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NH-12037/3/2025/Tunnel/Zone-I

Government of India

Ministry of Road Transport & Highways

(Tunnel Zone)

No.1, Parliament Street, Transport Bhawan, New Delhi-110001

Dated: 02nd September, 2025

To:

1. The Chief Secretaries of all the State Governments/UTs
2. The Principal Secretaries/ Secretaries of all States/ UTs Public Works Department/ Road Construction Department/ Highways Department (dealing with National Highways and other centrally sponsored schemes)
3. The Director General (Border Roads), Seema Sadak Bhawan, Ring Road, New Delhi- 110 010.
4. The Chairman, National Highways Authority of India, G-5 & 6, Sector-10, Dwarka, New Delhi-110 075.
5. The Managing Director, National Highway infrastructure Development Corporation Ltd.,2nd Floor, Tower A, World Trade Centre, Nauroji Nagar,New Delhi - 110029
6. All Engineers-in-Chief and Chief Engineers of Public Works Department of States/ UTs/Road Construction Department/ Highways Departments (dealing with National Highways and other Centrally Sponsored Schemes.
7. The Secretary General, Indian Roads Congress
8. The Director, IAHE, Noida, UP

Subject: Standard Operating Procedure (SOP) for NH Tunnel Alignment Studies and approval- reg.

Sir,

Tunnel projects are capital-intensive and are associated with high risk due to uncertainties of the underlying strata. Therefore, proper planning and investigations are critical for the successful implementation of tunnel projects. Improper /deficient alignment of road tunnels can lead to time and cost overruns during the execution stages.

2. To ensure the proper selection of tunnel alignment, a Standard Operating Procedure (SOP) has been prepared to establish a comprehensive and systematic approach, considering all critical factors are taken into account before finalizing the tunnel alignment. The SOP is enclosed as **Annexure**.

3. The alignment of all long tunnels (length >1.5 km) on National Highways shall be finalized in accordance with the aforementioned SOP. It may be noted that tunnel portals are

obligatory reference points in the alignment of a road corridor. Therefore, alignment proposals for all long tunnel projects shall be submitted to the Ministry through DG(RD)&SS for review, prior to the submission of alignment of a corridor or section of NH for approval by the Alignment Approval Committee in accordance with the Ministry's OM No. NH-14012/27/2014-P&M (Vol-IV) dated 20th September 2024 and its subsequent amendments. The alignment proposal must, inter-alia include all details and reports specified in the SOP.

4. The SOP shall also be referred to in the RFP for DPR and PMC consultancy services.

5. This issues with the approval of Hon'ble Minister (RT&H) and will be applicable to all executing agencies of this Ministry with immediate effect.

Yours Sincerely,

Encl: As above

02/09/25

(Bharat Kumar Sharma)
Assistant Executive Engineer
For Director General (Road Development) & Special Secretary
E-mail: tunnelzonemorth@gmail.com

Copy To:

1. All CEs in the Ministry of Road Transport & Highways
2. All ROs of the Ministry of Road Transport & Highways
3. NIC-for uploading on Ministry's website under 'What's New' and under 'Compendium'

Copy for information to:

1. PS to Hon'ble Minister (RT&H)
2. PS to Hon'ble MOS (RT&H)
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4. PSO to Secretary (RT&H)
5. PSO to DG (RD) & SS
6. Sr. PPS/PPS to ADGs/AS&FA/AS(NHIDCL Cell)/AS(Highways)

Standard Operating Procedure for National Highway Tunnel Alignment Studies and approval

1. Preamble :

The purpose of this SoP is to provide a comprehensive, objective, and replicable methodology for identifying, evaluating, and selecting optimal tunnel alignment options in National Highway (NH) projects in India.

Tunnel infrastructure plays a pivotal role in improving road connectivity, especially in mountainous, hilly, and ecologically sensitive regions. Tunnels facilitate direct, all-weather connectivity and help avoid terrain-related constraints such as steep gradients, unstable slopes, and landslide-prone areas. They reduce travel time, fuel consumption, vehicular emissions, and overall operating costs.

From a strategic and economic perspective, tunnel development is essential for enhancing border connectivity, supporting tourism, enabling socio-economic integration of remote areas, and ensuring national security.

However, planning tunnel infrastructure is inherently complex and multi-disciplinary. It requires harmonization of topographical, geological, geotechnical, geophysical, hydrological, environmental, social, and financial dimensions. Without rigorous, standardized studies and data-backed alignment evaluations, tunnel projects may face delays, cost escalations, and stakeholder conflicts.

This policy document provides an objective and structured Standard Operating Procedure (SOP) for conducting Tunnel Alignment Option Studies on National Highways. It prescribes the methodology for generating technically sound, environmentally sustainable, socially acceptable, and economically viable tunnel alignment options.

2. Alignment Alternatives

Objective: Generate technically feasible, environmentally compatible, and economically justifiable alignment options.

- The goal is to evaluate at least 3 alternative alignments with clear differentiators: shortest path, Geologically/geotechnically favourable, least social impact, and cost-optimized route.
- These alignments must avoid critical constraints like ESZs, heritage sites, fault lines, steep slopes (>45°), and existing urban settlements.
- All alignments should respect terrain geometry.
- Portal locations should be optimized for access, gradient, drainage, and minimal land acquisition.
- Portal selection considering stable slopes, drainage channels and land cover.

- Horizontal and vertical alignment designed for permissible gradient and minimum curve radius as per design speed [Clause 2.2 and Annexure-B of IRC:SP:91-2019].
- Classify tunnel type: Horseshoe, Circular, or Segmental [Clause 1.5 of IRC:SP:91-2019].
- Define excavation method: NATM, TBM, or Drill & Blast [Chapter 4 of IRC:SP:91-2019].

3. **Overall Process flow:** The overall methodology for tunnel alignment option study and approval includes:

- Identification of a preliminary corridor for tunnel construction
- Review of past investigation data and gap analysis
- Collection of high-resolution base-line data across multiple disciplines
- Development of technically viable alignment options
- Stakeholder consultations
- Gati Shakti Portal integration
- Evaluation of options, optimisation and deciding the best available alternative
- Documentation and submission

4. Procedure for Fixing Tunnel Alignment options

Step 1: Define Project Objectives

- Determine and document why a tunnel is needed:
    - Reduce travel time
    - Bypass steep terrain (e.g., ghat sections)
    - Avoid wildlife sanctuaries or urban centers
    - Improve road safety and geometric standards
    - Ensure year-round connectivity in snowfall zones (e.g., J&K, Ladakh, Himachal Pradesh)

Step 2: Preliminary Corridor Identification

- Study existing maps, topography, and satellite images to define the broad corridor.
- Identify potential tunnel alignments within these corridors.
- Define **control points** such as entry/exit portals, road intersections, and geological boundaries.
- Use GIS and DEM (Digital Elevation Model) tools to understand elevation profiles and gradients.

Step 3: Reconnaissance Survey

- Conduct field visits and aerial drone surveys to:
    - Validate topographical data
    - Locate ridgelines, valleys, rivers, fault lines
    - Identify settlements, existing roads, and utilities
- Produce a **Reconnaissance Report** with:
    - Tunnel length options
    - Broad geological zoning
    - Access to portals (construction feasibility)
    - Broad environmental sensitivities

Step 4 : Data Collection

(i) Review of Existing Investigations and Data

- Collect and review earlier literature on topographical, geological, geophysical, and hydrological investigations (if any) carried out in the project area by central or state agencies.
- Archive all earlier reports, maps, and borehole logs.
- Conduct a desk-based gap analysis to assess their relevance and sufficiency.

(ii) Primary Topographic and Terrain Survey

- Creation of High-resolution Digital Elevation Model (DEM) using high resolution satellite imagery, LiDAR or drone-based photogrammetry. Prepare longitudinal sections, contours, and 3D terrain models.
- Prepare terrain classification and slope stability maps (1:5000 or higher resolution).
- Mark proposed tunnel portals, access roads, muck disposal zones, safety areas.

(iii) Traffic Studies

- **Traffic Studies:** Conduct Classified Traffic Volume Count Survey, peak-hour analysis, and Origin-Destination (OD) surveys.

(iv) Geological, Geotechnical, and Hydrogeological Investigations

Develop a Geotechnical Investigation Interpretative Report (GIR) that synthesizes and interprets the geological, geotechnical, and hydrogeological data collected during field investigations. It must include:

- Corridor-wise geological synthesis including lithological and structural mapping

    - Tunnel-specific geological interpretation based on core logging and surface mapping
    - Geological mapping (rock types, discontinuities, weathering)
    - Assessment of rock mass quality and classification (RQD, Q-System, RMR, GSI)
    - Core logging to determine RQD, Unconfined Compressive Strength (UCS), and groundwater inflow
    - Geophysical Investigation (e.g., Seismic and Electrical resistivity surveys) to detect weak zones and aquifers
    - Assess tunnel rock classes using Q-System, RMR (Rock Mass Rating), and GSI (Geological Strength Index)
    - Lithological logs and cross-sections
    - RQD and core recovery values
    - Unconfined Compressive Strength (UCS), Point load tests, Permeability tests, slake durability tests
    - Geological discontinuity mapping (joints, faults, shear zones)
    - Groundwater table depth and flow characteristics, permeability
    - Identify high-risk zones for landslides, sinkholes, or fault crossings using remote sensing and historical data.

- Conduct borehole drilling and core logging as per **IRC SP:91-2019**:
    - For tunnels >1500 m: minimum 2 boreholes at each portal, 1 borehole at 25%, 50%, and 75% of tunnel length

- Develop a **Geological Reference Model (GRM)** that consolidates surface and subsurface data.

- Tunnelling implications based on expected geological conditions:
    - Support system requirements (temporary/permanent)
    - Anticipated water ingress or squeezing ground conditions
    - Geo-hazard zones including landslide-prone slopes, seismically active faults, and karst features (if any)
    - Recommendations for tunnel design and construction strategy including sequencing, heading methods, and instrumentation
    - Zoning of tunnel stretches by geological complexity and associated risk levels

(v) Satellite and Remote Sensing Inputs - To ensure centralized data management, spatial transparency, and inter-agency coordination, all tunnel alignment studies must be integrated with the PM Gati Shakti portal, developed by BISAG-N (Bhaskaracharya National Institute for Space Applications and Geo-informatics). This integration facilitates standardization, concurrent reviews, and intelligent decision-making support).

Key remote sensing inputs include:

- **Satellite overlays** for vegetation cover, forest boundaries, slope stability, and land use patterns.
- **Thermal and moisture anomaly analysis** using satellite-based data to assess geotechnical risks

Step 5 : Integration with PM Gati Shakti Portal

- **Alignment Overlay:** Use PM Gati Shakti portal to overlay tunnel alignments on infrastructure layers.
- **Identify Conflicts:** Highlight potential conflicts with utilities, transport corridors, and logistics zones.
- **Ensure Synergy:** Optimize alignment to support inter-modal connectivity (rail, road, port, airport).

Step 6 : Environmental and Forest Considerations

- Use BISAG-N overlays and MoEF&CC databases to map:
  - Forest areas, wildlife habitats, and eco-sensitive zones
  - Water bodies, wetlands, CRZ if applicable
  - Existing EIA database for regional biodiversity and species data

- For each alignment option:
  - Identify forest diversion needs (in ha) and applicable Forest (Conservation) Rules, 2022
  - Map Schedule-I species habitats and corridors (if present)
  - Overlay project footprint on Wildlife Institute of India maps
  - Identify if tunnel falls in or near Protected Areas or Eco-Sensitive Areas

- Conduct preliminary Environmental Screening as per MoEF EIA Notification, 2006:
  - Determine applicability of Category A/B EIA
  - Pre-scoping to estimate Terms of Reference (ToR)

Step 7 : Land Acquisition and Social Impact Analysis

Land acquisition (LA) and social impact considerations are integral to the tunnel alignment selection process. Alignment alternatives must minimize displacement, livelihood disruption, and acquisition of ecologically or culturally sensitive land. This section outlines the protocols to assess LA requirements and social impacts for each proposed alignment.

7.1 For each alignment option, the following assessments must be conducted:

- **Land Type Classification:**
  - Private, government, forest, revenue, defence, or institutional lands
  - Agricultural vs. non-agricultural (barren/waste) classification
- **Ownership and Tenure Mapping:**
  - Geo-referenced cadastral overlays from district authorities
  - Identification of tribal, tenancy, or leasehold lands
- **Built Environment Mapping:**
  - Households, shops, community assets (schools, temples, water sources)
  - GIS-based asset inventory within 100 m corridor on either side of alignment

7.2 Integration into Alignment Selection

- Tabulate alignment-wise land requirement (hectares), cost and number of affected households
- Score alignments for LA impact using a weighted matrix in Multi-Criteria Decision Analysis (MCDA)
- Ensure alignment selection minimizes displacement and is socially acceptable

Step 8 : Cost Estimation and Financial Viability

8.1 Cost estimation and financial viability analysis are critical to assess the techno-economic feasibility of each tunnel alignment option. This includes a structured evaluation of capital and recurring costs, realistic risk buffers, and potential returns.

8.2 Life-Cycle Costing (LCC)

In addition to capital costs, prepare life-cycle cost analysis to assess financial sustainability over a 30–50 year design horizon. LCC must include:

- Annual maintenance cost of tunnel civil infrastructure and MEP
- Energy consumption for lighting, ventilation, and safety systems
- Periodic repair and rehabilitation cost assumptions
- Environmental cost internalization (e.g., muck transport, monitoring)

8.3 Economic and Financial Viability Assessment

Each alignment must be evaluated for economic feasibility under standard cost-benefit frameworks:

- **Economic Internal Rate of Return (EIRR)** and **Benefit-Cost Ratio (BCR)**, including:
  - Vehicle operating cost (VOC) savings
  - Travel time savings
  - Reduced accident risk
  - Reduced GHG emissions and monetized carbon savings
- **Financial Internal Rate of Return (FIRR)**
  - Revenue estimation from tolls (if applicable)
  - O&M cost vs. revenue flow over concession period
- Sensitivity analysis for key risk parameters:
  - Traffic growth rate, construction delays, cost overrun, inflation

Step 9: Stakeholder Consultation - Engaging with affected stakeholders ensures alignment with policy, regulations, and public interests.

- Engage all relevant stakeholders early and throughout the planning process
- **Convene Interdepartmental Meetings:** Involve Forest, PWD, Railways, Irrigation, and Disaster Management Departments.
- **Community Consultation:** Conduct public hearings, especially in tribal and eco-sensitive areas.

Step 10: Alignment Optimization

10.1 Finalize alignment considering:

- Least construction and operational risk
- Minimal environmental/social impact
- Favorable geological conditions

10.2 Apply design constraints:

- Tunnel grade: ≤ 4% (preferably ≤ 2.5%)
- Minimum radius: ≥ 250 m for 80 km/h design speed
- Tunnel cross-section: as per IRC Guidelines
- Iterate tunnel alignment design to reduce adverse impacts:
  - Avoid ecologically sensitive areas
  - Reduce tunnel length while maintaining safe geometry
  - Minimize number of cross-passages/ventilation shafts
- Align tunnel with surface roads to minimize connector lengths
- Ensure proper portal orientation to reduce earthwork and construction effort

Step 11 : Decision Analysis Framework and Alignment Recommendation

The final selection of the preferred tunnel alignment must be based on an objective, transparent, and defensible Decision Analysis framework that aggregates technical, environmental, social, and economic performance across alignment options.

11.1 Structure of the decision analysis framework

- **Criteria Categories**:
  - Engineering and Geological Feasibility
  - Environmental and Forest Impact
  - Social and Land Acquisition Impact
  - Financial Cost and Viability
  - Connectivity and Strategic Importance

- **Indicators** under each category shall be both qualitative and quantitative, such as:
  - Geological risk score (based on GRM)
  - Length of tunnel and excavation complexity
  - Forest land (ha) and biodiversity hotspots affected
  - Net Present Cost (NPC), IRR, and ERR
  - Distance saved, regional accessibility, disaster resilience

Suggested evaluation criteria are provided in **Annexure A** for reference.

Step 12: Preparation and Submission of Alignment Option Study Report

- Compile findings from all study components into a consolidated Tunnel Alignment Option Study Report
- The report shall be structured in the following format:
  - Executive Summary
  - Introduction and Project Background
  - Methodology Adopted
  - Existing Data Review and Gap Analysis
  - Topographical and Geological Inputs
  - Environmental and Social Assessments
  - Outcome of Public Consultation
  - Risk analysis
  - Cost Estimates and Financial Viability
  - Decision Analysis Results
  - Recommended Alignment Option with Justification
  - Annexures: Maps, Reports, MCDA Tables, Satellite Images

5. Validation of Alignment Recommendation

The recommended tunnel alignment option shall be validated by:

- Reconfirming its compliance with technical feasibility, safety, environmental sustainability, and cost-efficiency parameters.
- Ensuring that statutory and regulatory prerequisites (e.g., forest clearance, wildlife clearance feasibility, land availability, seismic and hydrological stability) are reasonably addressed at the planning stage.
- Demonstrating alignment with national policy objectives and MoRTH Guidelines, IRC:SP:91-2019, and relevant codes.
- **Risk Register:** List risks like tunneling in poor geology, water ingress, R&R resistance, and clearance delays. Include mitigation strategies.

6. Final Recommendation

The final recommended alignment option shall be explicitly stated, with justification citing:

- Least environmental/social disruption
- Optimal tunnel length and gradient
- Engineering feasibility and constructability
- Compliance with MoRTH's guidelines and IRC codes.
- Stakeholder and inter-agency consultations (where applicable)

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Annexure A

Suggested Alignment Evaluation Criteria

Use a **Multi-Criteria** Decision **Analysis (MCDA)** approach for decision-making considering the following aspects of each proposed alignment option.

1. **Geometric Design**
    - Grade (preferably <2.5%, max 4%)
    - Horizontal curves (minimum radius 250 m for 80 km/h)
    - Tunnel length and cross-sectional requirements
2. **Geological Conditions**
    - Stability of rock mass
    - Presence of fault zones or weak strata
    - Groundwater inflow risks
    - Possibility of NATM or TBM methods
3. **Construction Feasibility**
    - Access to portals
    - Construction logistics (supporting infrastructure)
    - Muck disposal and material transport
    - Tunnel method suitability (TBM vs. Drill & Blast)
4. **Environmental & Forest Impact**
    - Protected areas (Wildlife, Reserved Forests)
    - Need for forest/wildlife clearances
    - Biodiversity impacts and mitigation
5. **Cost Estimate**
    - Construction and operation costs
    - Mitigation and environmental costs
    - Long-term maintenance
6. **Socio-Economic Impact**
    - Land acquisition needs
    - Resettlement or rehabilitation issues
    - Impact on local communities and employment
