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From afterthought to blueprint: Making wildlife-friendly linear infrastructure a design requirement, not post-hoc mitigation measures

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Abstract

Developing economies like India are pushing for aggressive linear transportation infrastructure (LTI) growth as a means to achieve economic and social development. Among LTI, roads and railway lines are the prime focus of infrastructure growth plans. Often, the focal project implementation areas, especially remote and rural reaches of the country, are near biodiversity-rich forests and wildlife corridors, and are impacted in various ways during the construction and operation of these projects. In its present form, LTI development planning in India occurs in isolation, with biodiversity and environmental protection measures considered much later in the planning stage. This process leaves little scope for incorporating appropriate environment and wildlife-friendly measures into LTI projects passing through ecologically sensitive habitats, with scarce options to mitigate the impacts of such projects. Further, considering the lack of inclusion of mitigation costs at the planning stage, delayed imposition of such costs on developers leads to inflation of budgets and delayed project implementation. Overall, the present model of LTI planning in India does not satisfy either financial viability, sustainability, or conservation objectives.

We assert that LTI planning through sensitive landscapes should include wildlife-friendly measures as a design requirement, rather than mitigation measures. These measures ought to be part of LTI planning and costing at the inceptive stages as a standard procedure. This can be made possible through early engagement with conservation agencies to pre-emptively evaluate alternatives, and, if unavoidable, integrate environment and wildlife-friendly measures into infrastructure design and costs. Such a framework would be beneficial from the project developers' perspective as it would lead to easier environmental clearances, realistic project budgets, and completion timelines. More importantly, it would ensure that all possible options have been explored to avoid and minimise impacts to biodiversity. Consequently, all unavoidable infrastructure projects in biodiversity-rich or sensitive landscapes must include provisions for environment and wildlife-friendly components in their design, which are built into project costs.

Keywords: Infrastructure planning, mitigation hierarchy, road ecology, sustainable development, wildlife crossing

Introduction

The growth in linear transportation infrastructure (LTI) in India over the past few decades has not only improved connectivity, but also the quality of life of its citizens (Pradhan & Bagchi, 2013). India has achieved the milestone of having the second largest road network (66.71 lakh km) and the fourth largest railway network in the world (68,584 route km), concurrent with its position as one of the world's fastest growing economies (PIB, 2024). Some of the drivers of this growth are rapid urbanisation, industrial, agricultural and economic growth, and the recognition of LTI's role in achieving socio-economic aspirations. Yielding a 60% growth in India's national highway network in the last 10 years, connecting 99% of rural habitations through the Pradhan Mantri Gram Sadak Yojana (rural connectivity scheme), and unifying goods and passenger movement through the Bharatmala Pariyojana are key initiatives by the government in the road transportation sector. Further, modernisation of rail travel and rail infrastructure through augmentation of trains, improvement in railway stations, rapid electrification of railways, and expansion of urban metro systems have been key milestones in the development of railways in India (PIB, 2024).

While these schemes have systematically propelled infrastructure growth in the country, planners often fail to recognise the impacts of these large-scale projects on biodiversity that can have long-term repercussions for ecological security. LTIs passing through ecologically-sensitive areas exert a range of impacts on biodiversity. These impacts include, and are not limited to, wildlife mortality and injury through collisions with vehicles and trains, impediments to wildlife movement, avoidance by wildlife of habitats near these infrastructure, exploitation of natural resources by humans through increased access, and overall loss of ecological integrity through fragmentation of once contiguous natural landscapes (Forman & Alexander, 1998; van der Ree *et al.,* 2015). However, the prevalent framework of LTI development leaves little scope for early integration of biodiversity concerns into development plans. The impacts of LTI on wildlife are considered much later in the LTI project development phase, and often lead to sub-optimal biodiversity mitigation strategies.

While the current progress in developing LTI across the nation is an important step in achieving economic self-sufficiency and social well-being, such growth at the cost of our natural wealth would impair ecosystem functions and, consequently, national ecological security. Thus, along with fulfilling economic aspirations of the country through development, safeguarding India's natural wealth should also be a priority and a long-term goal for the nation. Here, we aim to make the case for the integration of biodiversity concerns into LTI project design at the inceptive stages of development planning, instead of as post-hoc mitigation measures. Further, we assert that institutionalisation of such a framework is vital to ensure ecological security for a nation that relies heavily on nature and natural resources.

Is nature a speed-bump to economic prosperity?

There are direct benefits to the well-being of India's people and economy by safeguarding nature. In addition to the intrinsic values of preserving nature and wildlife as co-habitants of this planet, safeguarding nature will ensure the flow of the multitude of ecological services that benefit humans like the provision of water, carbon sequestration, and regulation of local climate, hydrological, and mineral cycles (Wood *et al.,* 2018). Further, ecosystem services provided by largely intact natural landscapes act to boost agricultural productivity (Reed *et al.,* 2017), bolster the resilience of human communities against climate change (Hisano *et al.,* 2018), and provide alternate sources of livelihood and economic security to local communities.

Thus, India's largely agrarian economy, socio-economic upliftment of India's populace, and important economic activities such as nature-based tourism are directly dependent on the well-being and integrity of natural resources of the country. Protecting the interests of nature and wildlife while planning and implementing LTI would not only benefit conservation but also secure the lives and livelihoods of the people who are the target beneficiaries of these development plans. From the conservation viewpoint, maintaining the integrity of wildlife corridors and habitat patches against fragmentation and species loss because of LTI reduces downstream costs of conservation actions such as habitat restoration, population augmentation, and wildlife relocation. However, while sustainable development has been flagged to be a key component of India's futuristic LTI development plans, multiple prospects of proactively integrating nature-friendly designs into this realm remain unexplored.

Mitigation or integration?

At present, the loss of human lives and financial losses from road accidents, wastage of fuel, time, and excessive pollution because of traffic congestion are seen as major costs to the environment and society. To resolve these issues, road safety and traffic management strategies like road widening, roundabouts on high traffic junctions, speed control, and guardrails are incorporated into road design. Flyovers and underpasses in cities to handle congestion, bypasses through densely populated settlements, and high-speed trains and metros to transport more passengers in less time are all requirement-based transportation designs. These strategies, for which guidelines are diligently followed by LTI development agencies, involve proactively altering the design of the infrastructure to accommodate requirements that have been anticipated.

Construction of transportation corridors in pristine, intact, and biodiversity-rich areas fragments once contiguous habitat patches (Nayak *et al.,* 2020) and cause wild animal mortality (Silva Lucas *et al.,* 2017). Further, emissions from LTI construction and operation can leach into the surrounding natural landscapes, causing pollution (Ahmed *et al.,* 2020; Ramachandra & Shwetmala, 2009). These, among other impacts, can also lead to significant ecological losses to the nation, adding to ecological restoration and conservation costs to the government. Vehicular collisions with large-bodied wildlife species can also cause significant damage to vehicles and can often be fatal for passengers. Thus, in anticipation of these costs, it is prudent to incorporate biodiversity concerns into LTI planning and design. Consequently, measures to plan alignments of LTI in biodiversity-rich and sensitive landscapes, and structural measures to enable wildlife crossing and reduce mortality, should be treated as integral designs for constructing roads and railway lines through sensitive habitats, and not mitigation measures. Inclusion of these measures in the initial stages of LTI planning and design would ensure that mitigation costs are included in project budgets. Given the sustainability aspirations of the government, seamless integration of biodiversity conservation in development cannot occur till such time that such measures are formally recognised among LTI development agencies as a design necessity, rather than an afterthought.

The prevalent framework

The prevalent system of Environmental Impact Assessment (EIA) in India begins at the screening stage, where projects are assessed for whether an EIA is required or not. At this stage, LTI project proposal costs and alignments have been finalised, and mitigation measures recommended through the EIA process (including avoidance of critical habitats or realignment) are either implausible or add to the pre-approved project costs. Further, formulation of LTI development plans, policies, and schemes does not involve strategic environmental assessments or SEAs, and sectoral or regional environmental assessments (Saxena *et al.,* 2016). As a consequence of this and isolated sectoral development planning, most large-scale development plans fail to adequately integrate biodiversity and environmental protection measures.

The mitigation hierarchy is a framework that aims to avoid, reduce, and compensate for adverse environmental impacts of developmental projects by avoiding critical habitats, altering project design and construction methods to reduce impacts, and restoring the natural state and function of alternate sites through the steps of Avoidance, Minimization or Mitigation, Remediation, and Compensation (CEQ, 2000). The hierarchy is ideally followed in that order, *i.e.*, first, avoid development and consequent impacts, second, include measures to minimize and

mitigate most impacts for unavoidable projects, and lastly, compensate for residual impacts.

Contrasted against this framework, the prevalent LTI planning and assessment paradigm in India leaves out ecology from the initial phases, which is why 'mitigation' at later stages is required. Mitigation, *i.e.*, the act of taking measures to reduce the severity or harmfulness of some activity, is thus seen as a band-aid for the impacts that could have been avoided. Some characteristics of the present LTI planning framework that have caused mitigation measures to gain a bad reputation are as under:

- In addition to a disconnect with environmental and natural resource managers, and stakeholders at planning stages, different transportation agencies belonging to the same sector have separate plans for LTI in the same geographical region, leading to multiple transportation corridors in the vicinity of each other, fragmenting landscapes multiple times.

- Consideration of alternative alignments is done primarily from the point of view of project finances and ease of land acquisition.

- Simultaneous land acquisition and environmental clearance application by user agencies for different segments of the same alignment leads to a *fait accompli* situation (Habib *et al.,* 2016). This results in non-feasibility of considering alternate alignments because of pre-emptive land acquisition and construction in land outside of protected areas.

- Non-inclusion of mitigation costs in the initial project budget dilutes mitigation efforts downstream.

Institutionalising integration of biodiversity in development plans

India's efforts in mitigating the impacts of LTI in the past decade have included construction of some of the world's largest wildlife crossing structures on highways (such as those on the National Highway 44 passing through the Pench Tiger Reserves, Maharashtra and Madhya Pradesh), and working towards retrofitting existing LTI. In addition to prohibiting the construction of new LTIs in protected areas (MoRTH, 2019), several road and railway line projects today have mitigation measures in the form of animal crossing structures integrated into the project design. With a few exceptions, these were mostly post-hoc measures that were thought of much after the technical project designs had been approved by authorities, and limited project budgets restricted the consideration of the whole range of mitigation measures. Until procedures to integrate biodiversity concerns into development plans from the initial stages are proactively institutionalised, such endeavours would remain knee-jerk reactions or subject to the prerogatives of decision-makers.

A framework for all stages of the mitigation hierarchy in planning LTI in ecologically sensitive areas

We present here a framework based on the mitigation hierarchy that enables early consideration of biodiversity concerns in LTI planning. Here, delineation of ecologically-sensitive areas where no infrastructure development should take place or 'no-go zones', using a range of criteria can be done during the project planning stage. This information and/or criteria should be further used to plan the optimum LTI alignments on a regional scale. Integration of wildlife-friendly road or railway line design, habitat restoration, and offset costs into project plans and budgets is central to our proposed framework.

Avoidance:

To earmark areas as no-go zones for LTI development, the formulation of appropriate biodiversity criteria is an essential first step to 'conservation planning' as it pertains to LTI development. These criteria may include biodiversity values of the region, such as importance in maintaining species and landscape connectivity, landscape uniqueness and composition, species diversity and endemism, unique ecosystem services, socio-cultural importance, and species and landscape conservation priority. Some of these areas may fall outside the purview of protected areas.

Development of such criteria would be subject to the availability of information denoting the fragility or sensitivity of a region for biodiversity. To this end, ecologists and conservationists must make concerted efforts to generate a readily available database of landscapes and regions at different spatial scales where LTI development should be avoided. This database should be easily accessible to LTI development agencies. In the absence of such information, LTI planners should initiate consultation with conservation agencies and researchers to generate this information. Further, rerouting of LTI alignments to avoid critical habitats would require mechanisms such as cost-benefit analyses to determine the best alternative alignments that would help achieve socio-economic benefits while reducing costs to nature and wildlife (Fyumagwa *et al.,* 2013). Alternative alignments should be designed accordingly, in consultation with all stakeholders, *viz.*, local communities, social scientists, and conservation agencies.

Avoidance of LTI alignments through ecologically-sensitive areas can also be achieved through inter-sectoral coordination and integrated planning, which has been highlighted as a critical strategy under the 'six pillars' of Gati Shakti, India's ambitious transportation plan for economic and sustainable development (PMGS-NMP, n.d.).

Wildlife-friendly LTI design and habitat restoration:

Wildlife-friendly strategies such as crossing structures and fencing, and site restoration measures for LTI should be integrated during the designing stage, as opposed to the prevalent practice of revising the approved project design at later stages to accommodate biodiversity concerns. Incorporation of wildlife-friendly designs are especially important for upgradation plans of existing LTI alignments, where implementing such measures can greatly reduce barrier and mortality effects. The design of such measures, as prescribed in best practice guidelines, should be done in consultation with biodiversity experts and infrastructure specialists.

Offsetting:

In India, the compensatory afforestation (CA) scheme is akin to biodiversity offsets, wherein user agencies are required to fund land acquisition and afforestation activities in non-forest land in lieu of forest land diverted for non-forestry purposes. The scheme allows for the reclamation and restoration of degraded lands, and in case of LTI projects, CA funds can be used for restoring degraded wildlife corridors, potentially leading to a measurable improvement in corridor functionality (Dutta *et al.,* 2018). This activity should go beyond mere afforestation, and can include corridor management, removal of invasives, strengthening of protection, and human-wildlife conflict mitigation in corridor areas. A description and timeline of activities should be included in the project plan too.

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Conclusion

In India, we have made significant strides in terms of mitigating the impacts of LTI on wildlife. These include some of the world's largest wildlife crossing structures on roads and railway lines in vital wildlife landscapes, and proactive efforts by LTI agencies to mitigate the impacts of new and existing infrastructure. Systematic efforts are now required to keep up the momentum of development that is in sync with nature conservation. These efforts must build on the lacunae of the prevalent LTI planning paradigm, which presently lead to downstream losses for both LTI projects and biodiversity.

Considering the importance of maintaining connected landscapes for long-term viable conservation, it is pertinent that LTI, which is a major threat to achieving this connectivity, also approaches planning in a similar way. In other words, strategic and sectoral planning, *i.e.*, LTI planning at a broader scale, and integration of wildlife-friendly measures into LTI design are central to ensuring the compatibility of India's development and conservation goals.

The need to inculcate LTI planning practices that safeguard nature and avoid critical intact landscapes is imminent, considering the accelerated increase in the Indian road and railway infrastructure, and the simultaneous recognition of the role of maintaining intact natural landscapes for human well-being. The framework proposed here aims to integrate these two national priorities, both of which have repercussions for socio-economic development and long-term ecological and economic security. Adoption of such a framework would help achieve overall socio-economic benefits from LTI development as well as the availability of ecosystem services from intact natural landscapes, particularly in rural India where most of the LTI projects are envisioned.

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CONFLICT OF INTEREST

Dr. Bilal Habib is the Managing Editor, and Dr. Akanksha Saxena is an Academic Editor at the Journal of Wildlife Science. However, they did not participate in the peer review process of this article except as authors. The authors declare no other conflict of interest.

DATA AVAILABILITY

No additional data was used in this research.

AUTHOR CONTRIBUTIONS

BH conceived the idea, AS wrote the first draft of the paper. Both BH and AS revised the initial draft and approved the final draft for submission. Both authors contributed equally to the paper.

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