LCA
National Highways of India

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Creating Innovative Solutions for a Sustainable Future

Life cycle assessment methods to support India's efforts to decarbonise transport

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About the study

Title	Reducing Carbon Footprint and Enhancing Climate Resilience of National Highways in India
Supported by	Ministry of Road Transport and Highways and the World Bank
Aim	1. To suggest strategies for reducing carbon footprint of NH network in India 2. To suggest strategies for enhancing the resilience of NH network to extreme climate change induced events

Project Reports: https://www.teriin.org/project/reducing-carbon-footprint-and-enhancing-climate-resilience-national-highways-india




INTERLINKED OBJECTIVES

Component I

Component II

Carbon Emissions from NH sector

Need for Carbon Emissions Reduction from NH sector

Need for making National Highways Climate Resilient

Climate Change impacts and extreme events

Increasing climate vulnerabilities of NHs

REDUCTION OF CARBON FOOTPRINT OF NATIONAL HIGHWAYS

OBJECTIVES

- To determine the **overall carbon footprint** of the NH network
- To suggest **low carbon interventions** for the highway sector
- To estimate carbon reduction potential of developing **'good-quality' highways** vis-à-vis **'poorly-maintained'** highways
- To provide recommendations for mainstreaming of **strategies, policies and enabling actions** for low carbon NH sector

Life Cycle Assessment (LCA)

LCA is a systematic way of evaluating the environmental impacts of products or activities by following a **‘cradle to grave’ approach** - it involves identification and quantification of **material and energy consumption** and **emissions** which affect the environment at all stages of the entire product of life cycle (ISO 14042)

Material consumption

Energy consumption

INPUT

All life stages of identified transport modes

Direct and Indirect

OUTPUT

Carbon emissions

Apply on

HIGHWAYS SECTOR

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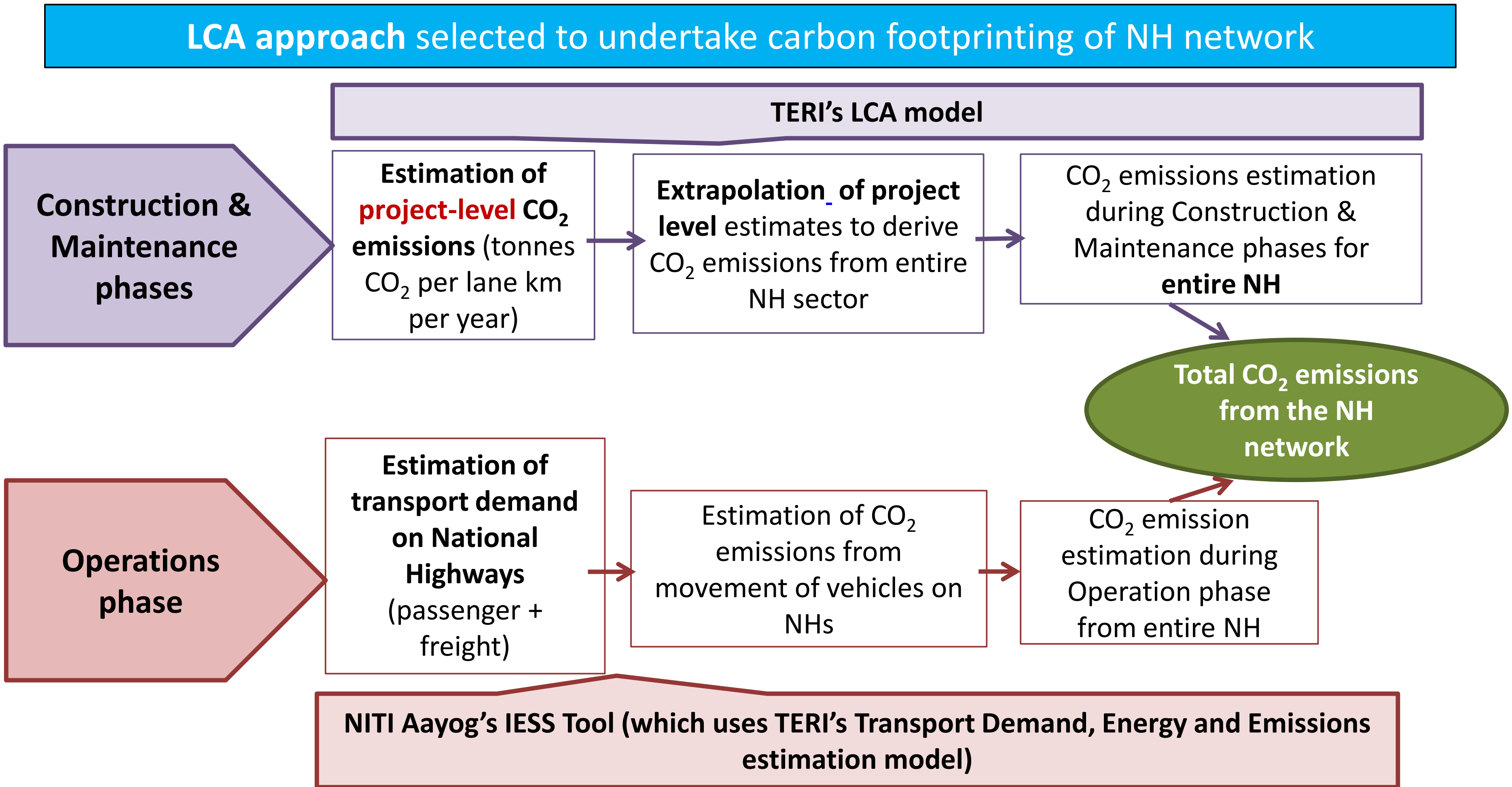
Estimating Carbon Footprint of NH sector - Approach

Life Cycle Analysis Approach Adopted

Total CO_2 emissions over the ***full life*** cycle of NHs considered

- CO_2 Emissions on account of **CONSTRUCTION**
- CO_2 Emissions on account of **MAINTENANCE**
- CO_2 Emissions on account of **OPERATIONS**

Methodology



International and Indian studies on carbon footprint estimates

Name of study	Design life of the road considered	Pavement typology	CO_2 emissions/embodied energy during the three phases of highway's life		
			Construction	Maintenance	Operations
International studies					
Life Cycle Assessment of Road: A Pilot Study for Inventory Analysis (Stripple, 2001)	40 years	Asphalt pavement	23 TJ/km (Embodied Energy) [Construction, maintenance and operations data combined value was available]		
		Concrete pavement	27 TJ/km (Embodied Energy) [Construction, maintenance and operations data combined value was available]		
Carbon Footprint for HMA and PCC Pavements (Mukherjee, 2011)	15 years	Asphalt pavement	511.27 (MT CO_2Eq./year/lane mile) [Construction, maintenance and operations data combined value was available]		
The Greenhouse Gas Emission from Portland Cement Concrete Pavement Construction in China. (Feng Ma, 2016)	Not indicated in the study/ paper	Concrete pavement	2,053.83 (ton CO_2/lane km)	X	X
Indian studies					
Methodology for Estimating Carbon Footprint of Road Projects: Case Study India (Asian Development Bank, 2010)	22 years	Asphalt pavement [NH (MP/UP): East West Corridor; 4 lane]	24 (ton/lane km/year)	2.8 (ton/lane km/year)	826.7 (ton/lane km/year)
Life Cycle Analysis of Transport Modes (TERI, 2012)	30 years	Asphalt pavement [Rohtak-Bawal NH-71; 4 lane]	28.7 (ton/lane km/year)	X	X
		Asphalt pavement [Delhi-Agra NH-2; 6 lane]	X	5.97 (ton/lane km/year)	X

Estimating Carbon Footprint of NH sector – Approach (C&M)

LCA approach selected to undertake carbon footprinting of NH network (consonance with **International and Indian best practices[1]**)

Construction & Maintenance phases

Estimation of **project level** CO_2 emissions (tonnes CO_2 per lane km per year)

↓

Extrapolation of project level estimates to derive CO_2 emissions from entire NH sector

↓

CO_2 emissions during Construction & Maintenance phases **for entire NH**

TERI's excel-based model developed as part of this study

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Phases and processes involved in Calculating CF (C&M)

Production of materials

Transport of materials

Movement of labour

Construction and maintenance at site

Construction + Maintenance (annual and periodic)

- Embodied carbon of materials and fuel; and consumption of energy for transport of materials
- Direct emission from machinery, movement of labour, materials, etc. during construction and maintenance phases
- Indirect emission from production of fuels like petrol and diesel

Selecting representative NH for CF Estimation

Selection of representative highways based on

Geographical and environmental parameters (Terrain, physiography, etc.)

Other highway parameters (Construction materials, Type of work, etc.)

- Coastal
- Desert
- Hilly
- Plain
- Concrete
- Greenfield

Identifying ongoing/under maintenance projects, which satisfy the above criteria, in consultation with the MoRTH

Exploring the availability of data for construction and maintenance phases from the representative National Highways

Selection of road stretches where data is available with the agencies

Estimating Carbon Footprint of NH sector – Approach (Operations)

Operations phase

Estimation of **transport demand** on National Highways (passenger + freight)

↓

Estimation of CO_2 emissions from movement of vehicles on NHs using NITI Aayog's IESS Tool

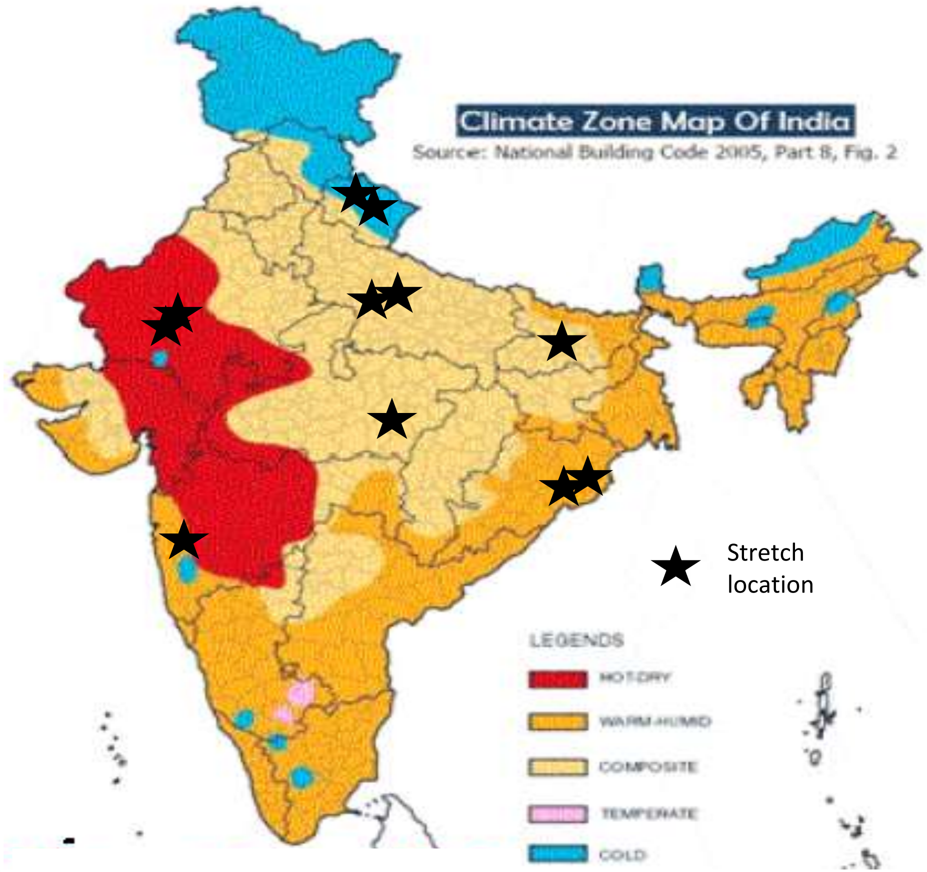
↓

CO_2 emissions during Operation phase from entire NH

NITI Aayog's IESS Tool
(which uses TERI's Transport Demand, Energy and Emissions estimation model)

Project level estimates – Representative Stretch Locations

- Primary data of 11 National Highways covering **860 km** used to estimate CO_2 emissions for construction and maintenance phases



Source: TERI Analysis

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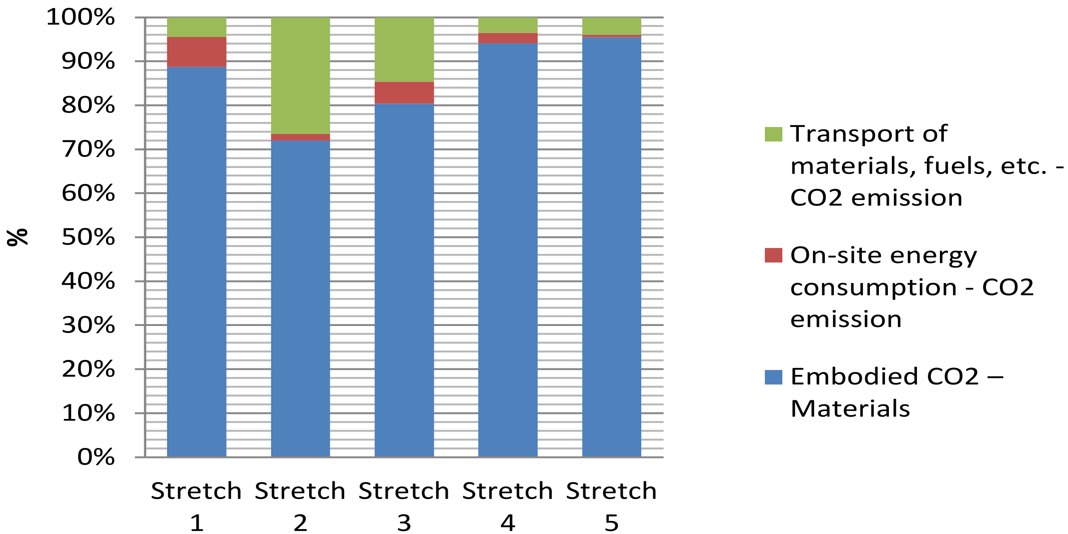
Project level Estimates - Key Findings

CO_2 emissions on account of **embodied carbon** in materials is in the range of **72% to 95.4%** of the total construction phase for the sample projects

Emphasizes the need to use low carbon/local materials



Stretch-wise emission share of transport of materials, fuel, etc.; on-site energy consumption; and embodied materials on account of construction
(Source: TERI Analysis, 2016)





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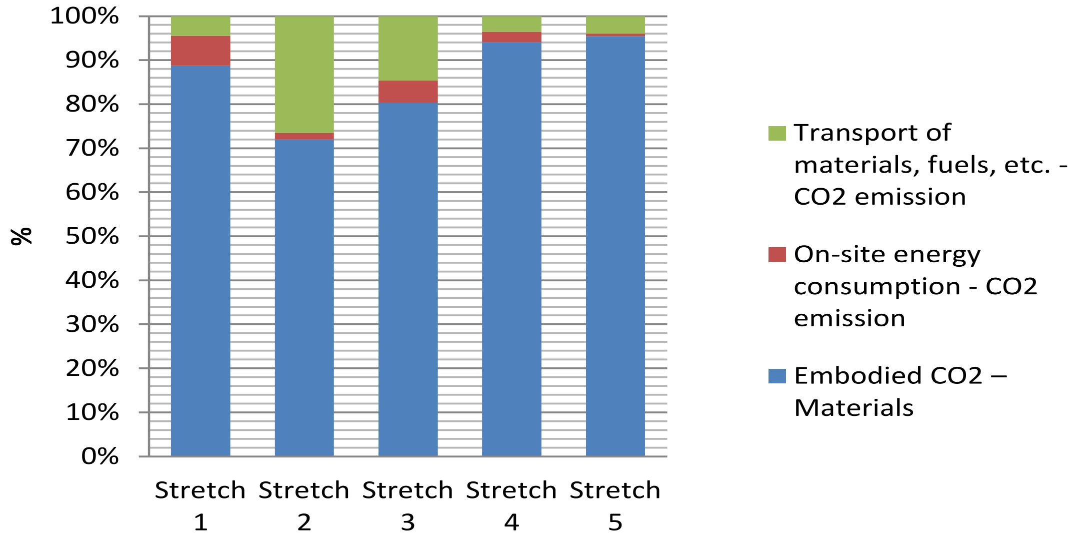
Project level Estimates - Key Findings

CO_2 emissions on account of **movement of** materials from source to site of consumption is in the range of **4% to 26%** of the total construction phase for the sample projects

Emphasizes the need to reduce the lead/use of efficient mode of transportation



Stretch-wise emission share of transport of materials, fuel, etc.; on-site energy consumption; and embodied materials on account of construction
(Source: TERI Analysis, 2016)

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Project level Estimates - Key Findings

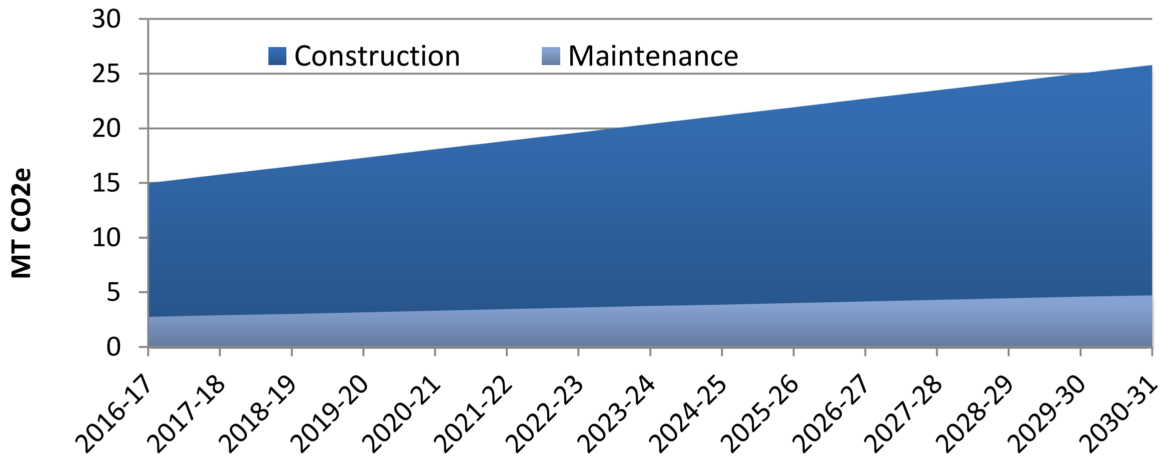
- Number of cycles of periodic maintenance also has a large implication on the resulting emissions from maintenance phase
- Preventive maintenance techniques help in extending the lifetime of road pavements
- Good riding quality leads to higher vehicle efficiencies, lower emissions, and cost savings

Emphasizes the need to maintain good quality road network

CO_2 emissions of entire NH network – C&M phases

Scaling up of project-level emissions

- Use of emission factors per lane km for construction and maintenance for different terrains to arrive at National-level CO_2 emissions
- The two phases account for about 14% of the total CO_2 emissions from the NH sector



NH length to grow from **3.3 lakh lane km** in 2016 to **5.7 lakh lane km** in 2030

Source: TERI Analysis, 2016

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Co_2 emissions - Operations phase

NITI Aayog's IESS model

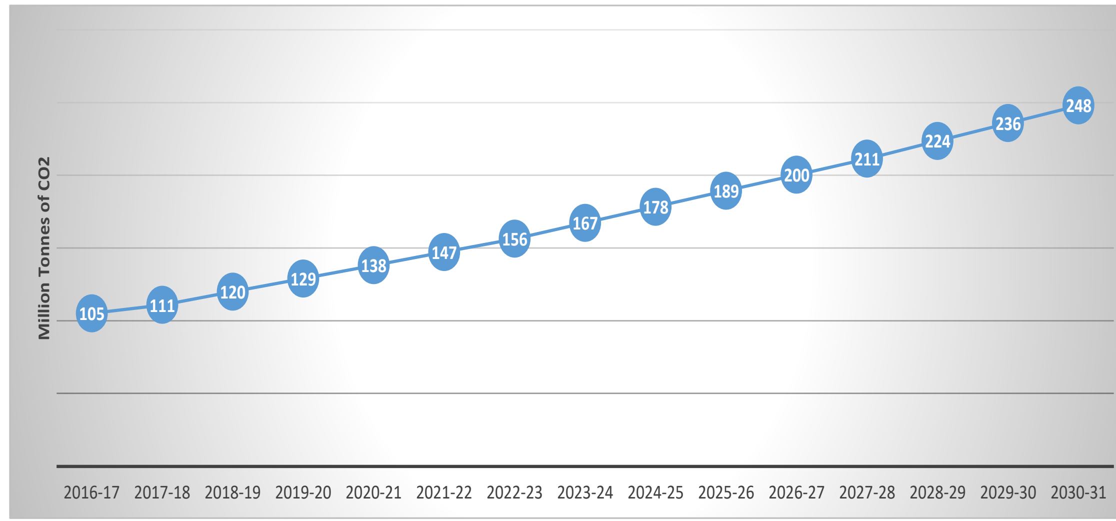
Traffic on NH (2016)

30% of total pass. km

50% of total tonne km

105 MT CO_2e from vehicle operations, which is **41% of total transport sector emissions**

Growth trajectory of CO_2 emissions from vehicular operations on National Highways



Source: TERI Analysis, 2016

Operations phase accounts for **86% of the total emissions** from the 3 phases

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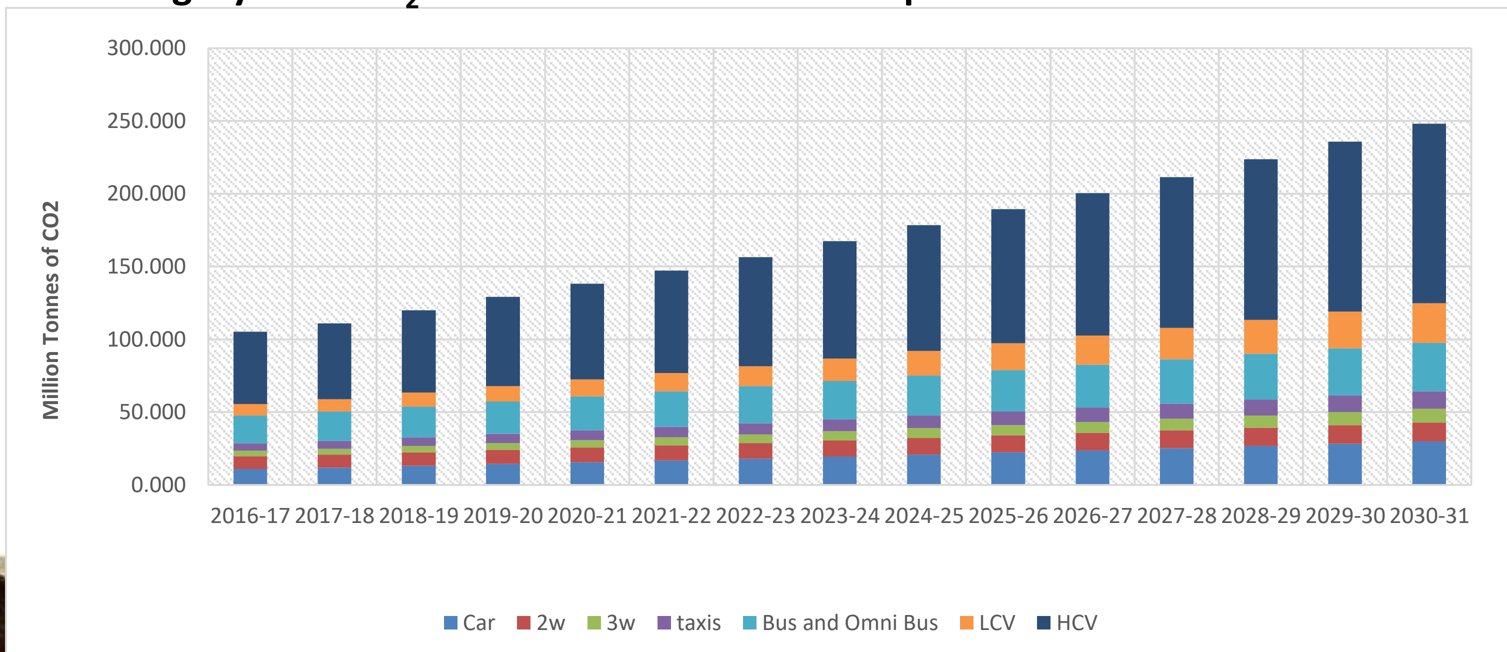
Co_2 emissions - Operations phase

Largest share of vehicular emissions on highways is from HDVs (47% in 2016-17), followed by bus and omnibus, cars, and LCVs

Category-wise CO_2 emissions from vehicular operations on Indian NH network

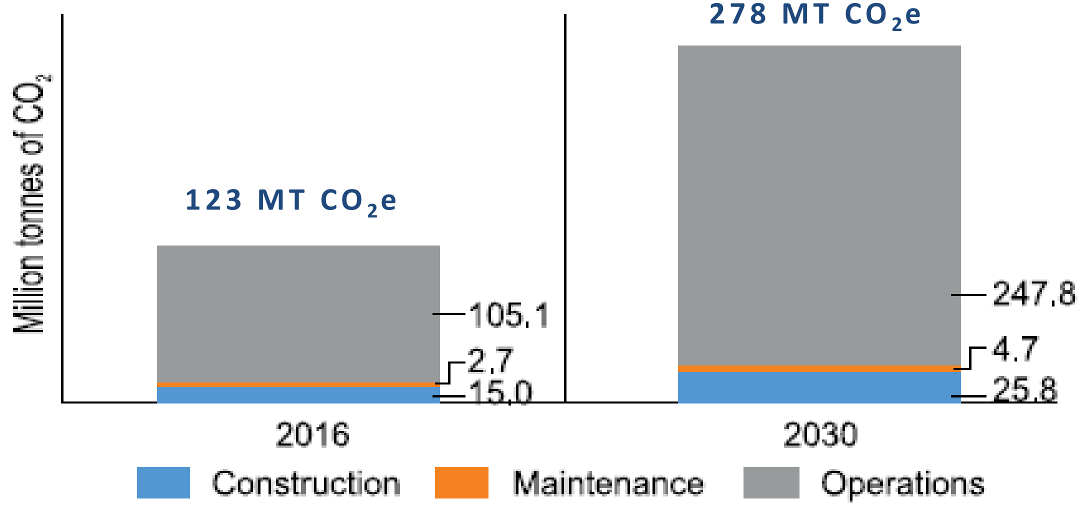


Source: TERI Analysis, 2016

Total CO_2 emissions – NH Sector (2016 & 2030)

- Operations phase is expected to continue to account for the maximum share in CO_2 emissions between 2016 and 2030 (i.e. 86%)

CO_2 emissions on account of construction, operation and maintenance of National Highways in India during 2016 and 2030



Source: TERI Analysis, 2016

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Interventions for emission Reduction (Operations Phase)

Expedite implementation of fuel efficiency norms	Improve fuel efficiency levels by 20%	Can lead to 15% reduction in annual highway emission in 2030
Fund provision for maintenance of NH network	Adequate budget/fund allocation towards highway maintenance for EPC projects	
Shift to larger trucks	Moving freight on larger trucks, with higher capacities	High engine-weight ratio: Use of engine capacity of >9 litres
Move to Electric Drivetrains/alternate fuels	Significant potential to reduce emissions, provided adequate infrastructure is in place	

Interventions for emission Reduction (Operations Phase)

Establish stringent regulations for reducing emissions from in-use vehicles → Establishment of a robust inspection and maintenance (I&M) regime and policy for phasing out/scrapping end of life vehicles (ELVs)

Creation of Carbon Sink through afforestation and reforestation → It is recommended that the process of tree plantation under the National Green Highways Mission be expanded to cover the entire NH length

Increase share of public transport → If measures undertaken to retain and improve share to 72%, corresponding reduction in emissions will be 10%





INTERVENTIONS FOR EMISSION REDUCTION (CONSTRUCTION AND MAINTENANCE PHASE)

Promote the use of

- **Green Construction Technologies**
  - Warm Mix Asphalt
  - Cold Mix Asphalt
  - Microsurfacing
  - Soil stabilisation
- **Alternate materials**
  - Reclaimed Asphalt Pavement (RAP)
  - Geo-Synthetics
  - Plastic Waste
  - Rubber Waste

INTERVENTIONS FOR EMISSION REDUCTION (CONSTRUCTION AND MAINTENANCE PHASE)

Planning stage

- Designing the vertical grade with higher initial speed with vertical grade less than 6%.
- Designing vertical curve higher K-values.
- Alignment selection – Use of *LiDAR*

Construction stage

Advanced highway construction practices

- Use of *efficient machinery and equipment*
- *Maintenance of machinery/equipment*
- Machinery and equipment with *advanced equipment technology and fuels*
- *Training* of equipment operator
- Slot dozing
- Production of bituminous and concrete mix
- Efficient transportation of construction material (water/rail)

Maintenance stage

- Routine/Periodic Maintenance
- Microsurfacing

Mainstreaming Interventions (construction and maintenance phases)

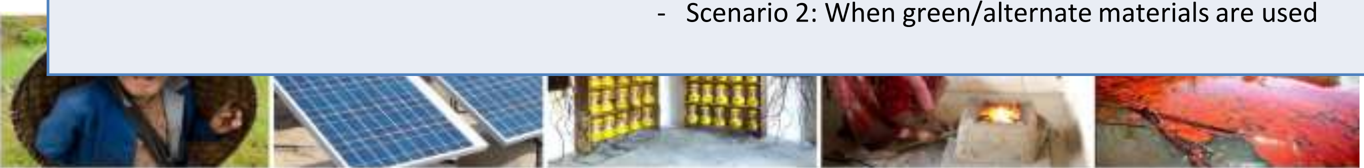
Topics	Recommendations
Developing National Highway Carbon Estimates for construction and maintenance phases	• The excel-based National Highway model/tool developed by TERI to estimate CO_2 emissions during construction and maintenance phases could be used by the DPR consultants while undertaking project feasibility studies • The DPR consultants will require training
‘Green Rating System’ for Indian National Highways sector	• Using TERI’s excel-based NH model, NHAI/MoRTH could develop a compendium of emissions estimated for various NH projects • Based on this, a ‘Green Rating System’ could be initiated, which would help quantify the performance of National Highway projects on a carbon footprint scale. • A pool of experts for evaluating carbon emissions could be housed in MoRTH under an appropriate department/unit proposed in Component II of the study
Better data management for estimating carbon footprint of NHs	• For a number of projects, complete data was not available for the estimation purpose. • A data template has been suggested, which could be used for energy and carbon emission related estimation

Mainstreaming Interventions (construction and maintenance phases)

Topics	Recommendations
Updating/enforcing IRC Guidelines and Codes for construction materials and methods	• There are several materials/methods which are covered under the IRC Guidelines/Rules but are not deployed or used due to various reasons • For these materials, more awareness or more demonstration projects need to be undertaken.
Construction materials/ methods not under IRC Guidelines/Codes	• More R&D and pilots projects need to be undertaken regarding such products with the help of PWDs and research organizations like CRRI • Adding these materials in IRC guidelines will give an option to the contractors to procure locally available materials and reduce the lead for procuring conventional materials from far off places
Constitution of R&D Innovation Support Fund	• R&D innovation support fund should be constituted to encourage/promote the use of green materials/technologies. • Some part of the incremental cost on account of using alternate/green materials could be borne by the implementing authority.

Mainstreaming Interventions (construction and maintenance phases)

Topics	Recommendations
Other policy and DPR related suggestions	• Government should ensure that certain percentage of National Highways should be developed using green materials or technologies • The additional cost burden should be shared, where the government/authority could use the R&D Innovation Support Fund to promote green materials/technologies • In the bidding document, competitive advantage should be given to the bidders/contractors who are keen to use green material/technology while constructing National Highways • To encourage the use of green/alternate materials in National Highways, life cycle analysis should be made mandatory for every project. In addition, the total life cycle cost and emissions of projects should be compared under two scenarios: - Scenario 1: When conventional materials/technologies are used - Scenario 2: When green/alternate materials are used



TERI study on urban transport LCA

A life cycle analysis of urban public transport systems in Indian cities

- BRTS

- MRTS

- http://www.codatu.org/wp-content/uploads/A-Life-Cycle-Analysis-of-Urban-Public-Transport-Systems-in-Indian-Cities-Shri-Sharif-Qamar-TERI-India.pdf

Selected TERI Reports

- Faster adoption of electric 2W in India: A perspective of consumers and industry
- Switching to a Sustainable Auto-rickshaws System
- Integrating electric buses in public transport: Kolkata's success story
- Roadmap for Electrification of Urban Freight in India
- Benefits of Cycling in India
- Impact of COVID-19 on urban mobility in India: Evidence from a perception study
- Making Mission Possible: Delivering a Net-Zero Economy
- Increasing the Rail Share in Freight Transport in India
- Comparison of Decarbonisation Strategies for India's Land Transport Sector: An Inter Model Assessment
- Reduction of Carbon Footprint in Highways Sector

Thank you

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