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Environmental Impact Assessment and Mitigation Strategies for Road Construction in Yavatmal Region

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ABSTRACT: This paper presents a comprehensive Environmental Impact Assessment (EIA) of the reconstruction and widening of existing bitumen roads into cement concrete (CC) roads under eleven road construction projects in the Yavatmal district, Maharashtra, covering a total length of approximately 400.992 km. The study evaluates the environmental impacts associated with various stages of road construction, including pre-construction, construction phases. Major environmental impacts such as air pollution, water contamination, soil degradation, noise pollution, biodiversity loss, construction and demolition waste generation, and socio-economic effects have been systematically identified and analyzed. Appropriate environmental mitigation measures have been proposed to minimize adverse environmental impacts through dust suppression, wastewater management, erosion control, waste recycling, ecological conservation, compensatory plantation, pollution control at crusher and ready-mix concrete plants, and adoption of sustainable construction practices. An Environmental Management Plan (EMP) has been prepared to facilitate effective implementation, monitoring, and regulatory compliance throughout the project lifecycle. In addition, environmental management costs have been estimated to support practical implementation of mitigation measures in accordance with relevant guidelines. The study concludes that although road construction inevitably affects the environment, the adoption of scientifically planned mitigation strategies, sustainable engineering practices, and effective environmental management can substantially reduce adverse impacts while improving transportation infrastructure.

KEYWORDS: Environmental Impact Assessment (EIA), Road Construction, Cement Concrete Road, Environmental Management Plan (EMP), Environmental Mitigation Measures, Environmental Management Cost.

I. INTRODUCTION

Road construction is a key driver of infrastructure development, improved connectivity, economic growth and social mobility. However, the process of planning, building, operating and maintaining roads also exerts considerable pressures on the environment — including soil and water degradation, biodiversity loss, air and noise pollution, changes in land use, and long-term ecosystem fragmentation. As infrastructure demands expand globally (especially in developing countries), there is heightened recognition that road development must be carried out in an environmentally responsible way.

Road construction is vital for enhancing connectivity, trade, and economic development. However, it can significantly impact the natural environment through deforestation, soil erosion, air and water pollution, noise, and habitat fragmentation. With rapid urbanization and growing infrastructure demands, it is essential to analyze these environmental effects and implement mitigation strategies to achieve sustainable development goals.

II. LITERATURE REVIEW

[1] The research by Trombulak and Frissell: Trombulak and Frissell conducted a broad review on the ecological effects of roads on terrestrial and aquatic ecosystems. They concluded that road construction leads to increased

sedimentation, dust deposition, toxic runoff, traffic noise, and interruption of wildlife movement corridors. The review also showed that aquatic habitats are damaged due to culvert construction and stream crossing activities.

[2] The research by Coffin (2007): Coffin reviewed the growing field of road ecology and focused particularly on wildlife mortality, habitat isolation, and disturbance of animal behavior caused by roads. The study noted that roads function as physical and behavioral barriers, preventing species migration and breeding. It also highlighted the role of noise and light pollution in altering species diversity. Coffin recommended wildlife crossings, underpasses, and green bridges as mitigation measures.

[3] The research by Santos et al.: Santos et al. developed a pavement life cycle environmental model and concluded that road construction materials significantly contribute to greenhouse gas emissions and energy depletion. Cement production, aggregate processing, and asphalt laying were identified as the most carbon-intensive activities. The study also found that frequent maintenance increases cumulative environmental burden.

[4] The research by Geneletti: Geneletti proposed a biodiversity impact assessment framework based on GIS and ecosystem rarity analysis for transportation projects. The study demonstrated that GIS mapping can identify environmentally sensitive corridors before alignment approval, thereby reducing forest loss and wetland encroachment.

[5] The research by Alkemade et al.: Alkemade et al. investigated global terrestrial biodiversity loss and reported that road density is a major contributing factor to habitat degradation. The study found that roads accelerate deforestation, increase human encroachment, and reduce species abundance in surrounding areas. It was observed that biodiversity reduction can occur several kilometers away from the road corridor.

[6] The research by Findlay and Bourdages: Findlay and Bourdages studied the response of wetland biodiversity to nearby road construction and found significant reduction in amphibian populations, plant diversity, and water quality. The researchers concluded that road runoff containing oils, sediments, and metals adversely affects adjacent wetland ecosystems. Their findings suggest that wetland proximity should be a major criterion in EIA route analysis.

[7] The research by Muench: Muench reviewed sustainability impacts associated with roadway construction and observed that material extraction, transportation, and paving equipment are responsible for substantial fossil fuel consumption. The author estimated that embodied carbon emissions from pavement production represent a major portion of the project's environmental footprint.

[8] The research by Gouveia et al.: Gouveia et al. reviewed life cycle assessment practices in road pavement infrastructures and concluded that aggregate quarrying, asphalt production, haulage, and machinery use are major environmental hotspots. The study also emphasized that construction equipment emissions contribute significantly to particulate matter and nitrogen oxides.

[9] The research by Phogat et al.: Phogat et al. examined environmental consequences of hill road construction and reported severe soil erosion, slope instability, vegetation stripping, and sediment inflow into streams due to hill cutting and blasting. The study emphasized that mountain roads create geomorphological disturbances much larger than plain terrain roads. Improper disposal of excavated muck was identified as a major source of landslides and drainage blockage.

[10] The research by Habibian et al.: Habibian et al. studied air quality degradation during road construction and reported that earthwork, crushers, concrete batching plants, and heavy diesel vehicles generate large quantities of PM₁₀, PM_{2.5}, CO, and NO_x. Dust emissions were found to exceed acceptable limits near construction corridors, affecting workers and nearby residents.

[11] Cuperus et al.: Cuperus et al. proposed ecological compensation guidelines specifically for highways and suggested a mitigation hierarchy of avoidance, minimization, restoration, and compensation. The study argued that environmental damage cannot always be prevented, but equivalent ecological restoration must be planned. Examples such as wildlife passages, compensatory afforestation, and wetland reconstruction were recommended.

[12] Delgado et al.

Delgado et al. analyzed transportation corridor noise and found that continuous construction and vehicle noise above 70 dB negatively affects nearby communities and avian habitats. The paper explained that drilling, compaction, blasting, and truck movement create temporary but intense acoustic stress. Long-term exposure can cause sleep disturbance, communication difficulty, and reduction in nesting success of birds.

[13] Rajaram et al.: Rajaram et al. investigated water quality changes associated with highway construction camps and found elevated suspended solids, oil-grease, cement slurry, and alkaline wastewater entering nearby streams. The study concluded that temporary construction facilities are major but often neglected sources of water contamination. Runoff from material storage areas and machinery washing zones significantly increased turbidity and reduced dissolved oxygen in receiving waters. This literature indicates that EIA must consider indirect pollution sources beyond the main carriageway alignment.

[14] Hoxha et al.: Hoxha et al. reviewed environmental impacts of urban roads using life cycle assessment and found that road construction contributes significantly to global warming potential, acidification, eutrophication, and particulate pollution. The study noted that urban road projects consume large quantities of concrete, bitumen, and steel, thereby increasing embodied environmental burden.

III. METHODOLOGY

The methodology involves a systematic process for identifying, predicting, and evaluating the environmental impacts of road construction. First, the study area was defined, and the baseline environmental impacts on air, water, noise, soil, ecology, and socio-economic conditions were determined. Next, key environmental issues were identified through scoping. The potential impacts of this study are analysed. The significance of the impacts was evaluated based on the magnitude, duration, and extent. The EIA process was used to analyse environmental impacts and suggest mitigation measures.

IV. SITE DESCRIPTION

The projects are located in yavatmal region. This are old bitumen road which are to be replaced by cement concrete roads. In this projects there is reconstruction and widening of old bitumen roads will be carried out. This project causes several impacts on the environment.

Table 1. Site Description

Sr No.	Package Number	Package Name	Data as per DPR	
			Length (km)	Civil Cost(Rs Cr)
1	EPC AM-II (43B)	Improvement to Rajgaon Uklipen Ansing MDR-3 km. 0/00 to 20/00 on EPC mode	20.000	87.41
2	EPC AM-II (43A)	Improvement to road MSH 12 Dongarkinhi Medshi Ridhora Rajura Kutardoha Kinhiraja Kata Washim Kekatumra Borkhedi road SH 400 km. 44/00 to 69/600 Tal. Malegaon and Part MSH 12 to Kata on EPC mode	25.463	112.36
3	EPC AM-II (43C)	Improvement to Dhanora Shendurjana Fulumari Waigaul MDR 19 km. 0/00 to Km. 40/500 Tq. Mangrulpir and Manora Part MSH 161 E to Dhanora to Waigoul on EPC mode	43.034	184.26
4	EPC AM-II (49A)	Manazgaon Nimba Nimkarda Digras Arni Talni SH-273 Km.184/600 to 227/100 Tq. Arni,Tq. Ghatanji Distt. Yavatmal (Arni to Talani	42.500	172.93
5	EPC AM-II (49B)	Improvement to Mangrul Darwha Loni Belora Akolabazar Ghatanji Shivani Road SH-290 Km 73/00 to 122/700 Dist.	49.963	184.13

		Yavatmal on EPC mode		
6	EPC AM-II (49C)	Improvement to Mangrulpir Darwha Loni Belora Akolabazar Ghatanji Shivini Road NH- 290 Bagwadi to Jawala phata km. 44/00 to 70/000 on EPC mode	27.890	118.00
7	EPC AM-II (50 A)	Improvement with Strengthening to Arvi Wardha Waigaon Ralegaon Ghatanji Parwa Mandwi Road SH-267 Km 101/700 to 140/100 In Tal. Kalamb, Ralegaon Dist. Yavatmal (Ralegaon to Metikheda to Ghatanji) on EPC mode	37.868	148.89
8	EPC AM-II (50C)	Improvement to Parva Kelapur Shibla Ghonsa Wani Road SH-314 (Ch. No. Km 40/000 to Km 77/500) (Length 27.50 Km) (Part- Shibla to Wani city) and Wadki-Khairi-Mardi-Nandepera-Wani-Chargaon- Shindola-Chandrapur upto District border SH-317 Part- Wani to Nandepera and Khairi to Wadki Ch. No. Km 155/500 to 165/600 (Part - Wani to Nandepera Village) and Ch. No.127/600 to 133/100 (Part - Khairi to Wadki) Tal. Wani Dist. Yavatmal on EPC mode	52.060	221.23
9	EPC AM-II (51A)	Improvement to Sawangi Satefal Ner Babhulgaon Wadki Chargaon Antargaon Road SH- 317 Km 0/00 to 31/00 (Sawangi to Ner) on EPC mode	30.614	128.20
10	EPC Vasantnagar	Construction of Digras Vasantnagar Kali Mohadi Pokhari Pohandul to NH-361 connecting to MDR-28 (Length 20 Km), Kali Wakad Bori old Road with Bridge ODR 154 (Length 7 Km), Bori Khamalwadi road ODR 155 (Length 5 Km) and Khamalwadi Vadad Singad road ODR 150 (Length 6.50 km) (Tal. Mahagaon Dist. Yavatmal) and Singad to Pohradevi (Length 12 km) on EPC mode	50.500	202.72
11	EPC ND-II (33D)	Improvement to 2 Lane with Earthen Shoulder for Fulsawangi, Kupti, Wanola, Panola, Palaiguda Road SH 51 Km 323/200 to Km 345/200 Tal. Mahur on EPC mode	21.100	86.95
			400.992	1647.080

V. ENVIRONMENTAL IMPACTS OF ROAD CONSTRUCTION IN YAVATMAL REGION

• Impacts on air quality

During site clearance operation i.e Clearing and grubbing operation the soil will get exposed and this will lead to increased dust generation particularly particulate matter PM_{10} and $PM_{2.5}$ due to wind action. Large-scale excavation and embankment and subgrade formation disturb soil. Generates high levels of fugitive dust (PM_{10} and $PM_{2.5}$). Dust spreads to nearby areas, especially during windy conditions. Major contributor to reduced visibility and respiratory problems. Use of equipment like excavators, loaders, graders, and rollers for earthwork operations emits pollutants such as carbon monoxide (CO), nitrogen oxides (NO_x), sulfur dioxide (SO₂), particulate matter (PM), continuous operation leads to cumulative air pollution. Breaking existing Bitumen pavements releases coarse and fine dust particles. Generates very high short-term PM levels. Crushers and Ready-Mix Concrete plants generate fine particulate matter such as dust from crushed aggregate and cement handling.



(a) (b) (c)
Fig. 1. Impacts on Air Quality (a) Air pollution from RMC plant (b) Dust emission from vehicle movement (c) Air pollution from Crusher plant

• Impacts on water quality

Removal of vegetation reduces natural ground cover, increases surface runoff and soil erosion. This leads to sediment transport into rivers, streams, and ponds. This Causes increased turbidity, siltation of water bodies, disturbance to aquatic ecosystems. Excavation, embankment formation, and exposed soil surfaces are highly prone to erosion. Rainfall washes loose soil into nearby drains, streams, and rivers. This leads to high turbidity and Total Suspended Solids (TSS), siltation of water bodies, reduced light penetration affecting aquatic life. Leakage from machinery, storage tanks, and refueling operations. Pollutants include oil and grease, hydrocarbons and toxic chemicals. In crusher washing of aggregates produces slurry. This wastewater contains fine particles and suspended solids. This will cause degradation of aquatic ecosystems, fish mortality due to low oxygen and toxicity contamination of drinking water sources, increased water treatment costs, long-term ecological imbalance.



(a) (b) (c)
Fig. 2. Impacts on Water Quality (a) Erosion of soil due to disturbed natural slope (b) Leakages of oil and fuel from plant and machinery (c) Waste water accumulating into natural streams

• Impacts Due To Noise

Use of light vehicles (jeeps, bikes) and small equipment, occasional geotechnical drilling or soil testing produces localized noise. Use of chainsaws, cutters, and small machinery for clearing and grubbing generates moderate noise levels 60–80 dB approx. Equipment like excavators, bulldozers, graders, and rollers used in earthwork activity produces high-decibel noise approximately 80–100 dB or more. Continuous operation leads to chronic noise exposure, disturbance to nearby residents. Activities like blasting and pneumatic drilling generate sudden, impulsive noise (very high intensity). Noise levels often exceeding 120 db.



(a) (b)
Fig. 3. Impacts Due to Noise (a) Noise produced by light vehicles (b) Noise produced by machineries during construction

• Impacts on Soil

Removal of trees, shrubs, and grass during site clearance exposes soil surface leads to loss of soil protection against wind and water, increased soil erosion, reduces organic matter and soil fertility. Fertile topsoil is removed for leveling and grading during earthwork. This impacts loss of nutrient-rich soil layer, reduced agricultural productivity (if farmland is involved). Improper storage may lead to further degradation. Cutting, filling, and grading will disturb large soil volumes. This leads to loss of topsoil and nutrients increased soil erosion and slope instability. In hilly areas, may trigger landslides. Continuous movement of heavy equipment compresses soil will results in reduced porosity and permeability, poor root penetration for vegetation, increased surface runoff and reduced infiltration. Borrow area excavation operation disturb land. It impacts localized soil degradation, loss of productive land.



(a)

(b)

(c)

Fig. 4. Impacts on Soil (a) Removal of fertile topsoil for plant setup (b) Removal of trees and topsoil from borrow area (c) Movement of heavy machinery compresses soil.

• Ecological Impacts of Road Construction

During pre-construction bushes are cut, roadside trees are marked for removal, grass cover is cleared for survey lines, shrubs are uprooted for temporary access. This leads to reduction in green cover. The construction phase includes all on-site engineering activities such as excavation, cutting and filling, embankment construction, blasting. All these activities cause solation of species populations, reduced breeding interaction, reduced movement of animals, increased local extinction risk. Dust settles on leaf surfaces, grasses, shrubs, crop edges. This leads to blockage of stomata, reduced photosynthesis, lower transpiration, leaf drying, reduced flowering and fruiting. Excavation also destroys ant colonies, earthworm habitat, termite mounds, soil arthropods. These causes disturbance in feeding behavior, interruption in migration paths, stress to shy animals, movement of birds away from the area.



(a)

(b)

(c)

Fig. 5. Ecological Impacts of Road Construction (a) Tree cutting during site clearance (b) Tree cutting during construction (c) Dust settle on leaves during construction.

VI. MITIGATION MEASURES

• Mitigation of Road Construction for Water Quality

There should be proper drainage at construction site. Temporary drains should be constructed around excavation areas, embankment slopes, material stockyards, plant locations, labour camps. Repair yards and parking areas release diesel, lubricants, grease, hydraulic oil. These pollutants can seep into soil and then wash into drains. Provide paved maintenance floor, oil interceptor, grease trap, spill collection tray. Runoff from exposed soil contains silt, clay, suspended solids, loose aggregate. Therefore, silt fences, check bunds, sedimentation tanks, settling ponds should be installed near drainage outlets. Industrial support units such as crusher plant, RMC Plant generate aggregate wash water,

cement slurry, dust suppression runoff. This water should be routed to settling tank, recycling pit, closed reuse system. wash water contains cement slurry, oil, suspended solids. Dedicated wash platform with collection pit should be used.

- **Mitigation of Road Construction for Air Quality**

Water should be sprayed on excavation areas, embankment surfaces, earthwork zones, unpaved haul roads, soil stockpiles, diversion roads. All trucks carrying soil, sand, cement, aggregate, fly ash, debris must be covered with tarpaulin. Use of PUC certified / low emission vehicles only such as pollution under control certified trucks, Bharat Stage compliant machinery, low sulphur diesel equipment should be used. This reduces exhaust fumes. Crusher plants generate stone dust, silica particles, suspended particulate matter, vehicular exhaust, conveyor dust. Water must be sprinkled on dust generation points. High-pressure nozzles should be installed at hopper unloading point, crusher mouth, screen discharge, conveyor transfer. Continuous mist keeps aggregates wet and suppresses PM10. RMC plants generate cement dust, fly ash dust, sand dust, mixer loading emissions, truck movement dust. Cement/fly ash must never be stored openly. For storing cement Use vertical closed silos, pressure relief valve, top bag filter.



Fig. 6. Mitigation for Air Quality (a) Sprinkling water on road for dust control (b) Sprinkling water at crusher for dust control (c) Air filter at RMC plant for dust control.

- **Mitigation of Road Construction for Noise Quality**

Old and poorly maintained machinery produce engine rattling, loose body vibration, excessive exhaust sound, metal impact noise. Therefore, all construction equipment should be regularly serviced, silencers and mufflers should be functional, worn-out parts should be replaced, low-noise modern machinery should be preferred. Noise generating equipment such as DG sets, compressors, generators, pneumatic drills must be fitted with exhaust silencers, acoustic enclosures, anti-vibration pads. Avoid noisy activities during late night, early morning, school examination hours, hospital peak quiet hours. Support facilities such as crusher, RMC plant, DG set, workshop, labor camp loading area should be placed as far as possible from residential houses, schools, hospitals, temples. Temporary barriers made of acoustic panels, plywood with absorbent lining, GI sheets with insulation, portable sound blankets should be installed around generators, crusher plants, drilling zones, batching plants, areas near residences/schools.

- **Mitigation of Road Construction for Soil Quality**

During site clearance, fertile topsoil should be removed separately (usually upper 15–30 cm) and stored in designated stockpiles. Topsoil contains organic matter, nutrients, microorganisms, seed bank. If mixed with subsoil or lost, land productivity decreases. Provision of erosion and sediment control measures such as silt fences, sediment barriers, straw bunds, check dams, contour trenches, sediment basins. These prevent movement of eroded soil from disturbed areas. Roadside slopes should be protected by turfing, hydroseeding, stone pitching, geotextile mats, retaining walls where needed. Borrow pits after soil extraction should be backfilled, graded, topsoiled, planted. Otherwise, they remain barren, erosion-prone, unsafe. At parking and maintenance areas provide impervious platform, drip trays, oil absorbent material, spill collection pit.

- **Mitigation Measures for Ecological Impacts**

Road alignment should avoid reserved forests, wetlands, wildlife corridors, bird nesting zones, marsh lands, dense plantation areas, riparian vegetation. Even slight rerouting can greatly reduce biodiversity loss. For every tree removed, plantation should be done at suitable ratio as per forest authority norms. Prefer native species, fruit-bearing species, pollinator-supportive shrubs, avenue plantation. Plantation should be done along road shoulders, median, nearby community lands, degraded forest patches. This helps restore long-term green cover and ecological shelter. Take measures such as avoid unnecessary widening, preserve mature trees where possible, mark no-cut zones, retain shrubs

on embankment margins. In ecologically sensitive stretches, avoid major disturbance during bird nesting season, amphibian breeding season, migration periods. Workers should be instructed not to kill reptiles/snakes, not to disturb nests, not to cut trees unnecessarily, not to dump waste in natural habitat. Where road passes through wildlife movement areas, provide wildlife underpasses, box culverts, small mammal tunnels, amphibian passages, canopy rope bridges for arboreal fauna.

VII. ENVIRONMENTAL MANAGEMENT PLAN

Environmental Management Plan (EMP) is the key to ensure a safe and clean environment. A project may have identified proper mitigation measures but without a management plan to execute it, the desired results may not be obtained. The present chapter on Environment Management Plan envisages proper implementation of mitigation measures to reduce the adverse impacts arising out of the project activities.

The following issues have been addressed in this EMP:

1. Mitigation measures for undesirable impacts caused
2. Details of management plans
3. Institutional set up for implementation of the EMP
4. Expenditures for environmental protection measures.

• Identification of Implementing Authority

The responsibility for the implementation of the EMP will be with the Maharashtra State Infrastructure Development Corporation (MSIDC), Consultants and Contractor. An environmental management cell (EMC) will be established for implementing the mitigative measures. To mobilize the appropriate expertise to design diverse type of mitigation measures. Contractor needs to be collaborating with order institutions in the public and private sector viz. State forest Department, State Public Health Engineering Department, State Traffic Department, and State Police Department etc. In addition, Regional Engineer will be appointed by project authorities for management of the project with the objective of reviewing and assessing the progress made by the concession company in implementing the suggested mitigative measures. The Implementation of EMP will be carried out by contractor and consultant under the supervision of MSIDC.

• Environmental Monitoring Plan

The air and noise quality monitoring will be performed at the same locations where baseline monitoring was carried out. Environment Management Cell (EMC) will be the prime agency for monitoring all activities. Project promoters will supervise all activities and accordingly advise to improve on areas where any shortcomings are observed. The EMC will provide all the monitoring results to project promoters who will keep a record of all information and suggest suitable measures to be adopted by the Contractor if any aspect is found to be diverting from the anticipated values/standards. The purpose of the monitoring plan is to ensure that the envisaged purpose of the project is achieved and results in desired benefits. The purpose of the monitoring plan is to ensure that the envisaged purpose of the project is achieved and results in desired benefits. The broad objectives are:

1. To evaluate the performance of mitigation measures proposed in the EMP
2. To evaluate the adequacy of Environmental Impact Assessment
3. To suggest improvements in management plan, if required
4. To enhance environmental quality
5. To satisfy the legal and community obligation

Table 2. Environment Monitoring Plan

Category	Stage	Measuring Parameter	Monitoring		Institutional responsibility	
			Frequency	Duration	Implementation	Supervision

Air	Construction Stage	PM10, PM2.5, SO ₂ , NO _x , CO, Pb	During entire civil construction stage	24 hours Twice a month	Contractor	MSIDC, Through an approved Consultants
	Operation Stage	PM10, PM2.5, SO ₂ , NO _x , CO, Pb	Twice a week for 2 weeks in each location in every season (except monsoons)	24 hours Twice a month	Contractor	MSIDC, Through an approved Consultants
Noise	Construction Stage	Noise levels on dB (A) scale	During entire civil construction stage or even later	24 hours Once a week	Contractor	MSIDC, Through an approved Consultants
	Operation Stage	Noise levels on dB (A) scale	Reading to be taken in one location once in a season.	Continuous s 24 hours	Contractor	MSIDC, Through an approved Consultants
Soil	Construction Stage	Monitoring of Pb, oil and grease	Once in a season for 3 seasons	-	Contractor	MSIDC, Through an approved Consultants
	Operation Stage	Monitoring of Pb, oil and grease	Once in a season for 3 seasons (except monsoons)	-	Contractor	MSIDC, Through an approved Consultants
Water	Construction Stage	Surface, Ground water quality (IS 10500:1991)	During entire civil construction stage or even later	Once a month	Contractor	MSIDC, Through an approved Consultants
	Operation Stage	Surface, Ground water quality (IS 10500:1991)	During entire civil construction stage or even later	Once a month	Contractor	MSIDC, Through an approved Consultants

• Budgets For Environmental Management Plan

As per Ministry of Road Transport and Highways (MoRTH) and Indian Roads Congress IRC:SP:108-2015, Environmental Management Cost for road projects is not taken as a fixed percentage only. it is prepared component-wise based on mitigation measures, monitoring, plantation, borrow area restoration, camp sanitation, safety, etc. IRC specifically includes EMP Cost as a separate DPR item (Item 39).

Based on the projects Total Length $\approx$ 400.992 km; Civil Cost $\approx$ ₹1647.08 Cr

Table 3. Biological Environment Cost

Item	Norm	Quantity	Rate	Amount (₹ Cr)
Avenue plantation	200 trees/km both sides	80,198 trees	₹1,500/tree	12.03
Compensatory plantation (1:3 tree cutting ratio)	Assume 25 trees/km cut	30,075 trees	₹2,000/tree	6.02
Maintenance for 3 years	20% of plantation cost	LS	—	3.61

Total cost for biological Environment = ₹21.66 Cr

Table 4. Air Pollution Control Cost

Table 5. Water Environment Protection Cost

Item	Basis	Amount (₹ Cr)
Water tanker for dust suppression	₹1.25 lakh/km	5.01
Covering vehicles with tarpaulin	Lump sum	0.60
Dust masks for workers	3000 workers	0.30
RMC plant and Crusher pollution control	11 plants	1.10

Total cost for air pollution control = ₹7.01 Cr

Item	Norm	Amount (₹ Cr)
Silt fencing near water bodies	₹40,000/km sensitive stretches	1.80
Oil interceptors at camps	11 camps	0.55
Septic tanks & soak pits	11 camps	0.88
Water quality testing	Quarterly for 3 years	0.33

Total cost for water environment protection = ₹3.56 Cr

Table 6. Noise Pollution Control Cost

Item	Qty	Rate	Amount (₹ Cr)
Noise barriers	8 km	₹40 lakh/km	3.20
Noise monitoring	24 locations	₹50,000/location/year	0.36
Ear protection for workers	LS	—	0.15

Total cost for noise pollution control = ₹3.71 Cr

Table 7. Environmental Monitoring and audit Cost

Item	Amount (₹ Cr)
Air monitoring	0.60
Water monitoring	0.33
Noise monitoring	0.36
Soil testing	0.20
Environmental audit	0.50
Reporting & compliance	0.30

Total cost for Environmental monitoring = ₹2.29 Cr

Table 8. Environmental Monitoring and audit Cost

Item	Amount (₹ Cr)
Borrow area rehabilitation	2.00
Turfing / slope stabilization	3.50
Quarry restoration	1.20
Topsoil preservation	0.75

Total cost for soil and land protection = ₹7.45 Cr

Table 9. Environmental Monitoring and audit Cost

Item	Amount (₹ Cr)
Construction debris disposal	2.20
Bituminous waste recycling	1.50
Camp solid waste management	0.60
Hazardous waste disposal	0.80

Total cost for waste management = ₹5.10 Cr

Table 10. Labour Welfare and safety Cost

Item	Amount (₹ Cr)
PPE kits	0.75
First aid & ambulance	0.90
Safety signage & barricading	2.50
Worker health checkup	0.40

Total cost for labour welfare and safety = ₹4.55 Cr

Table 11. Total Environmental Management Plan Cost

Component	Cost (₹ Cr)
Biological	21.66
Air	7.01

Water	3.56
Noise	3.71
Soil	7.45
Waste	5.10
Labour & Safety	4.55
Monitoring	2.29

Total Environmental Management Plan Cost = ₹55.33 Cr

Environmental Management Plan Cost % = $(55.33 / 1647.08) \times 100 = 3.36\%$

This is realistic for EPC road improvement projects under MoRTH because plantation and compensatory afforestation significantly increase cost. Therefore, total environmental management cost is 3.36% of the total project cost.

VIII. CONCLUSION

- Environmental impacts from road construction are diverse and interconnected, affecting air, water, soil, biodiversity, and communities. Mitigation is most effective when it is **proactive**, **site-specific**, and **integrated throughout the project life cycle**
- Adopting sustainable construction materials, green technologies, and rigorous environmental management systems ensures that road infrastructure development progresses in harmony with nature.
- By properly applying the mitigation measures suggested throughout the research, the environmental impacts of road construction will be minimized effectively.
- The Environment Management Plan costs **55.33 Cr** which is **3.36 %** of project cost i.e. **1647.08 Cr**. This Cost is satisfactory because overall benefits achieved by Environment management will be more.
- The environmental analysis and subsequent mitigation for road construction are not merely a regulatory compliance exercise but a fundamental requirement for sustainable infrastructure development. Effective analysis, rooted in the EIA process, ensures that both the natural and human environments are protected while realizing the socio-economic benefits of connectivity.
- The Proper Environment Management, Mitigation and integrate innovative green technologies are helpful to minimize the long-term carbon and ecological footprint of the road construction project.

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