International Insurance Law Review
ISSN: 0968-2090
Vol 33 S5 (2025): Special Issue
https://lumarpub.com/iilr

Environmental Risks and Insurance Strategies for Climate-Resilient Road Infrastructure in India: Policy Gaps, Risk Transfer Mechanisms, and Institutional Pathways

L. Somasundaram
Assistant Professor, Bharathidasan Institute of Management, Tiruchirappalli, India.
Email: somasundaram@bim.edu

Abstract
India's road infrastructure, comprising national, state, and rural networks, faces escalating environmental threats from climate-induced hazards such as floods, heatwaves, and landslides. These hazards compromise structural integrity, reduce asset lifespans, and increase maintenance expenditures, posing significant challenges to transport resilience. The purpose of this study is to estimate the nature and magnitude of environmental risks, examine the sufficiency of current insurance mechanisms, and recommend ways to incorporate climate resilience in road infrastructure planning and financing. The study method involved a mixed-methods approach integrating policy analysis, spatial risk assessment, and comparative analysis of insurance products. Historical and future climate data were examined in conjunction with contractual frameworks and case studies to determine vulnerabilities and institutional lacunae. Findings reveal that flooding is the most costly hazard and impacts more than 11,200 km of roads each year, with costs over ₹4,800 crore. Conventional insurance products continue to be narrow in scope, while parametric models offer quicker compensation but are hampered by adoption. Case studies show that climate-resilient designs can decrease maintenance expenses by as much as 40% and greatly extend asset life. The results point towards the necessity of comprehensive risk governance, niche insurance products, and innovative funding tools. Integrating climate risk analysis into planning and regulation procedures, coupled with enhanced institutional coordination and performance-based contracts, will be key to creating a climate-resilient road network infrastructure that can absorb tomorrow's environmental stressors.
Keywords: Climate Resilience, Road Infrastructure, Environmental Risks, Insurance Mechanisms, Infrastructure Planning

Introduction

India has one of the largest road networks in the world, including National Highways (NH), State Highways (SH), and rural roads that together constitute the backbone of economic growth, trade connectivity, and regional integration (Uprety & Chhetri, 2024). Road infrastructure acts as a key driver of industrialisation, agricultural supply chains, and social mobility, connecting distant communities with urban markets and basic services (Jena & Chaudhary, 2025). While demand for mobility has only continued to escalate, the durability and reliability of this network have progressively gained importance for maintaining national growth paths (Anjanappa, 2024). Yet more extreme climatic variability poses deep challenges to infrastructure stability. Floods that recur, extended heatwaves, and recurrent landslides have started to put pressure on design requirements, materials used during construction, and maintenance practices, damaging the life cycle of operation of key road assets (Goswami *et al.*, 2023; Singh, 2025). These once episodic

Citation: Somasundaram, L. (2025). Environmental Risks and Insurance Strategies for Climate-Resilient Road Infrastructure in India: Policy Gaps, Risk Transfer Mechanisms, and Institutional Pathways. *International Insurance Law Review*, 33 (S5), 278-290.

disturbances are now developing into systemic risks that challenge long-term transport resilience (Sundararajan & Suriyagoda, 2016).

The current study and policy experience in India regarding infrastructure risk management primarily deals with traditional construction stage exposures, including geotechnical failure, cost overrun, and project delay (Ali & Kamraju, 2025). Climatic hazards, though, are insufficiently included in risk transfer arrangements and project appraisal methodologies (Abbasov, 2025). The majority of insurance offerings for road infrastructure, including Contractor's All Risk (CAR) and Erection All Risk (EAR) policies, provide limited coverage after the construction phase, overlooking operational and post-construction risks (Srinivasan *et al.,* 2023). Additionally, holistic strategies integrating climate hazard projections with asset-level risk evaluations, financial protection mechanisms, and adaptive design thresholds are rare (Ray *et al.,* 2021). Such a gap has led to episodic reactions to environmental uncertainty, subjecting infrastructure assets to mounting climatic stressors throughout their life cycle (Rogers *et al.,* 2018). This deficit must be overcome to consolidate national transport planning with unfolding climate conditions and realise infrastructure sustainability (Arunachalam, 2024). The regulation of road infrastructure and connected risk management consists of a sophisticated institutional web. The Insurance Regulatory and Development Authority of India (IRDAI) governs the insurance industry, influencing the area and terms of risk transfer instruments (Singh *et al.,* 2018; Talwar, 2024). The Ministry of Road Transport and Highways (MoRTH) handles policy making and sector planning, and the National Highways Authority of India (NHAI) deals with the construction and maintenance of national highways (Ramaswami *et al.,* 2023). At the subnational level, State Public Works Departments (PWDs) deliver state highways and rural road projects, and the National Disaster Management Authority (NDMA) oversees disaster risk reduction planning (Chaturvedi *et al.,* 2024). Although their mandates complement each other, coordination is limited between these institutions, which inhibits building united strategies for climate-resilient infrastructure and end-to-end insurance coverage (Malik *et al.,* 2023).

The main aim of this study is to undertake a thorough evaluation of environmental threats on road infrastructure in India and analyse the efficiency of current insurance schemes in addressing these issues. It seeks to analyse the impact of climatic hazards like floods, heatwaves, and landslides on the structural integrity, operation, and lifecycle performance of different road infrastructures like pavements, bridges, tunnels, and cut slopes in national, state, and rural road networks. Another aim is to recognise existing gaps in available risk transfer tools and consider innovative insurance schemes that can more effectively keep pace with changing climatic conditions. Further, the analysis tries to decipher the institutional, regulatory, and contractual forces influencing the approach to environmental risks, with a specific focus on the relationship between IRDAI, MoRTH, NHAI, State PWDs, and NDMA. The study also aims to suggest policy avenues and financial frameworks incorporating climate risk analysis into infrastructure planning, improving insurance penetration, and increasing long-term resilience, making the road network operational, safe, and sustainable under future climatic conditions.

Methodology

Study Design and Analytical Approach

The study has a qualitative, mixed-methods design meant to bring together policy analysis, spatial risk assessment, and comparative assessment of insurance mechanisms. This is made possible to

Citation: Somasundaram, L. (2025). Environmental Risks and Insurance Strategies for Climate-Resilient Road Infrastructure in India: Policy Gaps, Risk Transfer Mechanisms, and Institutional Pathways. *International Insurance Law Review*, 33 (S5), 278-290.

facilitate an integrated comprehension of the intricate relationship between climate hazards, infrastructure susceptibility, and financial risk transfer tools. Policy documents, legislative provisions, and regulatory guidelines are subject to critical analysis to assess the institutional reaction to climate threats. Spatial data analysis facilitates the identification of spatial patterns in exposure to risk, and comparative product analysis emphasises structural gaps and opportunities for innovation. Multilayered methodology allows for thorough exploration of physical vulnerabilities and financial protection mechanisms within the road infrastructure sector.

Data and Scenario Development

The study is based on a blend of historical data sets and projected future climates to account for the entire range of environmental hazards. Observed patterns in rainfall intensity, temperature change, and frequency of extreme events are based on historical climate records between 1981 and 2020. Climate scenarios for future projections are modelled for the years 2030, 2050, and 2080 under the Representative Concentration Pathways (RCP) 4.5 and 8.5. Hazard frequency and magnitude are expressed in terms of return periods of 1-in-50-year and 1-in-100-year events for flooding, landslides, and heat waves. Uncertainty is handled with ensemble modelling and sensitivity analysis to allow rigorous scenario planning under multiple climate futures. This systematic method ensures that existing and future risk dynamics are identified for effective infrastructure planning and insurance product development.

The data used in this study are sourced from authoritative institutional publications. Historical climate and hazard information was obtained from the India Meteorological Department (IMD) and the National Disaster Management Authority (NDMA), with road damage and cost data provided by the Ministry of Road Transport and Highways (MoRTH). Insurance-related evidence was compiled from the Insurance Regulatory and Development Authority of India (IRDAI) and sector statistics published by the General Insurance Council of India. Institutional performance assessments relied on official reports of MoRTH, the National Highways Authority of India (NHAI), and IRDAI. Case study insights for the Madhya Pradesh Rural Connectivity Project were drawn from World Bank project documents, while findings on the Char Dham Highway Development were based on MoRTH/NHAI records. Lifecycle cost modelling utilised MoRTH/NHAI asset management data together with analyses by the Central Road Research Institute (CRRI). Contractual and financing arrangements were compiled from the Department of Economic Affairs (DEA), Ministry of Finance, and MoRTH/NHAI frameworks. These institutional sources ensure authenticity, traceability, and alignment of the study with officially published data.

Risk Mapping Tools and Methods

Spatial risk mapping is an integral part of the approach, integrating hazard, exposure, and vulnerability information within a geospatial context. Geographic Information System (GIS) layers for flood depth and frequency, landslide susceptibility, and heat stress indices are created. These are combined with infrastructure asset maps to select high-risk areas and vital vulnerabilities. A Multi-Criteria Decision Analysis (MCDA) methodology, complemented by the Analytic Hierarchy Process (AHP), is utilised to weight various risk factors and combine them into an aggregate risk index. Through this method, the highest-priority areas at which climate hazards will likely affect road infrastructure are determined, informing both engineering and insurance cover strategies.

Citation: Somasundaram, L. (2025). Environmental Risks and Insurance Strategies for Climate-Resilient Road Infrastructure in India: Policy Gaps, Risk Transfer Mechanisms, and Institutional Pathways. *International Insurance Law Review*, 33 (S5), 278-290.

Insurance Product Analysis

A comprehensive comparative analysis of current and pending insurance covers is performed to determine their applicability and sufficiency for road infrastructure exposed to climatic stress. The analysis compares the scope of coverage, exclusions, and performance under Contractor's All Risk (CAR) and Erection All Risk (EAR) policies, which largely cover construction-stage risks. Further layers of protection, including Natural Catastrophe (NatCat) add-ons, are evaluated for applicability to operational and post-construction stages. Parametric and index-based insurance structures are tested in terms of trigger design, basis risk, payment speed, and suitability for types of hazards. This evaluation also points out the shortcomings of classic indemnity-based structures and determines how new instruments might bridge gaps in coverage and enhance financial resilience.

PPP and Contractual Review

Public-Private Partnership (PPP) structures and infrastructure deals are comprehensively analysed to assess whether risk sharing and insurance liabilities are framed. The evaluation encompasses Engineering, Procurement and Construction (EPC), Hybrid Annuity Model (HAM), and Build-Operate-Transfer (BOT) structures, with a view to the allocation of environmental risks among public authorities, private developers, and financiers. Specific attention is paid to force majeure provisions, insurance requirements, and financial liability provisions under climate events. The results shed light on the manner in which contractual frameworks drive insurance solution adoption and risk-sharing arrangements in infrastructure delivery models.

Ethics and Equity Considerations

Equity and social protection are central to the methodology, shaping the choice of case studies and the interpretation of results. Locations are selected with care to ecological and social settings, focusing on places where wildlife corridors of migration, tribal lands, and environmentally sensitive areas overlap. Ethical concerns also include considering the distributional effects of climate threats and insurance schemes so that vulnerable groups and ecosystems are not unequally subjected to infrastructure development or risk transfer initiatives.

Limitations of the Study

Several limitations affect the scope and interpretation of results. High-resolution hazard and exposure data tend to be lacking in areas away from principal transportation corridors, which restricts the accuracy of spatial risk estimates in distant or underdeveloped areas. Parametric models, although promising, suffer from inherent basis risk, where payments may not perfectly align with actual damages, creating potential financial protection mismatches. Moreover, variations in data quality, methodology, and reporting practices of institutions can influence the comparability of insurance products and risk evaluations. Notwithstanding these limitations, the methodological framework provides a sound basis for assessing the convergence of environmental risks, infrastructure susceptibility, and financial resilience measures in Indian road infrastructure.

Citation: Somasundaram, L. (2025). Environmental Risks and Insurance Strategies for Climate-Resilient Road Infrastructure in India: Policy Gaps, Risk Transfer Mechanisms, and Institutional Pathways. *International Insurance Law Review*, 33 (S5), 278-290.

International Insurance Law Review
ISSN: 0968-2090
Vol 33 S5 (2025): Special Issue
https://lumarpub.com/iilr

Results

Environmental Risk Profile and Vulnerabilities

India's road infrastructure is subject to severe exposure to climate-related dangers, with floods, heat waves, and landslides being significant hazards. Pavements and bridges are often damaged by floods, whereas the deterioration of asphalt and structural fatigue accelerate due to high temperatures. Hilly landscapes are highly vulnerable to slope failures, causing connectivity interruption and amplifying maintenance requirements. Ecological hazards, including wildlife accidents and habitat disintegration, also impact network sustainability. These vulnerabilities highlight the need to incorporate hazard mapping, resilient design, and risk-based planning into infrastructure investment. Table 1 shows the frequency of major environmental hazards on road infrastructure, the degree of road damage, and estimated financial losses. The evidence presents flooding as the most common and destructive hazard, followed by heatwaves and landslides.

Table 1: Impact of Major Environmental Hazards on Road Infrastructure in India

Hazard Type	Avg. Annual Events	Affected Road (km)	Estimated Damage (₹ Cr)
Flooding	45	11,200	4,800
Heatwaves	20	7,600	3,100
Landslides	35	4,300	2,600

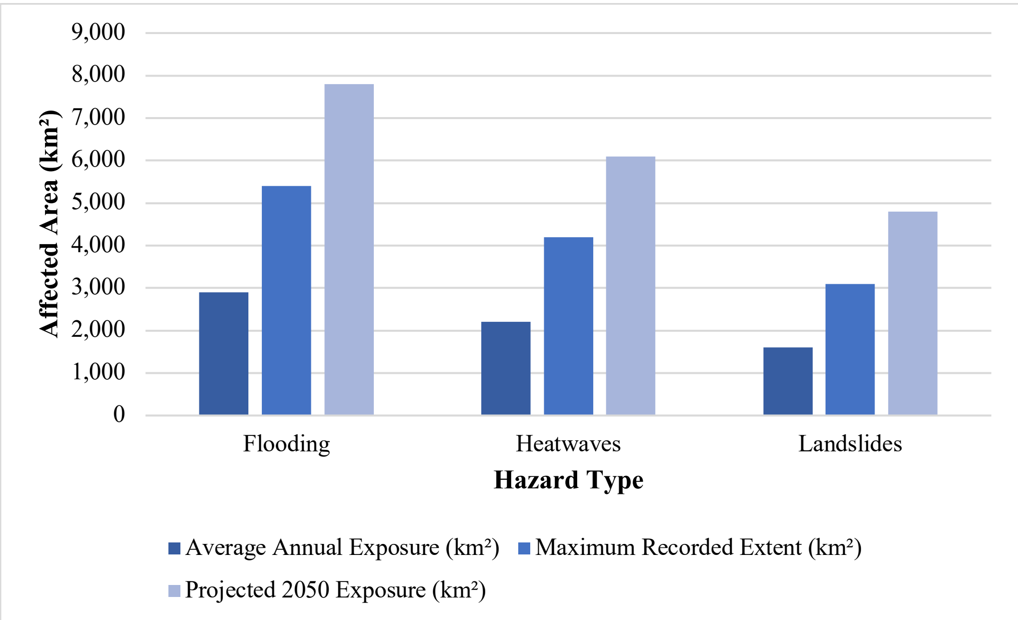

Figure 1: Comparative Hazard Impact Metrics on Road Infrastructure

Figure 1 shows the geographical extent of the impact of major hazards on road infrastructure. Flooding impacts approximately 2,900 km^2 per year, reaching a peak of 5,400 km^2 and estimated to reach 7,800 km^2 by 2050. Heatwaves affect 2,200 km^2 per year, growing to 6,100 km^2, and landslides impact 1,600 km^2, growing to 4,800 km^2.

Insurance Landscape and Market Gaps

Existing insurance products primarily address construction-stage risks through CAR and EAR policies, which give inadequate cover for climate-driven losses during operation. NatCat add-ons

Citation: Somasundaram, L. (2025). Environmental Risks and Insurance Strategies for Climate-Resilient Road Infrastructure in India: Policy Gaps, Risk Transfer Mechanisms, and Institutional Pathways. *International Insurance Law Review*, 33 (S5), 278-290.

provide limited protection but usually do not cover secondary effects like asset deterioration and permanent service interruption. New alternatives, such as parametric and index products, offer quicker settlements but are held back by basis risk and low take-up. As a whole, there remains a considerable gap between real-life infrastructure risk exposure and the extent of available financial protection in the Indian insurance sector. Table 2 shows a summary of the comparison of flagship insurance products applied to road infrastructure, including coverage share, cost of premium, and timing of payout. CAR/EAR policies have the largest market share, with parametric covers, although more rapid in payout, are still underutilised.

Table 2: Comparison of Insurance Products for Road Infrastructure Projects

Policy Type	Coverage (%)	Avg. Premium (₹ Cr)	Avg. Payout Time (days)
CAR/EAR	68	2.5	75
NatCat Add-ons	22	1.8	90
Parametric Cover	10	2.2	20

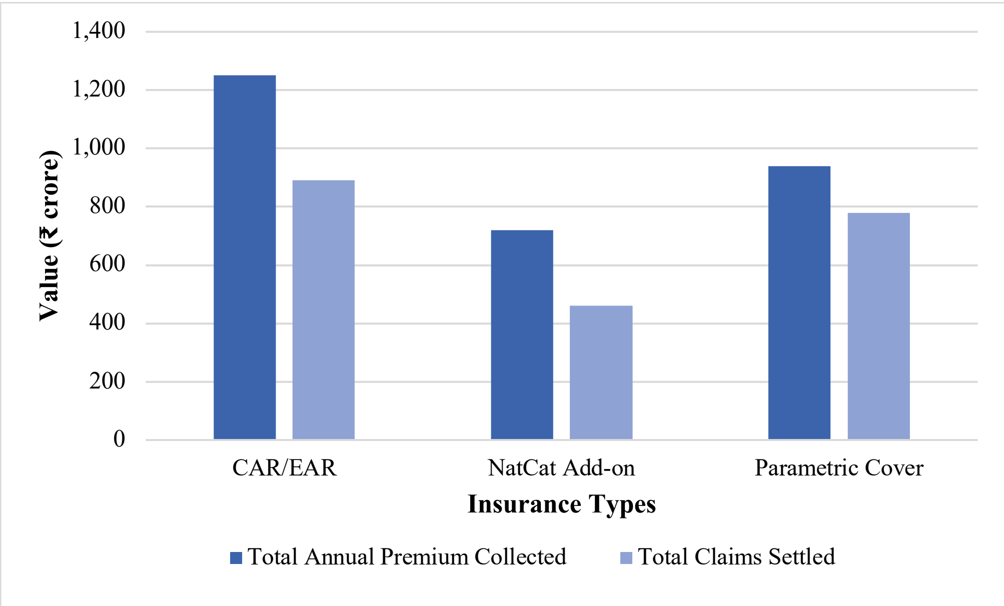

Figure 2: Comparative Analysis of Premium Collection and Claims Settlement Across Insurance Types

Figure 2 shows the performance of insurance. CAR/EAR received around ₹1,250 crore premiums and paid ₹890 crore in claims. NatCat Add-on received ₹720 crore and paid ₹460 crore, whereas Parametric Cover received ₹940 crore and paid ₹780 crore, reflecting improved settlement efficiency in parametric products.

Policy, Regulatory, and Institutional Framework

Operational regulatory tools like IRC Code 65-2017 and EIA guidelines constitute baseline guidelines for environmental considerations, but are customarily implemented inconsistently. Integration challenges between IRDAI, MoRTH, NHAI, NDMA, and State PWDs impede systematic climate risk governance. Penetration of insurance in infrastructure is low due to lacklustre mandates and restricted linkage to project approvals. Strengthening institutional coordination

Citation: Somasundaram, L. (2025). Environmental Risks and Insurance Strategies for Climate-Resilient Road Infrastructure in India: Policy Gaps, Risk Transfer Mechanisms, and Institutional Pathways. *International Insurance Law Review*, 33 (S5), 278-290.

and regulatory compliance is critical to mainstreaming climate resilience and integrating infrastructure finance with changing hazard patterns. Table 3 shows the responsibilities of principal institutions in climate risk management, together with their implementation scores and policy convergence scores. The findings reflect moderate levels of coordination, with areas for improvement in regulating actions and harmonising climate policy.

Table 3: Institutional Performance in Climate Risk Governance and Policy Alignment

Institution	Mandate Focus	Implementation Score (%)	Policy Alignment (%)
IRDAI	Insurance Regulation	70	65
MoRTH	Road Policy & Planning	80	72
NHAI	Project Implementation	75	68

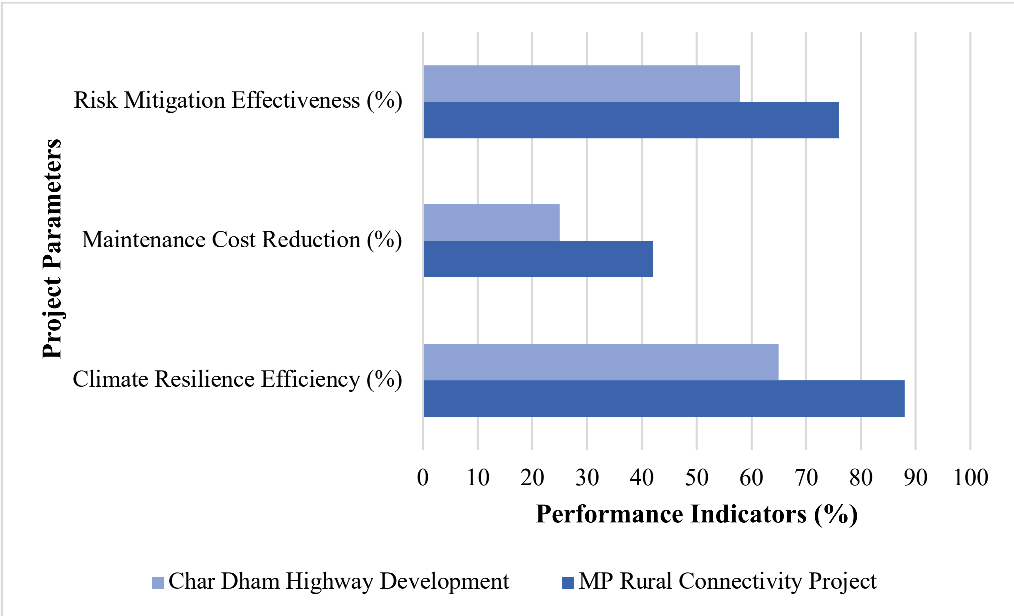

Figure 3: Comparative Performance of Road Infrastructure Projects under Climate Stress

Figure 3 shows project performance by resilience indicators. The MP Rural Connectivity Project has 88% resilience, 42% reduction in maintenance, and 76% risk reduction, whereas the Char Dham Project indicates 65%, 25%, and 58%, which are much stronger results for the MP project.

Case Studies and Applied Lessons

Two projects reflect different strategies to manage climate risk. The Madhya Pradesh Rural Connectivity Project reflects designs that are climate-resilient, reducing maintenance expenditures and improving the quality of services. In contrast, the Char Dham Project showcases conflicts between ecologically friendly preservation and infrastructure expansion, highlighting the importance of balanced planning. These case studies indicate that proactive adaptation and integration with the environment do enhance infrastructure performance and long-term sustainability, while reactive methods result in environmental compromises and cost inefficiencies. Performance indicators for two important infrastructure projects are presented in Table 4, indicating their climate risk strategy and performance. The Madhya Pradesh project

Citation: Somasundaram, L. (2025). Environmental Risks and Insurance Strategies for Climate-Resilient Road Infrastructure in India: Policy Gaps, Risk Transfer Mechanisms, and Institutional Pathways. *International Insurance Law Review*, 33 (S5), 278-290.

exhibits high resilience and cost efficiencies, whereas the Char Dham project indicates moderate adaptation under environmental stress.

Table 4: Comparative Performance Indicators of Key Road Infrastructure Projects

Project Name	Risk Strategy Score (%)	Maintenance Cost Reduction (%)	Resilience Rating
MP Rural Connectivity Project	85	40	High
Char Dham Highway Development	60	15	Moderate

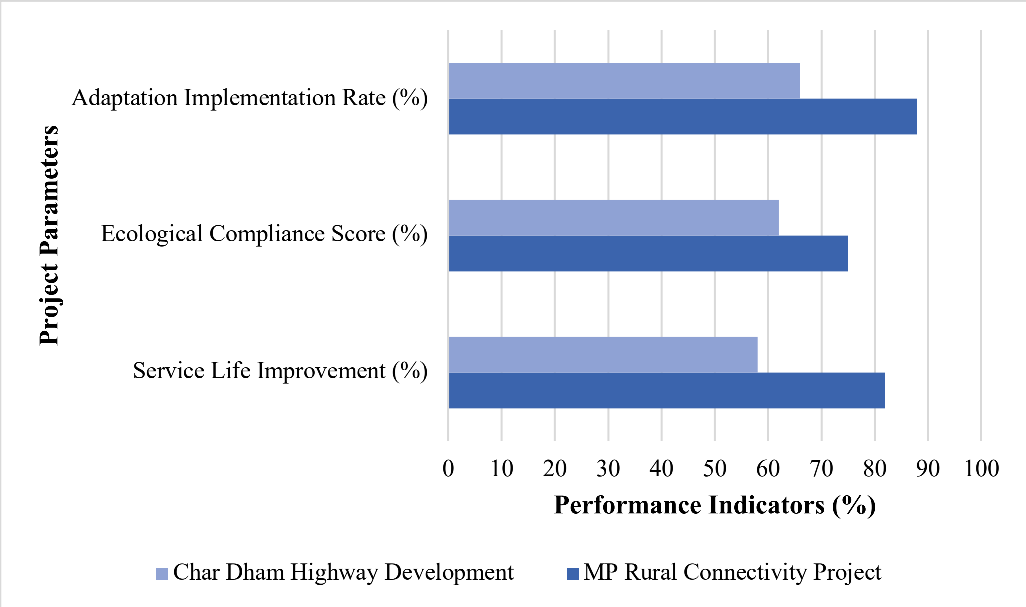

Figure 4: Comparative Performance Metrics of Road Infrastructure Projects

Figure 4 shows project performance in major indicators. The MP Rural Connectivity Project has 82% service life enhancement, 75% environmental compliance, and 88% adaptation implementation, whereas the Char Dham Project achieves 58%, 62%, and 66%, reflecting a higher capability of the MP project.

O&M Lifecycle Economics and Risk Implications

Climate hazards dramatically decrease asset life and boost maintenance costs. Roads that face repeated flooding need more frequent resurfacing, while material fatigue is accelerated by heat stress. They raise lifecycle expenses, affecting concession deals and performance contracts. Economic modelling suggests that forward-looking climate adaptation in insurance planning and design can lower overall O&M costs by as much as 30%. Implementation of climate resilience measures at early stages, therefore, provides significant long-term cost benefits for public authorities as well as private investors. The way in which various hazard scenarios affect maintenance cycles, lifecycle costs, and cost escalation rates is indicated in Table 5. Flood-prone areas have shorter maintenance periods and much greater expense, making it necessary for climate-adaptive design and planning.

Citation: Somasundaram, L. (2025). Environmental Risks and Insurance Strategies for Climate-Resilient Road Infrastructure in India: Policy Gaps, Risk Transfer Mechanisms, and Institutional Pathways. *International Insurance Law Review*, 33 (S5), 278-290.

Table 5: Influence of Climate Hazards on Maintenance Cycles and Lifecycle Costs

Hazard Scenario	Avg. Maintenance Cycle (yrs)	Lifecycle Cost (₹ Cr/km)	Cost Increase (%)
Baseline	8	1.5	-
Flood-Prone	5	2.3	53
Heat-Stressed	6	2.0	33

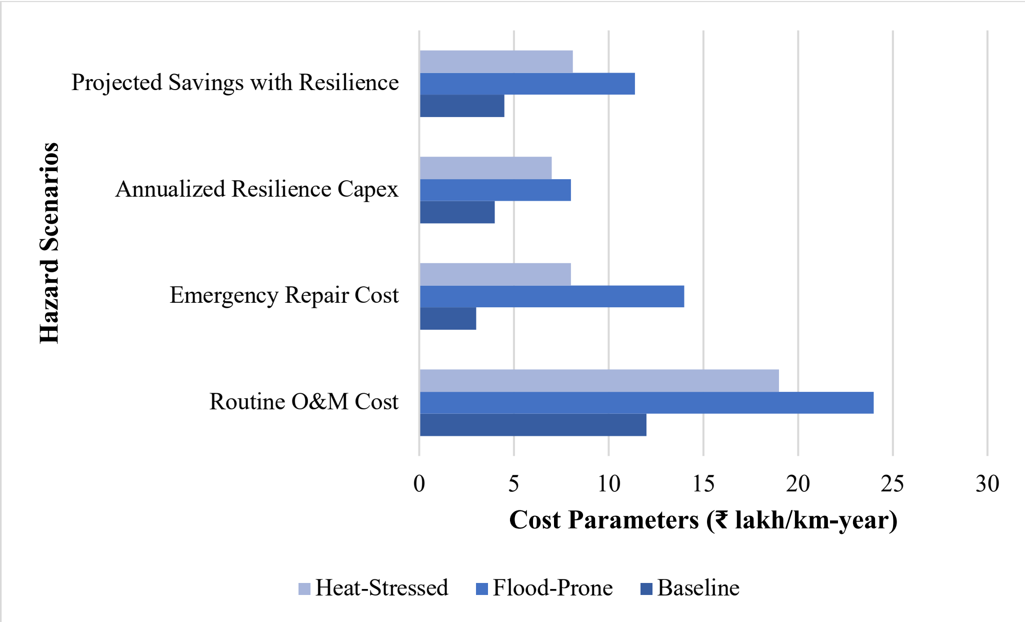

Figure 5: Comparative O&M Cost Distribution Under Different Climate Scenarios

Figure 5 shows O&M cost differences among scenarios. Normal costs increase from ₹12 lakh/km-year in base to ₹24 lakh/km-year in flood vulnerability and ₹19 lakh/km-year with heat stress. Repair during emergencies touches ₹14 lakh/km-year, while resilience savings are over ₹11 lakh/km-year.

Contractual, Financing, and Risk-Sharing Insights

Risk transfer in EPC, HAM, and PPP contracts continues to be imbalanced, and climate-related exposures are frequently under-priced. The great majority of agreements do not have effective provisions for extreme weather conditions, resulting in disputes and delayed recovery. New and innovative financing vehicles like catastrophe bonds, pooled risk funds, and disaster-linked insurance may be used to offer strengthened risk-sharing arrangements. Well-designed force majeure clauses and transparent insurance commitments in contracts would substantially enhance financial resilience and facilitate quick post-disaster recovery without loading public expenditure budgets. Table 6 shows the level of climate risk integration and financial innovation in dominant infrastructure contract models. PPP contracts have the highest risk transfer and innovative finance application levels, reflecting their increasing significance for resilient infrastructure delivery.

Citation: Somasundaram, L. (2025). Environmental Risks and Insurance Strategies for Climate-Resilient Road Infrastructure in India: Policy Gaps, Risk Transfer Mechanisms, and Institutional Pathways. *International Insurance Law Review*, 33 (S5), 278-290.

Table 6: Climate Risk Integration and Financing Innovation Across Contract Models

Contract Model	Climate Risk Clause (%)	Avg. Risk Transfer (%)	Financing Innovation Use (%)
EPC	40	45	20
HAM	55	60	35
PPP	70	75	50

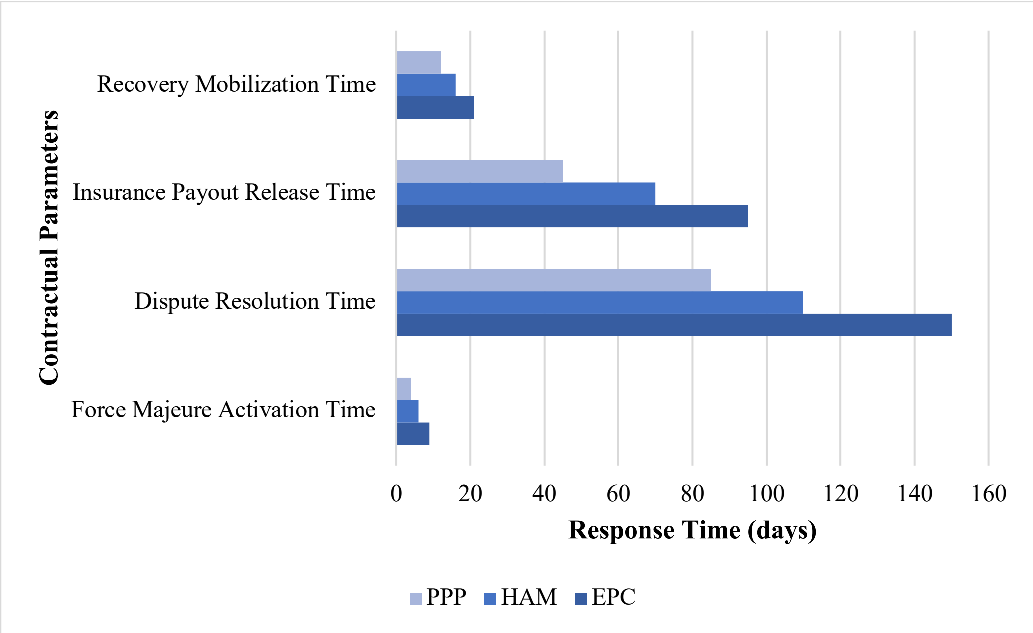

Figure 6: Contractual Response and Recovery Timelines Across Project Models

Figure 6 shows the response timelines for contract types. Force majeure responds in 9, 6, and 4 days for EPC, HAM, and PPP. Dispute resolution operates within 150, 110, and 85 days, insurance payments take 95, 70, and 45 days, and recovery mobilisation takes 21, 16, and 12 days, with PPP being the quickest to respond.

Discussion

The findings show a distinct relationship between climate-driven hazards and infrastructure vulnerability, with considerable economic and operational impacts. Flooding is the most common and destructive hazard, impacting more than 11,200 km of roads every year and incurring estimated losses of ₹4,800 crore (Table 1). Heatwaves and landslides rank next at ₹3,100 crore and ₹2,600 crore, respectively, asserting the necessity for region-specific adaptation policies. Insurance mechanisms, though vital, remain insufficiently developed. Traditional CAR/EAR policies account for 68% of market coverage but average 75 days in payout time, whereas parametric products, despite representing only 10%, settle claims in 20 days, indicating their efficiency (Table 2). Institutional analysis reveals moderate coordination, with MoRTH achieving an implementation score of 80% and policy alignment of 72%, whereas IRDAI's alignment remains at 65% (Table 3). Case studies also underscore the payoffs of anticipatory adaptation. The Madhya Pradesh Rural Connectivity Project demonstrates a 40% saving in maintenance costs and a high resilience rating, against 15% cost saving and moderate resilience for the Char Dham project (Table 4). Lifecycle economics demonstrate flood-prone areas have 53% greater costs with cycles shortened from 8 to 5 years (Table 5). Contractually, PPP models have the highest level of climate risk clause inclusion (70%) and shortest recovery mobilisation (12 days) in comparison to EPC models (21 days) (Table 6).

The report points towards an immediate need to embed climate resilience into all stages of infrastructure planning and finance. Sudden asset deterioration and rising O&M expenditures under climatic stress announce the need for adaptive design guidelines, improved material grades, and forward-looking risk modelling. Speeding up the implementation of parametric and catastrophe-tied insurance mechanisms can fill prevailing financial protection gaps and enhance post-disaster liquidity. In addition, institutional synergy is essential; efficient coordination among implementing and regulating bodies would improve enforcement, provide improved data sharing, and facilitate building integrated risk-transfer schemes.

The trends observed are in line with wider global evidence that road infrastructure in climate-sensitive areas is subject to increasing costs and decreased service life under intensified environmental pressures (Gupta *et al.,* 2019). Other studies highlight the effectiveness of parametric insurance in facilitating quicker payouts, further enforcing the potential advantages of its increased coverage (Salman *et al.,* 2025). The focus on proactive adaptation and incorporation of environmental appraisals into project design conforms to international best practice, which has demonstrated that such an approach can reduce long-term maintenance expenses by a large margin and increase network reliability. The PPP contract analysis is also in line with a global trend towards increased private sector participation in risk sharing and resilience financing (Krishnakumar, 2025).

Plans should target mainstreaming climate risk assessments in the project appraisal process, regulatory approvals, and funding structures. Having a common data repository of hazards and vulnerabilities would enhance forecasting accuracy and risk pricing. Creating specialised insurance products by asset types, geographic zones, and hazard profiles can further enhance financial resilience. Investment in climate-resilient and green infrastructure technologies, together with the inclusion of catastrophe bonds and sovereign risk pools, would diversify funding sources and minimise fiscal pressures. Finally, institutionalising resilience indicators and coupling them with performance-based contracts has the potential to make India's road sector a paradigm of adaptive infrastructure planning.

Conclusion

The study emphasises that climate-driven environmental hazards are a major threat to the sustainability and operability of India's large road infrastructure network. Floods, heatwaves, and landslides drastically shorten asset life cycles, increase maintenance, and cause disruptions in connectivity, with flooding alone inflicting an estimated loss of over ₹4,800 crore each year. Traditional mechanisms like CAR and EAR policies are still mostly limited to the construction period and provide insufficient post-construction protection against risk. Parametric and index-based insurance products exhibit higher payout efficacy but are still underutilised. Institutional fragmentation between regulatory and implementation agencies further limits the development of integrated climate risk strategies. Case studies demonstrate that projects incorporating climate-resilient design, adaptive planning, and effective risk management provide significantly enhanced resilience and cost effectiveness than those using traditional strategies. The conclusions support integrating considerations for climate risk into all phases of infrastructure development

Citation: Somasundaram, L. (2025). Environmental Risks and Insurance Strategies for Climate-Resilient Road Infrastructure in India: Policy Gaps, Risk Transfer Mechanisms, and Institutional Pathways. *International Insurance Law Review*, 33 (S5), 278-290.

planning, design, and financing. Enhanced coordination between institutions like IRDAI, MoRTH, NHAI, NDMA, and State PWDs is necessary to enhance the governance and sharing of data. Scaling up innovative financial tools, creating tailored insurance products, and the inclusion of resilience performance-based metrics in contracts can improve adaptive capacity. Proactive policy changes, well-informed hazard mapping, and continued investment in resilient technologies will be instrumental in protecting India's road infrastructure from growing climate uncertainties and guaranteeing long-term economic stability and connectivity.
This study also points further research requirements in this sector, particularly in the area of environmental impact analysis (EIA). EIA is a regulatory requirement in large projects before they can be commenced. The policy should strengthen the outcome analysis of EIA on a periodic basis.

References
1. Abbasov, R. (2025). Bridging Climate Adaptation Gaps: Economic Policies, Financial Mechanisms, and Stakeholder Integration for Resilient Development. American Journal of Economics and Business Management, 8(4), 1529-1541.
2. Ali, M. A., & Kamraju, M. (2025). Financial Imperatives and Innovations for Climate Resilience. In Global Climate Governance: Strategies for Effective Management (pp. 89-122). Singapore: Springer Nature Singapore.
3. Anjanappa, J. (2024). Unlocking Private Sector Potential in Climate Adaptation and Resilience in India. Available at SSRN 4947360.
4. Arunachalam, R. S. (2024). Climate Adaptation and Mitigation Finance for Low-Income Populations in India: A Comprehensive. Inclusive Finance India Report 2024, 115.
5. Chaturvedi, V., Ghosh, A., Garg, A., Avashia, V., Vishwanathan, S. S., Gupta, D., ... & Prasad, S. (2024). India's pathway to net zero by 2070: status, challenges, and way forward. Environmental Research Letters, 19(11), 112501.
6. Goswami, M., Gupta, A. K., Kishan, R., Baidya, S., Khan, Y. I., Prakash, S., ... & Nautiyal, S. (2023). An evaluation of climate resilient agricultural practices in India: a narrative synthesis of literature. Environmental Sustainability, 6(1), 7-23.
7. Gupta, A. K., Mani, N., Sarkar, B. B., Singh, S., & Katyal, S. (2019). Developing disaster risk resilient cities. Gorakhpur Environmental Action Group (GEAG), Gorakhpur (UP), National Institute of Disaster Management, New Delhi, India and United Nations Children's Fund (UNICEF), India, 72.
8. Jena, L. P., & Chaudhary, A. (2025). Adaptation Now: Bridging India's Climate Resilience Financing Gap. Available at SSRN 5300378.
9. Krishnakumar, S. (2025). Blue-Green Infrastructure for Climate Resilience: Aiding Urban Development. In Integrating Blue-Green Infrastructure Into Urban Development (pp. 99-128). IGI Global Scientific Publishing.
10. Malik, R., Verma, J., & Sharma, A. (2023). Climate Change Resilience Support in the Insurance Sector. The Impact of Climate Change and Sustainability Standards on the Insurance Market, 127-142.
11. Ramaswami, A., Pandey, B., Li, Q., Das, K., & Nagpure, A. (2023). Toward zero-carbon urban transitions with health, climate resilience, and equity co-benefits: assessing nexus linkages. Annual Review of Environment and Resources, 48(1), 81-121.

Citation: Somasundaram, L. (2025). Environmental Risks and Insurance Strategies for Climate-Resilient Road Infrastructure in India: Policy Gaps, Risk Transfer Mechanisms, and Institutional Pathways. *International Insurance Law Review*, 33 (S5), 278-290.

12. Ray, S., Jain, S., & Thakur, V. (2021). Financing India's disaster risk resilience strategy (No. 404). Working Paper.
13. Rogers, D. P., Kootval, H., & Tsirkunov, V. V. (2018). Early warning, resilient infrastructure and risk transfer. In Bridging science and policy implications for managing climate extremes (pp. 65-79).
14. Salman, M., Najid, S. V. P., Ali, U., Khairoowala, Z., & Siddiquee, T. A. R. (2025). Building for Tomorrow: Climate-Resilient Infrastructure Strategies for Urban Sustainability. In Urbanization, Climate Change, and Health: Integrating Strategies for Sustainable and Resilient Cities (pp. 291-311). Cham: Springer Nature Switzerland.
15. Singh, A. (2025). Fiscal Federalism and Climate Change: Building the Institutional Framework in India. Indian Public Policy Review, 6(1), 78-122.
16. Singh, D., Chopde, S. K., Raghuvanshi, S. S., Gupta, A. K., & Guleria, S. (2018). Climate resilient disaster risk management: Best practices compendium. Department of Relief and Rehabilitation, Govt of Maharashtra and Climate Change Innovation Programme-Action on Climate Today (ACT). P, 62(1), 5.
17. Srinivasan, M., Ghoge, K., Haldar, S., Bazaz, A., & Revi, A. (2023). Climate finance in India 2023.
18. Sundararajan, S., & Suriyagoda, N. (2016). Climate risks and resilience in infrastructure PPPs: issues to be considered. World Bank Group.
19. Talwar, S. S. (2024). Sustainable Development in India: Institutional Architecture, Sectoral Pathways, and Equity-Centred Transitions. Journal of East-West Thought (JET) ISSN (O): 2168-2259 UGC CARE I, 14(2), 406-421.
20. Uprety, S. K., & Chhetri, R. P. (2024). Adopting a Low-Emission and Climate-Resilient Development Pathway in Nepal. Prakriti Resources Centre: Kathmandu, Nepal.

Citation: Somasundaram, L. (2025). Environmental Risks and Insurance Strategies for Climate-Resilient Road Infrastructure in India: Policy Gaps, Risk Transfer Mechanisms, and Institutional Pathways. *International Insurance Law Review*, 33 (S5), 278-290.