nepal's first national park and a UNESCO World Heritage Site. Chitwan is known for its diverse wildlife, including a healthy population of Bengal tigers. As per the 2022 Tiger Census, CNP has 128 tigers which is the highest number of Tigers in any PAs.

1.6.2. Bardiya National Park (BNP): Situated in the western Terai region of Nepal, Bardiya National Park is the second biggest tiger habitat. It offers a range of habitats, including riverine forests, grasslands, and sal forests, providing suitable conditions for tigers and their prey. BNP has 125 tigers (Tiger Census, 2022).

1.6.3. Suklaphanta National Park (ShNP): Located in the far-western Terai region, ShNP is known for its grasslands and wetlands. While it is primarily recognized for its population of swamp deer (Barasingha), it also supports tigers and other carnivores. Tiger Census, 2022 showed a total of 36 tigers in ShNP.

1.6.4. Parsa National Park (PNP): Established relatively recently in 2017, Parsa National Park lies adjacent to Chitwan National Park and serves as an important corridor for wildlife movement between Nepal and India. It is home to tigers, leopards, wild elephants, and various other species.

1.6.5. Banke National Park (BaNP): BaNP is situated in the mid-western Terai region, was established to protect the habitat of Bengal tigers and other wildlife. It features a mosaic of grasslands, riverine forests, and woodlands.

These protected areas, along with other forested landscapes and buffer zones surrounding them, form crucial tiger habitats in Nepal. Conservation efforts in these areas focus on habitat protection, anti-poaching measures, community engagement, and research to monitor tiger populations and their prey. Through these initiatives, Nepal aims to ensure the long-term survival and well-being of its tiger populations.

1.7. WILDLIFE CONNECTIVITY:

Wildlife connectivity refers to the ability of wildlife populations to move freely across landscapes, without being obstructed by human-made barriers such as roads, fences, or urban development. It's a crucial aspect of conservation biology because it allows animals to access essential resources like food, water, mates, and suitable habitats, thereby maintaining genetic diversity and enabling population resilience.

Several factors that influence wildlife connectivity are;

1.7.1. Habitat fragmentation: When natural habitats are divided into smaller patches by human activities, such as roads, agriculture, or urbanization, it can impede the movement of wildlife between these patches.

1.7.2. Land use planning: Proper land use planning can help mitigate habitat fragmentation by preserving corridors or creating wildlife-friendly infrastructure like wildlife crossings or green bridges.

1.7.3. Natural barriers: Rivers, mountains, and other natural features can act as barriers to wildlife movement. However, maintaining connectivity across these barriers is essential for maintaining healthy populations.

1.7.4. Human infrastructure: Roads, highways, fences, and other human-made structures can disrupt wildlife movement patterns. Wildlife crossings, such as bridges or tunnels, are designed to mitigate these barriers and allow animals to safely traverse otherwise dangerous areas.

1.7.5. Ecological corridors: These are strips of habitat that connect larger areas of habitat. They can be natural features like rivers or man-made corridors like wildlife overpasses or underpasses.

1.8. ENHANCING WILDLIFE CONNECTIVITY

Efforts to enhance wildlife connectivity to maintain safe dispersal of wildlife in its habitat include:

1.8.1. Creating wildlife corridors: These are strips of natural habitat that connect larger areas of habitat, allowing animals to move between fragmented habitats.

1.8.2. Implementing wildlife crossings: These structures, such as wildlife overpasses, underpasses, or tunnels, provide safe passage for animals across roads or other barriers.

1.8.3. Conserving and restoring habitat: Protecting and restoring natural habitats is essential for maintaining wildlife connectivity.

1.8.4. Policy and planning: Incorporating wildlife connectivity considerations into land use planning and transportation infrastructure development can help mitigate negative impacts on wildlife populations.

1.9. WILDLIFE VEHICLE COLLISIONS (WVC):

Direct mortality from transportation infrastructure has been recognized as a serious and growing threat to wildlife populations across the globe, as well as contributing to human injuries, deaths, and property loss (Meijer *et al.*, 2018). Annually in the USA, wildlife-vehicle collisions on highways cause 200 human deaths and 30,000 injuries, and economic impact exceeds $8 billion USD/year (Huijser and Clevenger, 2007). On highways, it is estimated that 1 million vertebrates are killed each day in the USA (Foreman and Deblinger 2000), and as many as 340 million birds die in wildlife-vehicle collisions each year (Loss *et al.*, 2014).

All taxa of wildlife are affected by WVC-related mortality; amphibians and reptiles are most susceptible to road mortality, even at low traffic volumes (Fahrig and Rytwinski, 2009).

Nepal records almost 130-150 WVC incidents annually resulting into the death of wildlife (DNPWC Reports) and moderate to severe impacts to the passengers travelling on

Mahendra highway through PAs. Although the economic analysis of such wildlife and human casualties are almost never analyzed, such incidents result into uncountable human lives and economic losses.

1.9.1. WILDLIFE-FRIENDLY LINEAR INFRASTRUCTURE (WFLI):

Wildlife-friendly linear infrastructure refers to transportation or utility corridors that are designed and managed in a way that minimizes their impact on wildlife and promotes ecological connectivity.

Traditionally, linear infrastructure has posed significant challenges to wildlife populations. These structures can fragment habitats, disrupt migration routes, and create barriers to movement for many species. They can also lead to increased wildlife mortality due to collisions with vehicles or infrastructure, electrocution from power lines, or habitat loss.

To address these issues, wildlife-friendly linear infrastructure aims to incorporate measures that mitigate the negative impacts on wildlife and enhance ecological connectivity. Some of the key principles and practices of wildlife-friendly linear infrastructure include:

1.9.1.1. Habitat conservation and restoration: The design and planning of linear infrastructure projects should consider the preservation and restoration of wildlife habitat along the corridor. This can include maintaining or creating green spaces, wildlife corridors, and vegetation buffers that provide suitable habitat and promote movement for wildlife.

1.9.1.2. Wildlife crossings: Constructing wildlife crossings, such as wildlife overpasses or underpasses, can enable animals to safely navigate across roads, railways, or other linear structures. These crossings are designed to mimic natural habitat and reduce the risk of wildlife-vehicle collisions.

1.9.1.3. Fencing and exclusion measures: Strategic placement of wildlife fencing can guide animals to use designated crossings and discourage them from accessing areas where they may be at risk. Fencing can be combined with exclusion measures, such as culverts or fencing with jump-outs, to prevent wildlife from entering hazardous areas.

1.9.1.4. Monitoring and research: Regular monitoring of wildlife populations and their movements can provide valuable data to assess the effectiveness of wildlife-friendly

infrastructure measures. Research can help identify optimal design strategies and improve existing practices.

1.9.1.5. **Collaboration and partnerships**: Collaboration between infrastructure developers, environmental organizations, government agencies, and local communities is crucial to successfully implement wildlife-friendly linear infrastructure. By working together, stakeholders can share expertise, resources, and ensure the long-term viability of wildlife conservation efforts.

1.9.1.6. **Consideration of other environmental factors:** Wildlife-friendly linear infrastructure should also consider other environmental factors, such as minimizing light pollution, noise pollution, and pollution from runoff or spills that may affect wildlife populations.

1.10. BACKGROUND

Backed by political stability, Nepal advances towards attaining its target to improvise its status of Least developed country to middle-income country (MIC) by 2030 (National Planning Commision, 2016). To meet this visionary dream, there is an urge for intense infrastructure development in Nepal. However, Intense prioritization for infrastructure development overlooks their impacts on natural wellbeing. Despite having standard procedures and protocols of Environmental assessments during project planning, swift need for infrastructures often hustles with project execution ahead of environmental assessments. This trend will be detrimental for conservation in a long term.

With national priority on widening existing highways, introducing new highways along east-west and north-south territories, initiation of Mechi-Mahakali electrified railways, exploring potentials on hydropower production, transmission lines across Nepalese territory in the form of National and feeder grids, irrigation canals along fertile land of Terai will impose inevitable pressure on wildlife ecology throughout the Nepalese territory.

Forest degradation, habitat fragmentation, barrier effect, wildlife vehicle collision (WVC), drowning are the major impacts of Linear infrastructures on wildlife. Increased accessibility to wildlife habitat due to intrusion of linear infrastructures promotes unhealthy competition between human and wildlife.

This study tries to assess the current status wildlife connectivity in Terai Arc Landscape (TAL) in Nepal which is home to mega-fauna species including Asian Elephants, Greater One Horned Rhinoceros, Bengal Tiger among other multiple faunal species being fragmented by multiple series of linear infrastructure including Roads, Railways, Transmission lines and Irrigation canals. As linear infrastructure evades through critical wildlife biodiversity hotspots including protected areas system and wildlife corridors, this study tries to assess the impact of linear infrastructure on wildlife connectivity and probable mitigation measures to safeguard wildlife in Tiger Range Habitats of Nepal.

This study will be focused on the studies conducted in various stretches of TAL regarding the impacts of linear infrastructure on wildlife mobility within PAs and beyond PAs across wildlife corridors. The impacts of Highways among other linear infrastructure will be dealt in this research regarding the studies conducted so far in this sector considering the impacts on wildlife mobility together with the mitigation measures devised to help wildlife cross these linear infrastructures.

1.11. STATEMENT OF THE PROBLEM

The rapid development of linear infrastructure, such as roads, railways, and transmission lines, in the tiger range habitats of Nepal has raised concerns about its negative impact on wildlife connectivity and the subsequent implications for wildlife conservation. This issue demands urgent attention and investigation to identify the extent of the problem and develop effective mitigation measures.

The expansion of linear infrastructure has resulted in habitat fragmentation and disruption of wildlife corridors, hindering the movement of wildlife species, including tigers and other endangered species. Fragmentation poses a significant threat to the long-term survival and genetic diversity of wildlife populations, leading to increased vulnerability to poaching, reduced access to essential resources like food and water, and a higher risk of human-wildlife conflicts.

Furthermore, the construction and operation of linear infrastructure often entail environmental disturbances, such as deforestation, soil erosion, noise pollution, and increased human presence in previously undisturbed areas. These disturbances can have far-reaching ecological

consequences, including changes in animal behavior, disruption of breeding patterns, and loss of habitat connectivity critical for wildlife movement.

The lack of adequate research and data on the impact of linear infrastructure on wildlife connectivity in tiger range habitats of Nepal exacerbates the problem. Without a comprehensive understanding of the scale and nature of the issue, it becomes challenging to develop targeted and effective mitigation measures. This knowledge gap hinders the development of sustainable infrastructure planning and decision-making processes that balance economic development with wildlife conservation goals.

1.12. RESEARCH QUESTIONS:

The research question set for this assessment are;

1. What is the status of Linear Infrastructure development in TRH of Nepal?
2. What are the hotspots of wildlife road kills in TRH of Nepal?
3. What are the mitigation measures to safeguard the wildlife in context of LI in TRH of Nepal?

1.13. OBJECTIVES:

The main objective of this thesis is to assess the impacts of linear infrastructure on wildlife connectivity and to identify the mitigation measures to safeguard wildlife in Tiger Range Habitats of Nepal.

The specific objectives include;

1. To document the status of linear infrastructure development scenario in TRH of Nepal.
2. To analyze the hotspots of wildlife road kills in TRH of Nepal.
3. To identify the mitigation measures to safeguard wildlife in TRH of Nepal.

1.14. RATIONALE OF THE STUDY

Linear infrastructure development is a major threat to wildlife connectivity and the survival of endangered species in Tiger Range Habitats (TRH) of Nepal. It is therefore important to understand the impacts of such development and to identify and implement effective mitigation measures to safeguard these species. The proposed research aims to contribute to this effort by

assessing the impact of linear infrastructure on wildlife connectivity and by identifying and evaluating probable mitigation measures to safeguard.

This study will contribute to the understanding of the impact of linear infrastructure on wildlife connectivity in TRHs of Nepal and provide practical recommendations for safeguarding wildlife in these areas. The findings of this study will be relevant not only to Nepal but also to other countries with similar conservation challenges.

1.15. LIMITATIONS OF THE STUDY:

The limitations of the study are;

1. The study has only focused in details about the tiger species impacted by Linear Infrastructure.
2. This study does not highlight the impacts of LI other than highways.
3. The wildlife road kills data from various PAs had limited GPS coordinates.

CHAPTER 2

2. LITERATURE REVIEW:

2.1. GLOBAL INFRASTRUCTURE DEVELOPMENT CONTEXT:

The global context of infrastructure development predicts a total of 25 million km of new paved roads to be anticipated by 2050. (Laurance *et al.*, 2014). By this statement, a rationale can be derived that 75% of the built infrastructure that will be in place in 2050 does not exist today. The scenario is that 90% of this infrastructure will be constructed in the developing nations.

By 2050, nearly 24,000 km of new roads are to be built in Asia's Tiger Conservation landscapes. Experts have predicted that the road – construction spree in Asia could mean the end of the road for Tigers. (Carter *et al.*, 2020)

2.2. GLOBAL SCENARIO OF BIODIVERSITY DECLINE:

The Living Planet Report (WWF, 2022) shows that there is a decline of populations of mammals, birds, fish, reptiles, and amphibians have on average declined by 60% between 1970 and 2014. The Earth is estimated to have lost about half of its shallow water corals in the past 30 years. A fifth of the Amazon has disappeared in just 50 years. Globally, nature provides services worth around $125 trillion a year, while also helping ensure the supply of fresh air, clean water, food, energy, medicines and much more.

2.3. NEPAL'S CURRENT STATUS IN BIODIVERSITY CONSERVATION:

Nepal is uniquely located at a juncture of two geographic realms – the Palaearctic and the Indo-Malayan realm which provides it with an opportunity of a unique biodiverse region with rich species diversity. Further to it, as Nepal is the world's most altitudinal varied country with its lowest point of 56 masl and highest point of 8848.86 masl, it is home to iconic flagship wildlife species including Bengal Tiger (Panthera *tigris*), Asian Elephants (Elephas *maximus*), Snow Leopard (Panthera *uncia*), Greater One horned rhinoceros (Rhinoceros *unicornis)* and many other iconic flagship species to prey species.

A total of 44.74% of the total land area of Nepal is under Forest cover. Whereas, a total of 23.39% of the total area is under protected area (PA) system. Despite the global trend of decline

in Biodiversity Conservation, Nepal is actually being able to demonstrate the best of conservation practice when it comes to biodiversity conservation. (WWF Nepal, 2019)

2.4. NEPAL'S INFRASTRUCTURE DEVELOPMENT PRIORITY:

Government of Nepal is motivated towards upgrading the existing East-West and constructing and upgrading North-South highways across Nepal to meet the infrastructural needs. 15th Five Year plan by National Planning Commission (NPC, 2019) envisions the increase in road length in Nepal by 18,000 Km by 2100 B.S. This motivation will bring out economic benefits to the country while it will also have sustained impacts on natural resources mainly biodiversity.

4 East-West Highways have been envisioned including the existing 2 lane Mahendra Highway (1028 km) being upgraded to 4 lanes, Mid hill (Pushpalal) highway (1776 km) being explored on a full fledge will increase connectivity within hills of Nepal and Madan Bhandari Lok Marga (1225 km) envisioned to traverse through the foothills of Churiya ranges will increase connectivity therein. The Postal highway (1792 km) will connect Bhadrapur in the East to Dodhara in the Far West. One of Nepal's transformatory project of Mechi-Mahakali electrified railway (1205 km) will further enhance Nepalese' ability and productivity. Roadways and Railways will undoubtedly contribute towards increased connectivity of people ultimately contributing towards prosperous Nepal.

Table 2: Indicative representation of GoN's achievement until 14th plan and target for 15th plan for infrastructure development (Source: NPC)

SN	Description	14th plan Achievement (FY 2073/74- 2075/76)	15th plan Target (FY 2076/77- 2080/81)
1	Road Development (km) National Highway blacktopping	6,979.00	15,000.00
2	Railway line (km)	42.00	112.00
3	Hydropower production (MW)	1020.00	5,000.00

National priority for infrastructure development is currently focused in widening existing highways as well as introducing new ones along the East-West and North-South territories;

alongside initiation of the Mechi-Mahakali electrified railways, and exploration of potential hydropower projects and transmission lines across the Nepalese territory; and irrigation canals, along the conservation hotspots of Terai Arc Landscape. Needless to say, all these large infrastructures impose inevitable pressure on wildlife bionomics throughout Nepal as planned infrastructure cut through national forests, corridors and core protected areas. (Carter *et al.*, 2023) With more developmental activities on board, the environmental impacts associated within will certainly be on rise. With federalism, state and local governments have been empowered with resources which have been exploited to maximum limit increasing the accessibility of infrastructure development in local level.

Nepal envisions to create a network of basic infrastructure required to ease lives and generate employment opportunities. Hydropower being one of very high potential green source of energy, Nepal's priority for clean and green energy of 5000 MW by 2023 is a generous target, yet the impacts it imposes on river basins should be closely monitored and impacts reduced.

Statistics of Local Road Network (SLRN) published by (DoLIDAR, 2016) shows that among 57,632 km local roads in Nepal, almost 74.3% of the roads is earthen and cannot serve during all weather conditions. These roads have enormous environmental hazards and could trigger dry and wet landslides, and cannot withstand climate change impacts, thus results in detrimental impacts on natural wellbeing. The focus now should not be to increase the length of the roads but to increase the quality and standards of existing roads to benefit societies.

2.5. EXISTING POLICY AND INSTITUTIONAL MEASURES

Government of Nepal is dedicated in delivering environment friendly measures to standardize infrastructure development. Environment protection is a minimal mandatory requisite for infrastructure development, yet the environment assessments which is a mandatory provision needs to be standardized and a duly follow up mechanism of such endorsed assessments should be put into practice to achieve sustainable development practices.

The constitution of Nepal signifies for the formulation of acts, bylaws, policy, standards and guidelines which favors environment protection whereas, being a signatory of Multilateral Environment Agreements (MEAs) and international processes like SDGs, Paris Agreement etc. GoN commits for promotion of environment protection at federal, state and local levels. Other stakeholders like private sectors, bilateral aids, special Government to Government

agreements like Belt and Road Initiatives (BRI) and Millennium Challenge Corporation (MCC), and multilateral agencies like World Bank, Asian Development Bank among others contribute towards development of infrastructure in Nepal who are equally concerned about environmental priorities.

Local governments have been empowered with substantial budget for infrastructure development where a mandatory biodiversity conservation act was required. This has been recently formulated and is being endorsed at local levels. Similar strategies will be followed for state levels.

'Wildlife Friendly Infrastructure Construction Directives, 2022 (WFICD)' prepared in coordination by Department of Roads (DoR) involving various stakeholders' ministries and departments is now under endorsement process which shall further lay pathways for linear infrastructure development in Nepal. Conservation has emerged as a must agenda even within development fraternity which obviously is a positive aspect because of which new guidelines, protocols and laws shall emerge according to the need in future.

2.5.1. WILDLIFE FRIENDLY INFRASTRUCTURE CONSTRUCTION DIRECTIVES (WFICD), 2022:

WFICD is a policy statute endorsed by Government of Nepal for the promotion of Wildlife friendly approaches for the development of linear infrastructure. The details of the directives is provided in Annex 2.

2.5.2. MOBILITY OF TIGERS IN PARSA AND BARDIA NATIONAL PARK

This was the first systematic research on tigers in Nepal using radiotelemetry or GPS tracking data since the 1980s. It was found that the highway more strongly constrained the space use and habitat selection of the male tiger in Parsa National Park than the female in Bardia National Park. Over the entire study period, the female on average crossed 10 times more often per week than the male, and when he was near the highway, he was over 11 times more probable to not cross it than to cross during the day. However, it was also found that the cessation of traffic during the pandemic lockdown relaxed tiger avoidance of roads and made the highway more permeable for both animals. They were 2–3 times more probable to cross the highway during the lockdown than before the lockdown. In the month following the lockdown, the space use

area of the male tiger tripled in size (160–550 km^2), whereas the female's shrunk to half its previous size (33–15 km^2).

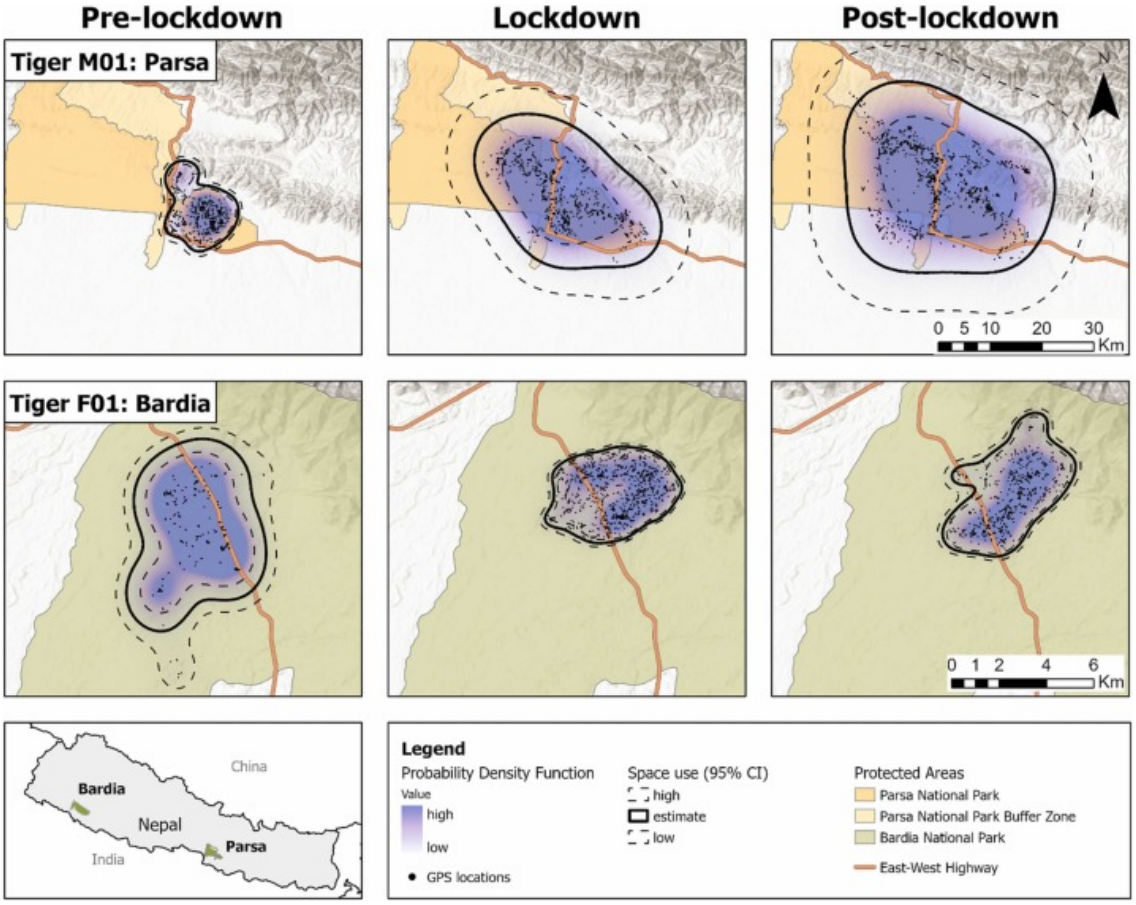

Figure 3: Individual tiger space use areas in Bardia National Park (western Nepal) and Parsa National Park (central Nepal) during each COVID policy period (pre-lockdown, during lockdown, and post-lockdown). Space use areas and utilization probability density function were modeled using area-corrected Autocorrelated Kernel Density Estimation (OUF anisotropic model). The solid black outline represents the estimate and the dashed lines represent the low and high 95% confidence intervals. Source: (Carter *et al.*, 2023)

2.5.3. MITIGATION MEASURES

The impacts on natural well-being and wildlife due to growing infrastructure is on high attention recently. Development and Conservation stakeholders have now begun communicating on ways to reduce these impacts to promote sustainable green infrastructure which would benefit both human and wildlife. As a result of this, a "Wildlife Friendly Linear

Infrastructure" guideline has been prepared and forwarded for endorsement which shall have a longer-term positive direction to infrastructure developers in the country to account for wildlife conservation in Nepal.

Strict Environmental scrutiny should be the basic requirement for any infrastructure development. By duly following the recommendations of environment assessments, implementation of mitigative actions is a must. Besides, hierarchical module of Sustainable green infrastructure i.e. Avoidance of critical biological hotspots at first, introducing mitigation/minimization measures and compensation should be duly followed.

Figure 4: Wildlife underpass constructed at Aaptari of Narayanghat-Muglin highway section in Barandabhar Forest Corridor (Source: Pramod Neupane)

Mitigation measures constructed for the safe movement of wildlife across linear infrastructures, be it Nepal's first wildlife underpasses in Narayanghat-Muglin road have resulted in better safe passage of wildlife across the highway structure. (Use and Effectiveness of Wildlife Crossing Structures in Nepal, WWF Nepal, 2019). 15 mammal species have been found using the wildlife crossing structures – 4 underpasses in Aaptari and Ramnagar sections of Narayanghat-Muglin

highway crossing through Barandabhar Forest Corridor. The underpasses are constructed together with the guiding fences – 150 meters either side to facilitate funneling of wildlife towards the crossing structure.

These measures have been proven successful in reducing wildlife casualties due to vehicle wildlife collision. However, there is even more need of replication of successful interventions and research-based promotion of new technologies to empower development practices in Nepal.

CHAPTER 3

3. MATERIALS AND METHOD

3.1. STUDY AREA:

The study area of this research is the entire area of Terai Arc Landscape (TAL) in Nepal with major focus on highway infrastructure crossing through the TRH in 5 PAs and wildlife corridors. TAL is a transboundary landscape with India where the area of TAL in Nepal covers a vast area of 24,710 sq. km with a network of six protected areas, forests, agricultural lands and wetlands, with over six million people depending on its forests for food, fuel, and medicine. The total length covered during the research period includes a total of 682 km length along the East-West (Mahendra Highway) between Parsa NP in the East to Gaddachauki in the Far West region.

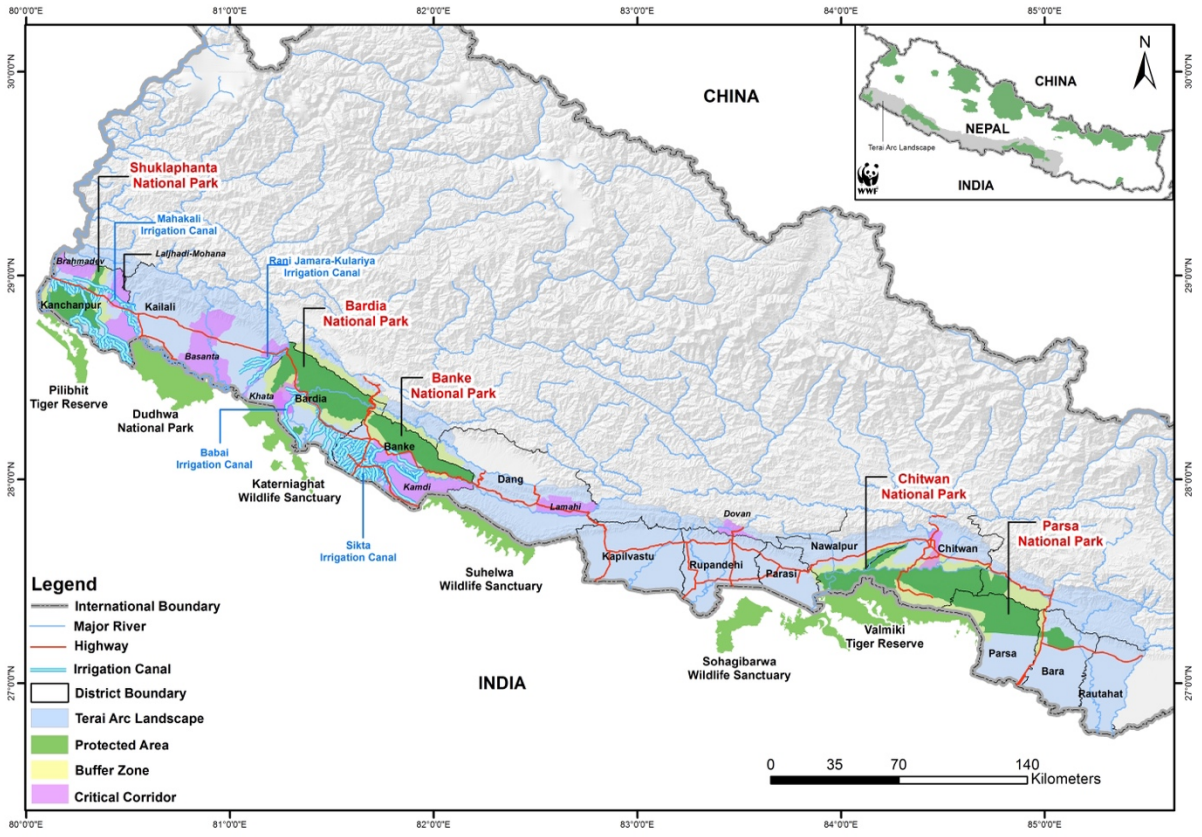

Figure 5: Map of Terai Arc Landscape showing TRHs in 5 PAs and Mahendra Highway (Source: WWF Nepal)

3.2. RESEARCH DESIGN

The research design adopted for this thesis is as shown below;

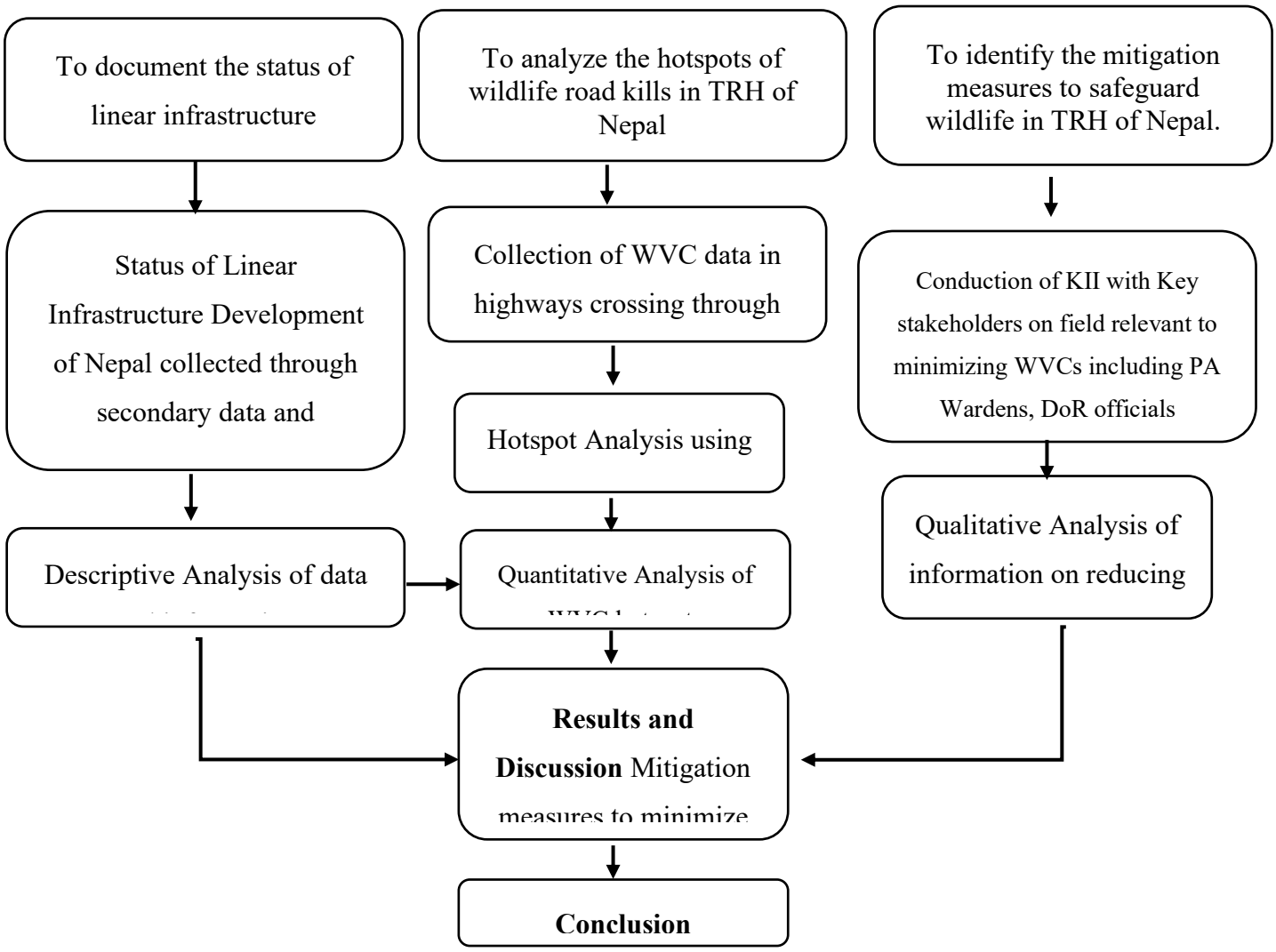

Figure 6: Flow chart of Research design

3.3. OBJECTIVE WISE RESEARCH MATRIX

Table 3: Objective wise research matrix

Objectives	Data needs	Data collection method	Data Analysis method	Expected outcomes
To document the status of linear infrastructure development scenario in TRH	Location data, stocktaking of information	Secondary data sources, literature review	Descriptive analysis, Comparison with conservation impacts	Status of highway sections through PAs
To analyze the hotspots of wildlife road kills in TRH of Nepal	GPS locations of Wildlife vehicle collisions	Collection through publications, Excel sheets	GIS Mapping of data sources	Hotspots of WVCs
To identify the mitigation measures to safeguard wildlife in TRH of Nepal.	Qualitative data	Literature Review, Key Informant Interviews (KIIs)	MS Excel	Crossing structures for minimizing impacts on Wildlife

3.4. SAMPLING TECHNIQUE:

The research was done on a full-length coverage strategy, thus not a sampling technique was just engaged. For this, all 4 PAs of TRH were visited and KII was done with respective Wardens of all PAs. Then the information and data obtained during the field trip study were collected and analyzed.

The primary data regarding the road kills as observed during the travel have been collected by the researcher during the road travel through-out 680 km of Mahendra highway section crossing through 4 PAs in TRH.

3.5. RESEARCH METHOD

Both Primary and Secondary data collected during the research period were used for in the research.

3.5.1. PRIMARY DATA COLLECTION:

During the course of field visit, various road kills of multiple wildlife, domestic and stray animals were captured and collected. Various other data and information during the field visit were also collected. The Key Informant Interviews (KIIs) were conducted with various authorities including park officials, field staffs of Department of Roads, Nepal Army officials who are engaged in recording data, rescue and rehabilitation of wildlife involved in WVCs. The KII format and authorities consulted during KIIs together with the questions for KII format is provided in the annex section.

3.5.2. SECONDARY DATA COLLECTION:

The secondary data were collected for the research using the publications, national reports, research documents and journal articles. The GPS locations of the road kills as a result of WVCs were collected from all 4 PAs within the study area. A decade long data (2012-2022) of road kills due to WVC were collected. The linear Highway and other linear infrastructure data were collected from DoR, DoWRI, DoRW and NEA websites.

3.5.3. DATA ANALYSIS

Data analysis was done using GIS mapping tool using ARC GIS Version 10.8. The decade long data on WVCs in Mahendra highway crossing through 4 PAs were plotted on maps to generate hotspot maps. These maps produce sensitive maps indicating the locations of frequent road kills which needs mitigation measures to minimize the impacts for the safe dispersal of wildlife.

CHAPTER 4

4. RESULTS AND DISCUSSION:

4.1. INFRASTRUCTURE STATUS IN TRH

4.1.1. East-West Highway (Mahendra) Highway through Protected Areas of Nepal:

Mahendra highway crosses through 4 among 5 tiger bearing PAs where individual length of highway section crossing through PAs are listed in the table below. It does not directly cross through Chitwan National Park (CNP), rather delineates through the buffer zone for a length of 23 KM in the west of Narayanghat towards Nawalparasi. A total of 160 km of Mahendra highway crosses through the core and buffer zone of these Protected Areas (PAs).

Table 4: Mahendra highway crossing through PAs in Terai Arc Landscape

S.N.	Mahendra Highway through PAs	Length (Km)	Remarks
1	Parsa NP	20	Amlekhgunj-Pathlaiya, Dudhaura-Eastern extension
2	Banke NP	105	Mahendra and Ratna Highway
3	Bardiya NP	31	Karnali-Amreni, Rambhapur-Sainabar
4	Shuklaphanta NP	4	Arjuni-Champapur
	Total	**160**	**Km**

4.1.2. CURRENT STATUS OF WVC IN NEPAL

In FY 2079/80 (FY 2023) alone, 558 unnatural wildlife deaths were recorded nationally, of which road kills contributed to 25%. Mainly the deaths recorded in VWC are of prey bases including deers, wild boars and other middle-sized herbivores. An analysis demonstrates that tigers face a ubiquitous and mounting threat from road networks across much of their 13-country range. (Neil et. al., 2019).

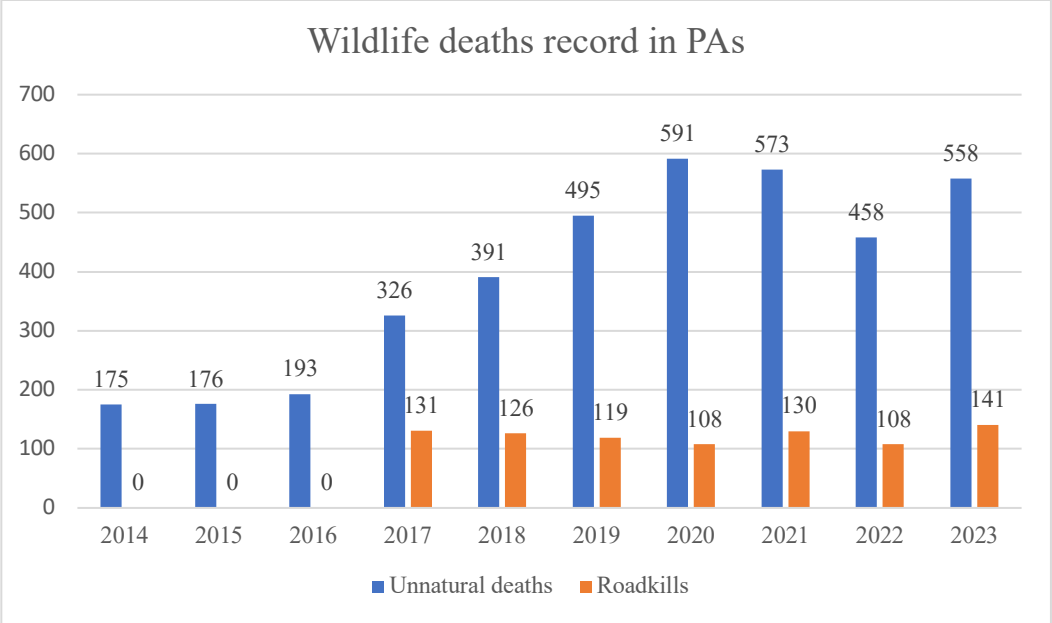

Figure 7: Wildlife deaths record in PAs in Nepal (Source DNPWC)

Wildlife casualties due to WVC and wildlife drowning in irrigation canals are the most abundant causes of unnatural deaths of wildlife. The WVC in Bardiya National Park (BNP) and Banke National Park (BaNP) contributes to almost 70% to 95% of the total WVC which could be related to the highway length stretch which falls under PA system.

Table 5: Wildlife deaths due to Wildlife vehicle collision (WVC) (Source: DNPWC, BaNP and BNP Annual Reports)

Fiscal Year	Wildlife deaths due to WVC				
	Bardiya National Park (BNP)		Banke National Park (BaNP)		National WVC deaths data
	No. of deaths	Percentage	No. of deaths	Percentage	
2072/73	19	-	43	-	-
2073/74	63	48.09%	61	46.56%	131
2074/75	56	44.44%	72	57.14%	126
2075/76	27	22.69%	45	37.82%	119
2076/77	35	32.41%	48	44.44%	108
2077/78	49	37.69%	44	33.85%	130
2078/79	45	41.67%	52	48.15%	108
2079/80	58	41.13%	66	46.81%	141

East-West Highway (Mahendra highway) crosses through the core PAs in different sections, while Ratna Highway (North from Kohalpur) crosses through Bardiya National Park.

The infrastructures planned as such does come with huge impacts on Natural wellbeing. The pristine forest which holds a wide range of not only biodiversity but also the sources of precious water will be lost in the process. The impacts of forest loss do not however limit within project development phase, it will have even sustained detrimental impacts throughout the use of such linear infrastructures.

The roads being planned and constructed also crosses the transboundary landscapes and bisects the major identified wildlife corridors. If not checked in time, the highways envisioned now will increase Vehicle Wildlife collision scenario even more, thus making them the death traps - not only vulnerable for wildlife but also imparting a huge loss to human as well.

Thus, infrastructure development should follow a fully planned, crucial analytical impactful study to protect the natural wellbeing to the most possible extent so that its negative impacts are minimized and envisioned infrastructures could be sustainable. The infrastructure development should be backed up by researches checking on the precise location of frequent wildlife crossing

zones. As wildlife usually follow a regular trail, such locations should be identified and crossing structures should be constructed at such critical zones to reduce WVC.

The current status of WVC is a huge conservation problem. While Nation is celebrating conservation success on doubling the tiger population (nearly triple the TX2 target), the declination in numbers of the pray base and unhealthy intrusions of infrastructures in their habitat is creating a havoc in conservation of top ranked predators to maintain the growing population sustained. This has also increased the trend of human wildlife conflict (HWC) within and nearby PAs and corridors. (Carter *et al.*, 2020, 2023; Ram *et al.*, 2021)

Proper planning and management of infrastructure development duly following the Environmental considerations during project planning promotes forest protection which eventually safeguards river systems, manages watersheds and ultimately results proper management of healthy ecosystem.

For this, the linear infrastructure planning should be done in such a way that those structure does not fragment the pristine forest area and wildlife habitat. In cases where avoidance cannot be done, enough crossing structures such as Over and under passes, viaducts, bridges should be provided within wildlife habitat across the linear infrastructures as well as introduce natural intrusions to ease drinking water accessibilities as water holes nearer the crossing zones creates a favorable condition for crossing successes. The river corridors should be clearly demarked for easy flow of wildlife along river sides on their habitat to maintain the ecological flow.

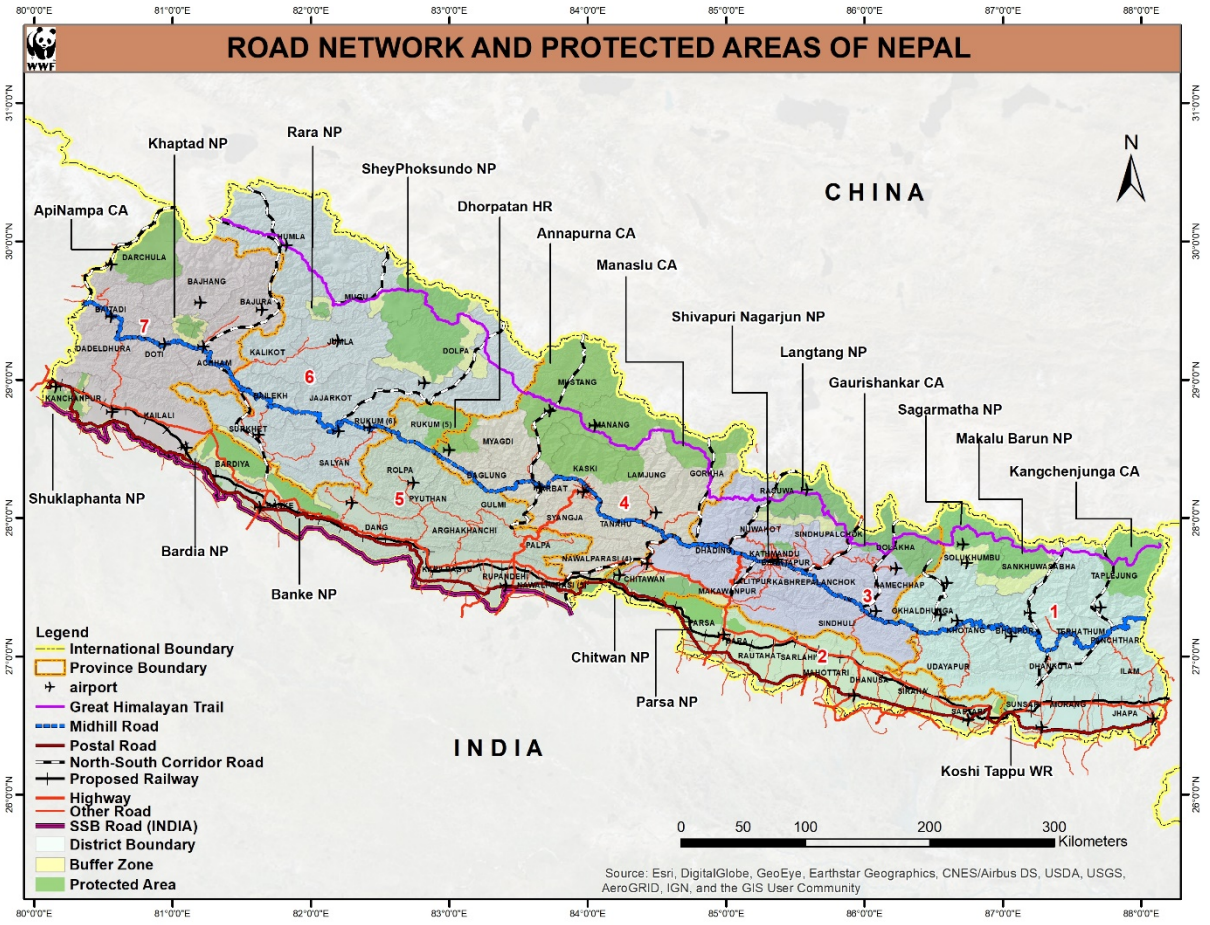

Figure 8: Road Network and Protected Areas of Nepal (Source: WWF Nepal)

4.1.3. LINEAR INFRASTRUCTURE IN CHITWAN-PARSA COMPLEX

The map below shows the linear infrastructure in Chitwan-Parsa complex. Mahendra highway crosses through the Parsa National Park's core area in the eastern section whereas follows the path of the buffer zone of PNP and CNP. Barandabhar forest corridor, one of most critical wildlife corridors in Nepal. Barandabhar is fragmented by Mahendra Highway in East-West and Narayanghat-Mugling highway in North-South. Likewise, the planned Railway line passes from Nijgadh towards Hetauda and follows a parallel path to Mahendra highway and crosses through Barandabhar corridor in Chitwan.

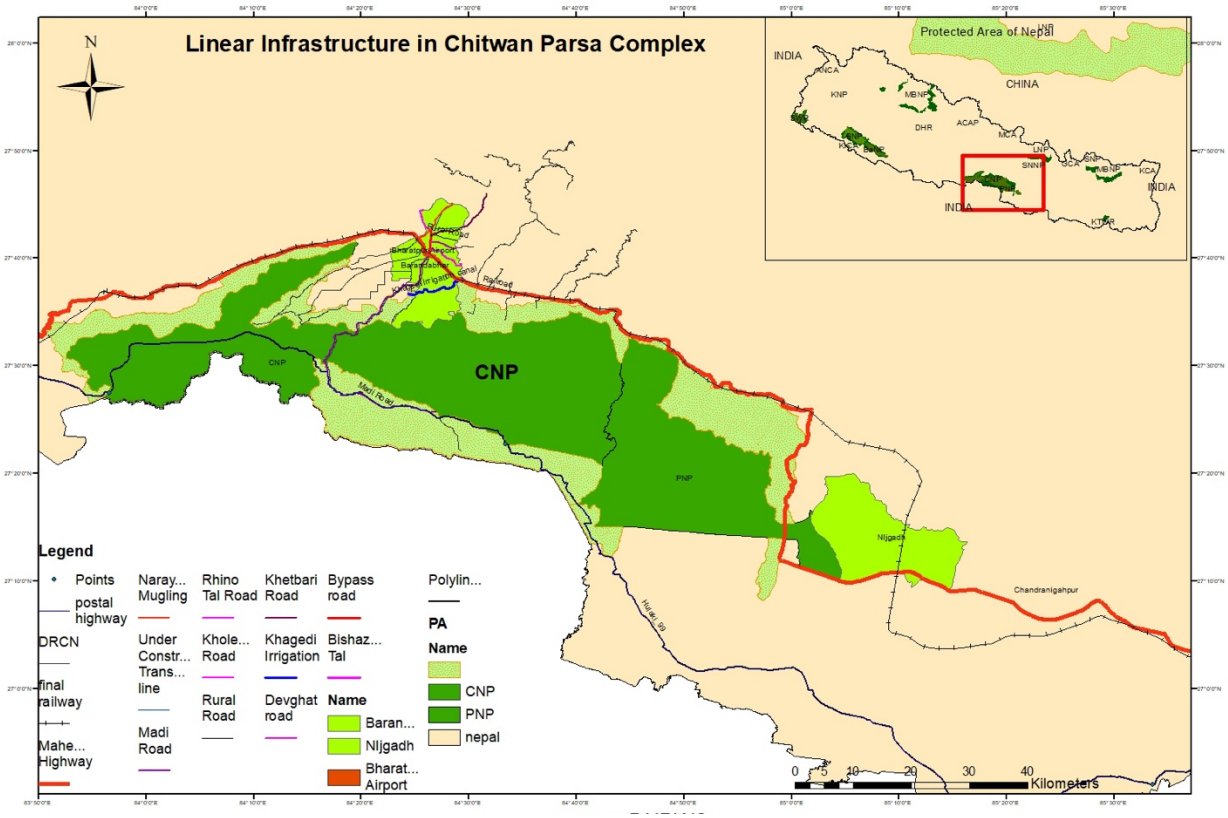

Figure 9: Linear Infrastructure in Chitwan-Parsa Complex

4.1.4. LINEAR INFRASTRUCTURE IN BANKE BARDIA COMPLEX

The map below shows the existing Mahendra highway which is being upgraded to 4 lane highway from existing 2 lane standard which will create immense pressure to wildlife dispersal in the future. Likewise, the map also shows Babai Irrigation Project's main and subsidiary canal structures crossing through the core and buffer zone of BNP along with Sikta Irrigation Projects Canals crossing through BaNP and Kamdi wildlife corridor. Likewise, the proposed East-West Electrified railway's alignment is shown in the map which follows a parallel path to Mahendra highway. Similarly, the postal highway which connects the border cities in the southernmost part of the country within Banke-Bardiya complex is shown in the map.

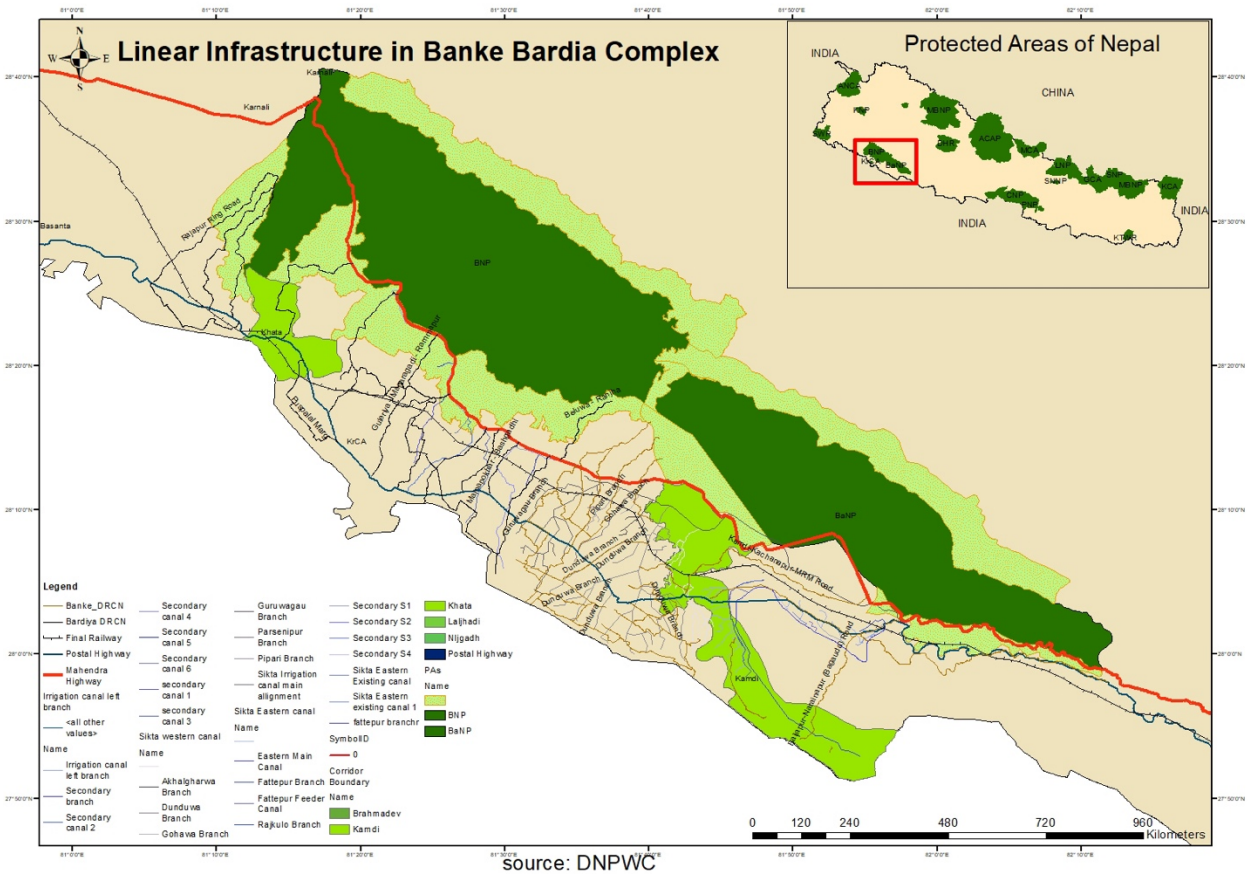

Figure 10: Linear Infrastructure in Banke – Bardiya complex

4.1.5. LINEAR INFRASTRUCTURE IN SHUKLA NP

The map below shows the linear infrastructure assemblage in ShNP. Mahakali I, II and III projects' canals cross through core and buffer zone of ShNP. Mahendra highway crosses through the core of ShNP through 4 km length whereas Postal highway's Daijee – Beldadi section crosses through the core of ShNP parallel to Mahakali I project's main canal. The planned railway crosses through ShNP parallel to Mahendra highway.

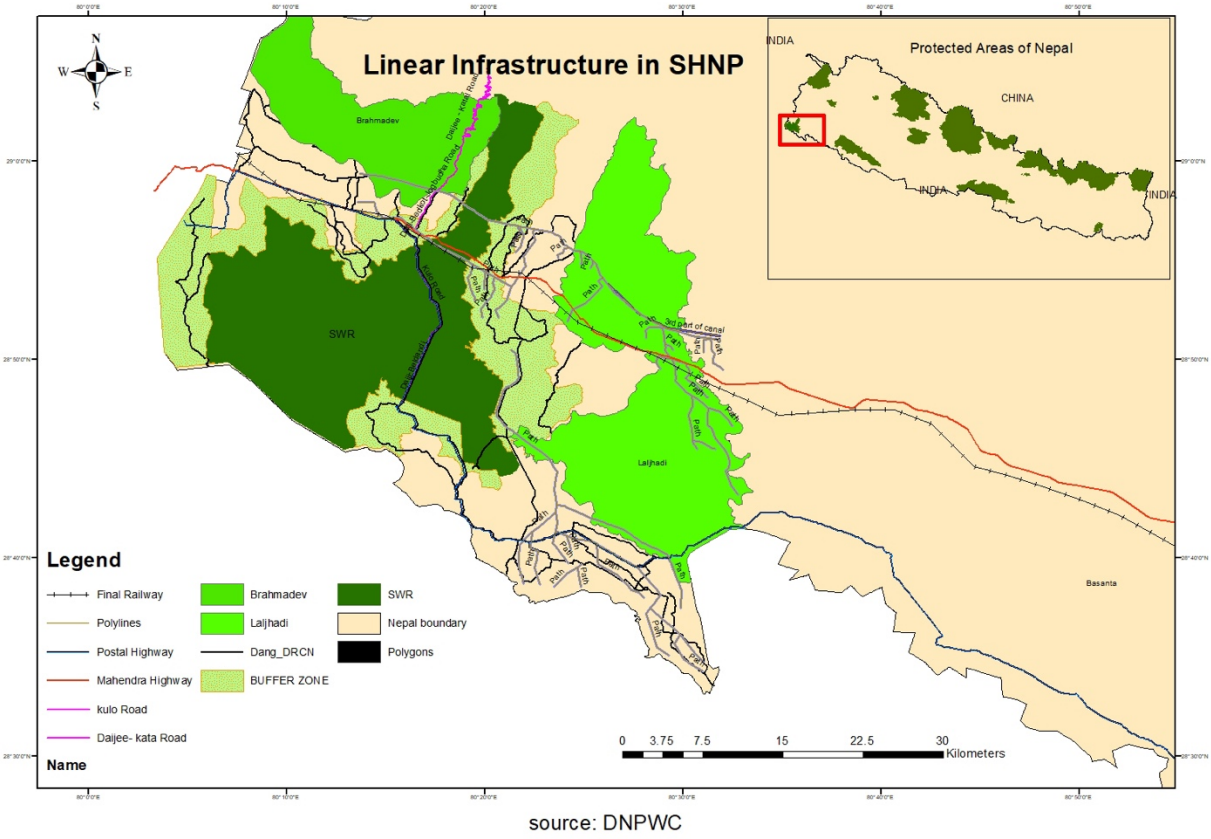

Figure 11: Linear Infrastructure in ShNP

4.2. WILDLIFE ROAD KILLS HOTSPOT ANALYSIS

The hotspot analysis was done using the road kills from the database of WVCs from 4 PAs across TRH in Nepal. The hotspot analysis showed prime locations in the GIS maps of the Mahendra highway within PAs where mitigation measures are of utmost requirement to safeguard wildlife mobility across the highway.

4.2.1. HOTSPOST ANALYSIS IN BANP

The WVC data in Banke over the decade period between 2013-2023 shows the wildlife road kills concentrated over the straight span of the highway within BaNP implying to the root factor of increase in speed of the vehicles. Also, the wildlife cross at these major sections for the need of food and water to reach to the rivers on the southern part as BaNP is comparatively a dry Protected Area.

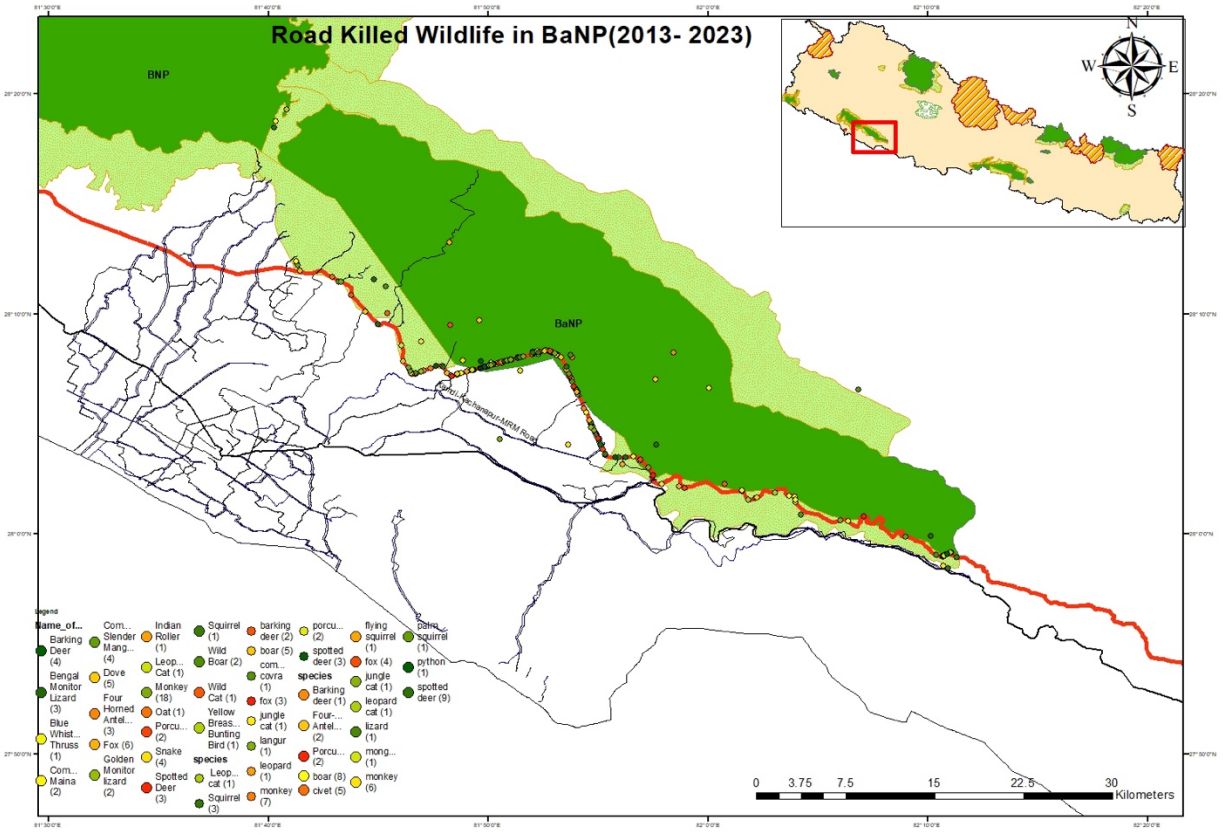

Figure 12: Road kills due to WVC in BaNP (Source: BaNP)

4.2.2. Hotspot Analysis in BNP:

The WVC data of BNP shows the concentration of wildlife road kills in the sector Amreni-Chisapani which has high abundance of wildlife also because of the connectivity within the park. This section is also comparatively straight where the tendency of the increase in vehicle speed is high which eventually result into WVC incidents. Going through the data, the WVC incidents was found to be more frequent in Winter time than in Summer which indicates the misty season contributes to non-clarity of vision to the drivers.

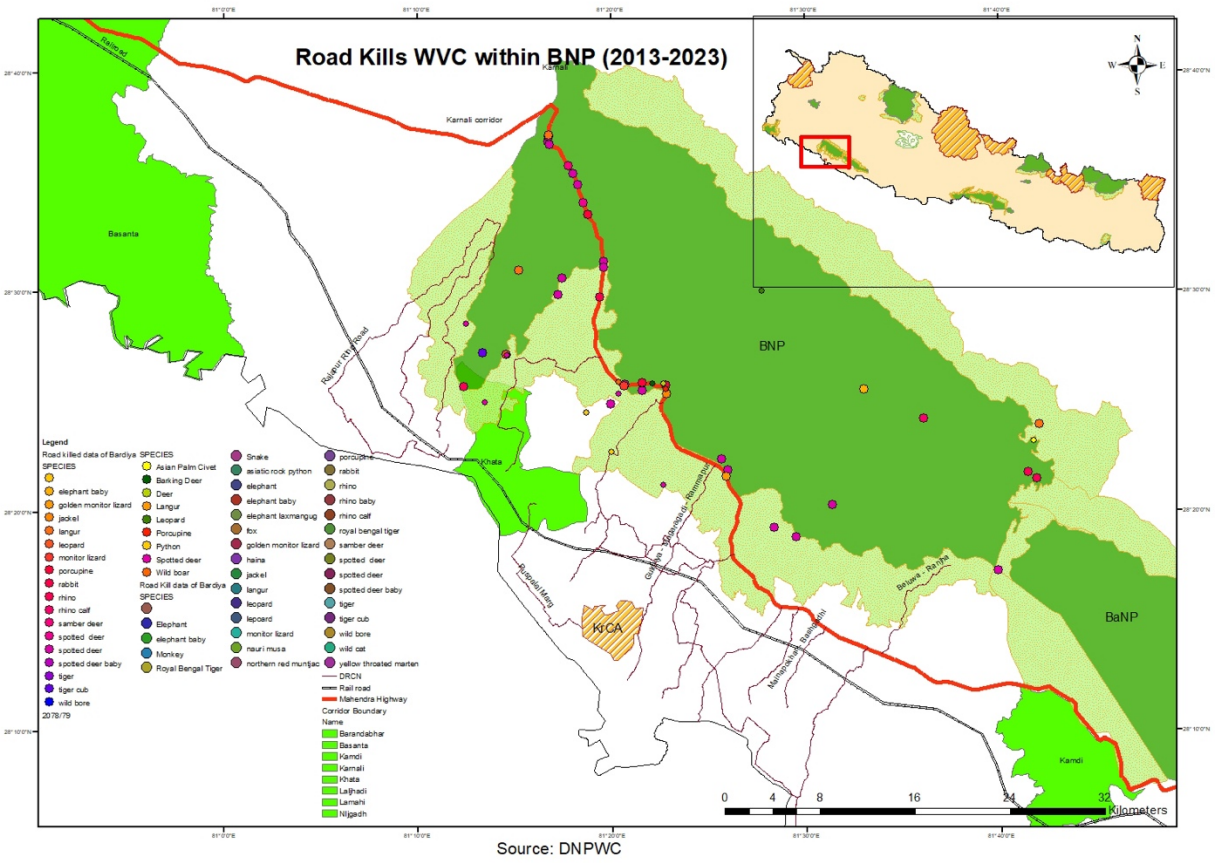

Figure 13: Road kills due to WVC in BNP

From the results above, following conclusion can be derived. The outcomes of the WVC hotspots analysis of highways within two parks indicates the following;

1. The drivers' tendency for the increase in vehicle speed in the straight road increases the probability of WVCs resulting to the road kills incidents.
2. The road kills data analysis found that the WVC incidents were recorded more during the night and early morning period in compared to the rest of the day, thus indicating the temporal impact on WVC cases.
3. The WVC data indicated more of road kills occurred during the winter period. This is because winters are foggy contributing to less visibility for the drivers. Also, wildlife have a tendency to avoid cold dews and water droplets in the vegetation and grasses where they are attracted towards open spaces and eventually die because of WVC incidents.

4.3. MITIGATION MEASURES:

Mitigating the impacts of linear infrastructure development on the safe dispersal of wildlife is crucial for maintaining ecological connectivity and reducing habitat fragmentation. The mitigation measures for safe dispersal of wildlife across highways were found as follows with the rigorous consultation with Wardens of respective PAs along with key stakeholder i..e. Nepal Army officials engaged in wildlife Search and Rescue (SAR), and Environment Inspector of Department of Roads.

4.3.1. **Wildlife Crossings:** Construction of wildlife crossing structures such as underpasses and overpasses to provide safe passage for wildlife over or under linear infrastructure. These structures should be designed considering the specific needs and movement patterns of target species.

4.3.2. **Fencing Modifications:** Modification or enhancement of fencing along linear infrastructure to prevent wildlife from accessing high impact areas like roads or railways. This can include wildlife-friendly fencing designs that allow for the movement of smaller animals while still deterring larger species.

4.3.3. **Vegetation and Habitat Management:** Implementation of vegetation and habitat management practices that enhance wildlife movement and dispersal. This includes preserving and restoring natural vegetation, creating vegetated corridors, and maintaining suitable habitats along linear infrastructure.

4.3.4. **Noise and Light Reduction:** Minimization of noise and light pollution associated with linear infrastructure to reduce their disturbance to wildlife. This can be achieved through the use of noise barriers, strategic placement of lighting, and adhering to regulations and guidelines for noise and light pollution control.

4.3.5. **Speed Reduction and Traffic Calming measures:** Implementation of speed reduction measures, such as speed limits, speed bumps, or traffic calming structures, to reduce the risk of wildlife-vehicle collisions. Slower vehicle speeds give wildlife more time to detect and avoid traffic.

4.3.6. **Public Awareness and Education:** Raising public awareness about the importance of wildlife dispersal and the potential impacts of linear infrastructure. Educate drivers, local communities, and infrastructure developers about wildlife behavior, the need for caution near wildlife crossings, and responsible driving practices.

4.3.7. **Monitoring and Research:** Conduction of regular monitoring and research to assess the effectiveness of wildlife dispersal mitigation measures. This helps identify potential issues, evaluate the success of implemented measures, and inform adaptive management strategies.

4.3.8. **Collaboration and Partnerships:** Fostering collaboration among relevant stakeholders, including transportation agencies, conservation organizations, and local communities. Work together to develop and implement effective wildlife dispersal mitigation plans, share knowledge and resources, and ensure long-term monitoring and maintenance of implemented measures.

4.3.9. **Integration of Wildlife Considerations in Planning:** Integration of wildlife dispersal considerations early in the planning and design phases of linear infrastructure projects. This includes conducting environmental impact assessments, identifying potential wildlife corridors, and incorporating wildlife-friendly design elements from the outset.

During consultation with DoR, Wildlife crossing structures – mostly underpasses are prioritized for minimizing the impacts of highways on wildlife dispersal. Underpasses in highways are comparatively easy, effective and efficient structures to facilitate wildlife mobility.

Moreover, the wildlife sizes have been classified to devise wildlife crossing dimension as per WFICD, 2022. The wildlife species abundant in Nepal are classified as per four categories which are;

1. Small wildlife species:-

   Amphibian and reptiles like tortoise species, snake species, monitor lizard Gohoro species, crocodile species, lizard species, frog, Small mammal species like squirrel species, rabbit species, porcupine species, civet species, otter species, mongoose, rat, monkey species, salamander species, red panda species, leopard cat, *linsang* (Prionodon),

2. Medium wildlife species:- Small wild cat species, palm civet (toddy cat), wild dog *{Dhole),* jackal, fox, linx, small deer species, blackbuck, four horned antelope *chauka,* hyena, leopard, dolphin, wild boar species.

3. Big wildlife species:- Greater One- Homed Rhinoceros, tiger, bear species, big deer species, Himalayan tahr *{Jharal),* ghoral, blue bull (Boselaphus tragocamelus), gaur *Gauri gai* (Bos Gaurus3, wild buffalo)
4. Giant wildlife species:- Asian elephant

Table 6: Wildlife crossing structure recommendation as per WFICD

Size Class	Underpass structure type	Focal Wildlife Taxa	Minimum Underpass Dimensions			
			<20 m Length		>20m Length	
			Width (m)	Height (m)	Width (m)	Height (m)
Small	Concrete Box Culvert, Arch Culvert	Reptiles, Amphibians, Mustelids	2.0	2.0	3.0	2.5
Medium	Concrete Box/Arch Culvert	Small Ungulates, Small felids, Bears	6.0	3.0	8.0	3.0
Large	Arch, Bridge	Large Ungulates, Bovids, Large Felids, Large Canids	10.0	4.0	15.0	4.5
Very Large	Arch, Bridge	Asian Elephants	12.0	6.5	15.0	6.5

Crossing structures - underpasses have been found effective in safe dispersal of wildlife across highway infrastructure. (WWF Nepal, 2019). The crossing structures as recommended in the table above is shown in the figures below for general understanding of crossing structure type. The Arch structure allows better visibility to the wildlife which encourages successive crossings in wildlife in the crossing structures.(Wildlife Institute of India, no date)

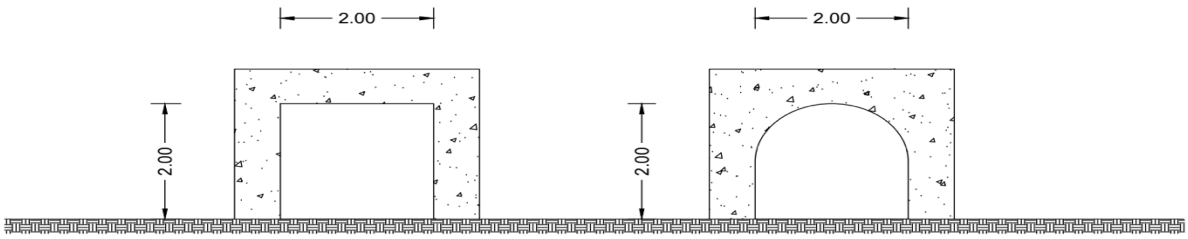

Figure 14: Wildlife underpass structure – Culvert: Box and Arch designs for Small wildlife species

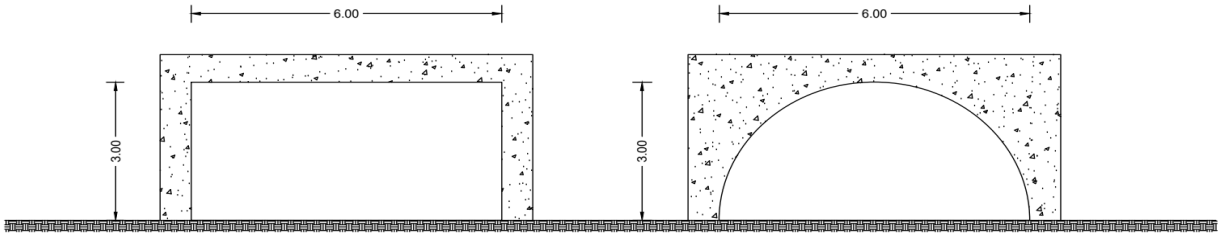

Figure 15: Wildlife underpass structure – Culvert: Box and Arch designs of medium wildlife species

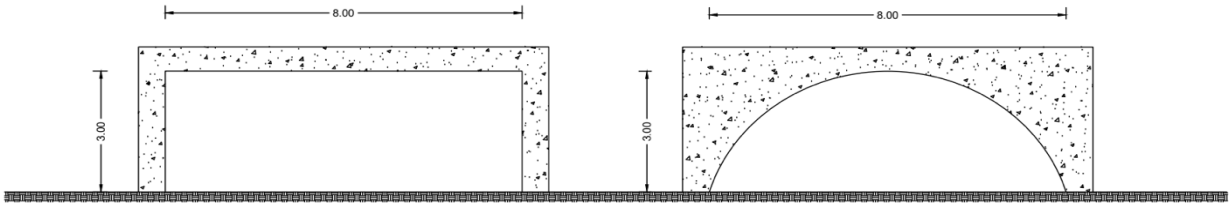

Figure 16: Wildlife underpass structure – Culvert: Box and Arch designs of medium wildlife species

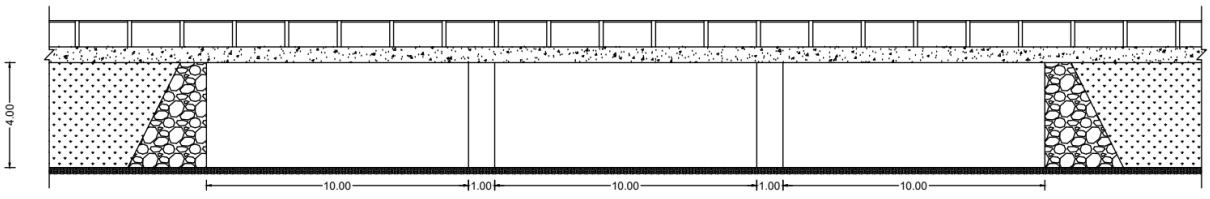

Figure 17: Wildlife underpass structure – Bridge design of Large wildlife species

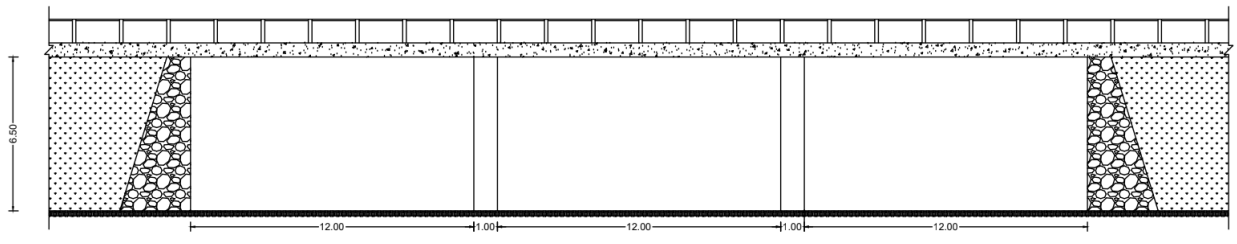

Figure 18: Wildlife underpass structure – Bridge design of Very Large wildlife species

4.4. DISCUSSION

The linear infrastructure development and upgrading scenario may put the wildlife conservation scenario into peril if the developmental priorities fail to meet the environmental considerations.

As the LI development will have sustained impacts on wildlife dispersal, the infrastructure development fraternity should be aware and motivated to incorporate wildlife friendly approaches in LI development. The hotspot analysis of WVC shows concentrated collaboration of road kills data which indicates for certain pragmatic scenario which could be studied, analyzed and thereby mitigation measures devised to minimize the impacts on wildlife dispersal. The mitigation measures, mostly with major examples of wildlife underpasses are effective in minimizing the impacts together with support infrastructure including guiding fences, water holes among other approaches. The dimension of crossing structures adopted to the standards as suggested by the WFICD will help expedite better opportunities for the successful use of wildlife crossing structures.

The first ever constructed wildlife underpasses structures in Aaptari and Ramnagar in Barandabhar Forest Corridor within Narayanghat-Muglin highway exhibited successful usage of such structures by 15 mammal species during the survey period of three months – intermittent within 2 years. The results of assessment of these underpasses conducted by WWF Nepal through Hariyo Ban Program showed similar results as per the findings of this research.

Likewise, the Wildlife Crossing structures – flyovers constructed in NH 7 crossing through Pench Tiger Reserve in India follows the crossing structure dimensions as identified by this research for large mammals. The biodiversity baseline assessment conducted for upgrading of Narayanghat-Butwal section of Mahendra highway has recommended similar crossing structures sizes to facilitate wildlife across the highway.

Thus, the wildlife friendly mitigation measures for facilitative safe dispersal of wildlife across Mahendra highway in TRH of Nepal exhibits assemblage of information supporting the fact of minimizing the impacts on wildlife dispersal.

CHAPTER 5

5. CONCLUSION AND RECOMMENDATIONS

5.1. RAPID GROWTH OF INFRASTRUCTURE, IMPACTS OF LI ON WILDLIFE

Large linear infrastructure, mainly the development of roads and highways are on rise in Nepal. The development of new roads and upgrading of existing highways in the Tiger Range habitats have meaningful inter-relation contributing to more of WVC cases in the long run. This has implications on wildlife conservation as Wildlife dispersal for food, shelter and reproductive needs are seriously hindered by roads and highways. The genetic transfer of wildlife species could be threatened by this infrastructure on critical wildlife habitats. The Roads and Highways thus have sustained impacts on Wildlife dispersal and eventually wildlife conservation.

5.2. HOTSPOT ANALYSIS OF WILDLIFE ROAD KILLS

Hotspot analysis of wildlife road kills is a measure to identify the blackspots of WVCs. This will help document and identify the probable location of mitigation measures required within the highway/road section to minimize the impacts on wildlife. This will help to make strategies to implement wildlife friendly practices to safeguard wildlife dispersal across linear infrastructure.

5.3. MITIGATION MEASURES TO SAFEGUARD WILDLIFE

The mitigation measures in the form of Wildlife underpass and Overpass are essential for the minimization of impacts of LI on wildlife dispersal. Wildlife underpasses, which have shown significant positive results in the reduction of WVCs are the way forward for the incorporation of Wildlife friendly approach in LI development. Crossing structures should be designed and implemented in integration with Water holes and fencing structures to increase the probability of wildlife usage.

5.4. RECOMMENDATION

Following recommendations are made based on the outcome of this research.

1. Linear infrastructure that are upcoming and being upgraded in important biodiversity areas should follow wildlife friendly linear infrastructure development practices to safeguard wildlife dispersal.

2. Wildlife mitigation measures should be carefully placed in strategic locations of wildlife crossing zones following the evidences of wildlife abundance and hotspot analysis.
3. Mitigation measures should follow proper dimensions to facilitate wildlife usage. The mitigation measures should be made natural as far as possible and they should be wildlife friendly to enhance effective use.

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ANNEXES

ANNEX 1

Key Informant Interview's Questionnaire used during the field visit area;

1. What is the current scenario of WVCs in Mahendra highway crossing through PAs?
2. Is the database of Road kills of wildlife maintained by the Park authority on a regular basis?
3. What is the format of data collection of WVCs? Are GPS coordinates recorded properly?
4. How are the data on WVCs generated on field utilized in analysis to identify wildlife kill hotspots?
5. What could be done to minimize the impacts of WVCs and facilitate wildlife to cross through highways?
6. What should be the desirable sizes of wildlife crossing structures?
7. What should be the basis of selection of strategic locations for wildlife crossing structures?
8. Are you aware of any assessment of mitigation measures in highways?
9. Have you considered assessing of the existing mitigation measures?

Personnel and authorities interviewed during the field work.

1. Mr. Manoj Aryal, Environment Inspector, Geo Environmental and Social Unit, Department of Roads, Babarmahal, Kathmandu
2. Mr. Shyam Kumar Shah, Ecologist, DNPWC (Immediate Past Chief Warden of BaNP), Babar Mahal, Kathmandu
3. Mr. Ramesh Kumar Yadav, Asst. Conservation Officer, PNP, Aadhabhar, Pathlaiya
4. Mr. Manoj Kumar Shah, Chief Conservation Officer, BaNP, Dhakeri, Banke
5. Mr. Ashok Kumar Ram, Chief Conservation Officer, BNP, Thakurdwara, Bardiya
6. Mr. Pramod Kumar Bhattarai, Chief Conservation Officer, ShNP, Majhgaun, Kanchanpur
7. Mr. Raghu Nath Rupakheti, Major – Department of Wildlife and National Parks, Nepal Army
8. Mr. Deepak Khadka, Lt. Colonel, Rudradhwaj Battalion, Shuklaphanta NP
9. Mr. Madhu Sudan Basnet, Captain – Shiva Dal Battalion, Bardiya NP
10. Mr. Basudev Dhimal, Lt. Colonel – Shree Mehar Battalion, BaNP
11. Mr. Basant Gautam, Lt. Colonel – Arjun Ban Battalion, PNP

ANNEX 2

Wildlife-friendly Infrastructure Construction Directives, 2022

Preamble: Whereas, it is expedient to make infrastructure of linear nature to be constructed in the habitat and area of movement of wildlife as friendly to them in order to reduce wildlife accidents by making the movement of wildlife secure and thereby to decrease the conflict between human and wildlife;

Therefore, the Government of Nepal has, having exercised the powers conferred by Section 33A. of the National Parks and Wildlife Conservation Act, 1973, formulated these Directives.

Chapter 1

Short name and commencement: (1) These Directives may be cited as "(the) Wildlife-friendly Infrastructure Construction Directives, 2022."

Definitions:

S.N	Terms	Meanings
1	Very Sensitive Area	National Parks, wildlife reserve, biological corridor or wetland areas listed on the Ramsar List.
2	Other Forest area	forest areas other than very sensitive area and sensitive area.
3	Promoter	an agency, company, organization or individual having obtained permission to study, construct and operate infrastructure project
4	Technical Team	means a technical team to be formed pursuant to Sub-section (2) of Section 6.
5	Infrastructure	linear infrastructure like road, railway, irrigation canal, river training and management structures including dam and embankment, pipeline of oil or gas, electricity transmission line, dam of hydropower project, headrace canal, headrace pipe and penstock pipe and other similar linear infrastructure

6	Ministry	the Ministry of Forests and Environment of Government of Nepal
7	Wildlife-friendly Infrastructure	Viaduct, bridge, flyover, culvert or an underpass infrastructure of similar nature through which wildlife can move Village road bridge, eco-bridge, canopy bridge or an overpass infrastructure of similar nature above which wildlife can move Ramp, guiding fence, guiding wall, avian deflector or structure of similar nature which is used for movement of wildlife and to provide access to source including water available in those structure.
8	Department	Department of National Parks and Wildlife Conservation.
9	Concerned body	Department or office under government ownership that constructs infrastructure or regulates and monitors or provides permission for infrastructure construction.
10	Sensitive Areas	Environment Conservation Area; Conservation Area; Forest Conservation Area; Buffer Zone Area; Eco-tone of various types of habitats.

Chapter-2

Provisions relating to Formulation of Plans

Infrastructure to be constructed outside very sensitive area:

This provision emphasizes conducting a feasibility study for infrastructure projects to ensure they are located outside very sensitive areas. If infrastructure has to be constructed in very sensitive areas, the prooter must propose alternatives that minimize adverse impacts on wildlife habitats, biological corridor and ecosystems. Sustainable options considering physical, biological, social, and economic aspects with a focus on constructing wildlife-friendly structures should be explored.

Prior Permission to be obtained:

This provision requires prior permission from the Ministry before conducting a feasibility study for infrastructure projects in very sensitive area. When applying for permission, the promoter must include information outlined in Schedule-1. The Ministry is responsible for granting permission within 21 days if the feasibility study is found appropriate.

Discussions to be held and Coordination to be made:

As per this provision, if infrastructure projects are proposed in very sensitive or sensitive areas, stakeholder's discussions and coordination is a must, from the very beginning. During feasibility studies, coordination is required with the concerned Warden or Divisional Forests Officer.

Study to be conducted by Technical Team:

This provision outlines the requirement for conducting a detailed study by a technical team before preparing a Detailed Project Report for infrastructure projects, especially those in very sensitive, sensitive, or other forest areas in specific regions. The technical team comprises experts in civil engineering, wildlife, forest, and relevant infrastructure subjects, all with at least a post-graduate level degree in related subjects. The technical team shall identify and design wildlife-friendly structures based on various factors such as potential wildlife impact, species behavior, environmental conditions, safety, past wildlife accidents, wildlife data, recommendations from feasibility reports, and lessons learned from previous projects.

The study report must include details of wildlife in the area, adverse impacts analysis of wildlife habitats, and recommendations for wildlife-friendly structures based on specified standards. The technical team must coordinate with the relevant authorities, particularly the Warden or Divisional Forest Officer, during the study and report preparation process.

Detailed Project Report (DPR) and Cost Estimation to be prepared:

This provision requires the promoter to prepare a Detailed Project Report (DPR) along with the design and cost estimation of wildlife-friendly structures based on the study report. During the preparation of the DPR and cost estimation, the written recommendation of the concerned Warden or Divisional Forests Officer must be obtained and included in the report.

Chapter 3

Construction of Wildlife-friendly Structure

Wildlife-friendly structure to be constructed:

This provision mandates the construction of wildlife-friendly structures in accordance with the detailed project report prepared under Section 7 and approved by existing laws. During construction, measures to reduce adverse impacts must be implemented. Additionally, structures such as walls, guiding fences, and noise-resistant structures must resemble wildlife habitats and utilize local materials as far as possible.

Provision regarding use of forest area:

As per this provision, while extending and constructing infrastructure and wildlife-friendly structure, the use of forest area and land compensation shall be according to forest federal law.

Acts not to be committed while constructing infrastructure and wildlife-friendly structure

This provision prohibits harmful actions during infrastructure and wildlife-friendly structure construction, including causing adverse impacts on wildlife habitats, corridor and ecosystems, creating pollution, cutting down trees, harming wildlife, and violating existing laws. It prioritizes protecting endangered species, important ecosystems, water sources, and activities outlined in approved environmental study reports.

Wildlife-friendly structure to be made in infrastructure to be constructed or already constructed:

This provision requires that if infrastructure is already built or being constructed and it poses a threat to wildlife, wildlife-friendly structures must be incorporated. The concerned Warden or Divisional Forests officer can recommend to the promoter to include such structures. A study should be conducted in collaboration with the Divisional Forest officer, and appropriate wildlife-friendly structures should be built accordingly.

Repair and Maintenance:

This provision states that the responsibility for repairing and maintaining wildlife-friendly structures lies with the or promoter. They must:

Clean and manage vegetation and waste along roads and railways depending on the region.

Repair and maintain structures near irrigation and river control.

Trim vegetation near electricity transmission lines.

Repair and maintain other infrastructure.

Install signage and billboards in areas with significant wildlife presence.

Before carrying out these actions, permission must be obtained from the relevant Warden or Divisional Forests Officer.

Chapter 4

Miscellaneous

Provision regarding to Committee

According to this provision, a committee is established for the recommendation of the construction of infrastructure projects such as transmission lines, highways, railways, hydropower, etc., within protected areas. The committee comprises secretaries from relevant ministries. The functions include determining national infrastructure corridors within protected areas and facilitating the implementation of development projects in these areas.

Monitoring:

This provision mandates monitoring to ensure compliance with wildlife-friendly infrastructure. It involves assessing whether construction is according to detailed project reports, environmental studies, and approved designs. Monitoring is conducted by the department or provincial forest directorate, who then submit reports to the respective Ministry. If recommendations for implementation are made based on monitoring reports, the promoter must promptly implement such recommendation. The promoter should also assist in monitoring activities and report preparation.

Amendment to Schedule:

The Ministry may, by publishing a notification in the Nepal Gazette, amend the Schedules as required

Schedule-1

(Related to Sub-section (2) of Section 4)

Subject matter to be included in the application provided for prior permission

Name of the project;

Name and address of concerned body or promoter;

Four boundary (coordinate) of the forest that may be used by the project and forest area that may directly impact by the project in the map;

Full address of place of project implementation;

Type of National Park/Wildlife Reserve/ Forest Conservation Area / Ramsar site / Biological corridor pursuant to existing Forest Act or National Park and Wildlife Conservation Act;

Main wild fauna and flora species found in project area;

Estimated area (in hectare) of forest area required for the project;

Other relevant details

Schedule-2

(Related to Clause (a) of Sub-section (5) of Section 6)

List of wildlife found around infrastructure construction area to be referred in the report

Small wildlife species:-

Amphibian and reptiles like tortoise species, snake species, monitor lizard Gohorospecies, crocodile species, lizard species, frog,

Small mammal species like squirrel species, rabbit species, porcupine species, civet species, otter species, mongoose, rat, monkey species, salamander species, red panda species,

leopard cat, *linsang* (Prionodon),

Medium wildlife species:-

Small wild cat species, palm civet (toddy cat), wild dog *{Dhole),* jackal, fox, linx, small deer species, blackbuck, four horned antelope *chauka,* hyena, leopard, dolphin, wild boar species.

Big wildlife species:-

Greater One- Homed Rhinoceros, tiger, bear species, big deer species, Himalayan tahr *{Jharal),* ghoral, blue bull (Boselaphus tragocamelus), gaur *Gauri gai* (Bos Gaurus3, wild buffalo)

Giant wildlife species:-

Wild elephant

Schedule-3

(Related with Clause (b) of Sub-section (5) of Section 6)

List of adverse impact that may be caused on wildlife habitat by the infrastructure

S.N.	Area	Adverse impact
1.	Park, wildlife reservoir, Conservation, Area, Forest Area, Biological corridor	Habitat Area Fragmentation Hindrance on food, water resource, safe reproductive place and grazing Increase in wildlife accident and death Destruction on ancestral diversity Habitat Destruction Reduction, destruction of food and habitat area Compulsion to go outside forest area for food and living Creation of human-wildlife conflict Deforestation Exploitation of river based materials Changes in Habitat (a) Spread of useless and inedible *michaha* (invasive) species Increase in poaching Changes in number and structure of species Changes in condition of threatened, vulnerable and protected species in endangered condition

		Other impact
2.	Wetlands	Wetlands shall be buried and water get dry, cause pollution, cause destruction, spread of *michaha* (invasive) species, depreciation on biological diversity Impact caused on livelihood of local community dependent on wetland Other impact
3.	*Chure* and Environment Protection Area, Important Biological Area	Impact on underground water flow, land destruction, landslides, change in flow of water, impact caused on lower coastal area Habitat destruction and contraction of important species Other impact
4.	Adverse impact of environmental pollution caused in air, water, noise and soil	

Schedule-4

(Related to Clause (c) of Sub-section (5), Sub-section (7) of Section 6 and Sub-section (2) of Section 7)

Basic Standard of Wildlife-friendly Structure

Underpass Structure:

S.N.	Categorization of wildlife		Minimum Shape of Underpass	
			Less than 20 metre	20 metre or more

		Type of Underpass Structure	length		than 20 metre length	
			Width (metre)	Height (metre)	Width (metre)	Height (metre)
1.	Small wildlife species	Culvert	2.0	2.0	3.0	2.5
2.	Medium wildlife species	Culvert or bridge	6.0	3.0	8.0	3.0
3.	Big wildlife species	Bridge	10.0	4.0	15.0	4.5
4.	Giant wildlife species	Bridge	12.0	6.5	15.0	6.5

Note: Length of wildlife-friendly structure means width of infrastructure

Overpass Structure:

For wild elephant, rhinoceros species grazing on land, the gradient leading to the overpass should not exceed 20° (twenty degrees) and width of the overpass shall be at least 20 metre (twenty metre).

For other species grazing on land other than elephant and rhinoceros, the gradient leading to the overpass should not exceed 30o (thirty degrees) and width of the overpass shall be at least 10 metre (ten metre).

For arboreal species living in the trees like monkeys and squirrel, canopy bridge made of materials like rope or wire shall be constructed that should be at least five metre above the infrastructure like canal, road, railways.

Other Structure:

Ramp shall be constructed in irrigation canal and river control structures as required.

Headrace pipe of hydropower project and penstock pipe, petroleum pipe including other pipeline of same nature shall be buried under ground as far as possible.

in case of electricity transmission line equipment like avian diverter, reflector, insulator shall be installed in the wires as required

Schedule-5

(Related to Sub-section (5) of Section 7)

Subject matter to be included while giving opinion or recommendation

Name and construction area of the project

Important wildlife species found in project area

Detail including map, coordinate of wildlife movement pathways

Type, place and number of appropriate structure for facilitation of wildlife movement

Opinion or recommendation of concerned official

Other relevant details.