Developing Methodology to estimate WTW impacts in Heavy Haul Transportation

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IHHA 2025
13TH INTERNATIONAL HEAVY HAUL ASSOCIATION CONFERENCE 2025
November 17-21, 2025 | The Broadmoor, Colorado Springs, CO, USA

Introduction

- India's freight transport is a major energy and emissions source, producing 14% of national GHGs. Freight uses over 40% of the sector's final energy, and roads consume 90%.
- Demand will rise from 2,000 to over 10,000 billion tonne-kilometres between 2020 and 2050, underscoring the need for cleaner options.
- Prior studies focus on tailpipe impacts and overlook upstream Well-to-Tank emissions. This work delivers a Well-to-Wheel assessment tailored to India. Unlike GREET, which reflects U.S. conditions, we adapt the GHGenius LCA model to India's context.
- With coal supplying 49.3% of electricity, benefits of rail electrification can be overstated unless grid carbon intensity is included raising a key policy question about electric rail's true role under current and alternative mixes.
- Our approach supports better freight policy and energy-system investment decisions. Applied to major corridors, it yields insights for sustainable logistics, higher efficiency, and progress toward national climate goals and Indian Railways' 2030 net-zero pledge.

Experimental work

- Customized GHGenius Life-Cycle Assessment (LCA) to estimate complete Well-to-Wheel (WTW) emissions , covering extraction, processing, distribution, and end use.
- GHGenius offers broader fuel pathways and flexibility than GREET/AFLEET/MOVES, adapted for India's mix of coal, CNG, biomass, and ethanol.
- Focus on DMIC, BMEC, AKIC (India) and Dhaka–Chattogram (Bangladesh) for regional comparison.
- Integrated with FlexSim v25.2.0 to model 2024 freight and passenger flows under alternative energy scenarios.
- Crude extraction (offshore 0.85× U.S., onshore 1.3×), distribution via pipeline 56%, rail 23%, road 20%; refining energy 0.059 J/J; materials use +10% energy vs North America.
- Coal mining 300,000 kJ/t; methane 10,500 L/t (UG), 1,800 L/t (OC); gas 1,134 MJ/t; 95% vehicles locally produced; tailpipe scaled from MOBILE6.2C to Bharat Stage VI.

Results

- Upgraded GHGenius estimated freight emissions for road heavy-duty vehicles and electric rail for 2019–2024.
- For road HDVs (WTT): CO_2 decreased from 1324 to 1318 g/km; CH_4 increased 2.97 to 2.99 g/km; NO_x decreased 5.16 to 5.12 g/km.
- For electric rail (full fuel cycle): 430,574 to 412,375 g-CO_2-eq/GJ delivered.
- In 2024, rail carried 39% of tonne-km but produced only 14% of WTT and 2% of TTW emissions.
- Road carried 61% of tonne-km yet generated 86% of WTT and 98% of TTW emissions.
- Corridor totals: DMIC 2.42 Mt CO_2-eq (lowest), AKIC 3.88 Mt, BMEC 6.18 Mt.
- Rail commodity drivers: AKIC wheat 81,593 t (80%); BMEC cement 73,433 t (45%) and clinker 54,888 t (33.7%); DMIC containers 24,805 t (39.1%).
- Reducing coal share to 30% with 95% T&D cuts WTW up to 44.7%; efficiency gains alone at 49.3% coal yield only 3.8–7.6%, as a result of which grid decarbonization dominates.

Conclusions

- Shifting freight from road to rail, combined with cleaner electricity, gives the largest emission reductions.
- Rail carried 39% of tonne-km but produced only 14% of WTT and 2% of TTW emissions.
- Lowering coal share to 30% cuts WTW emissions by up to 44.7%.
- Results confirm that transport and power policies must work together to maximize decarbonization.
- Cleaner air, reduced fuel exposure, and faster progress toward India's climate goals.
- Future benefits include Use finer-scale (state-level) data, capture seasonal variations, and test biofuel/hydrogen & multimodal options.

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Acknowledgments

The authors acknowledge the funding and support provided by the Indian Railways and the International Union of Railways (UIC) for this research. The authors also thank the Centre for Railways Information Systems (CRIS) for providing the datasets.

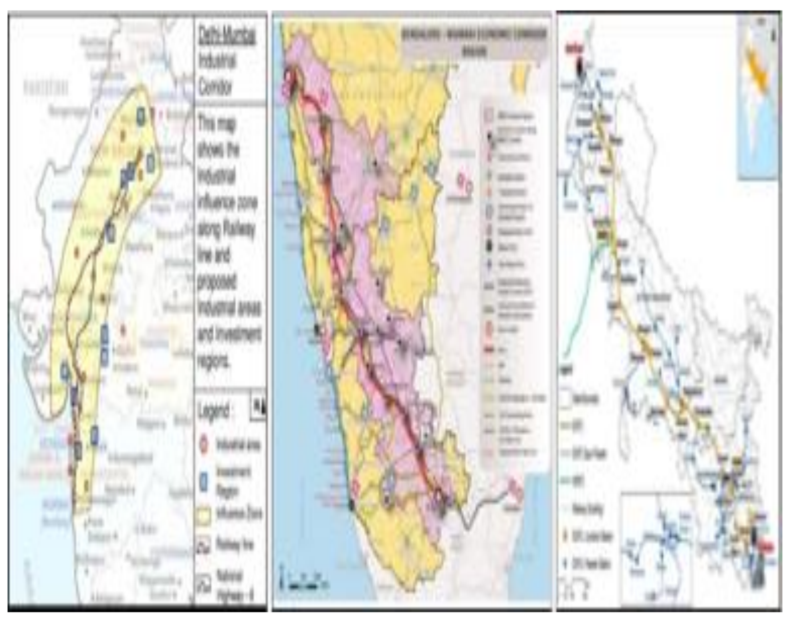

Figure 1. (a) DMIC corridor; (b) BMEC; (c) AKIC.

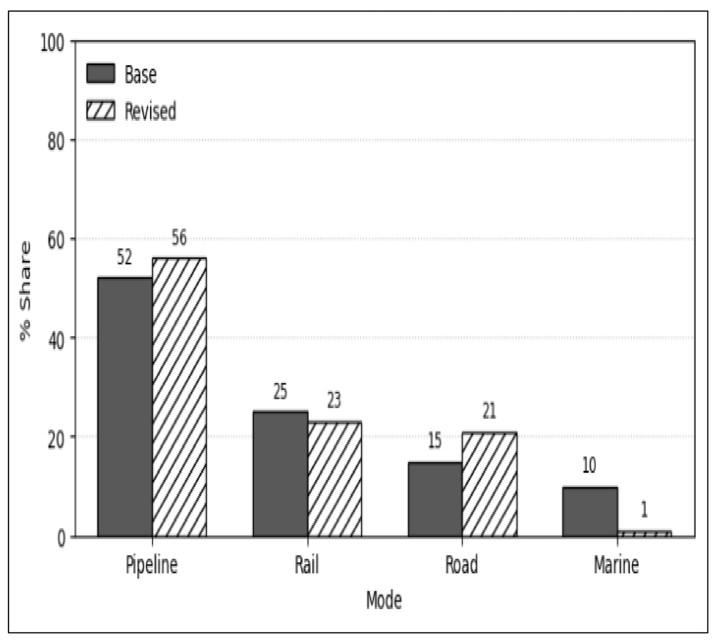

Figure 2. Base and Revised mode share for petroleum distribution

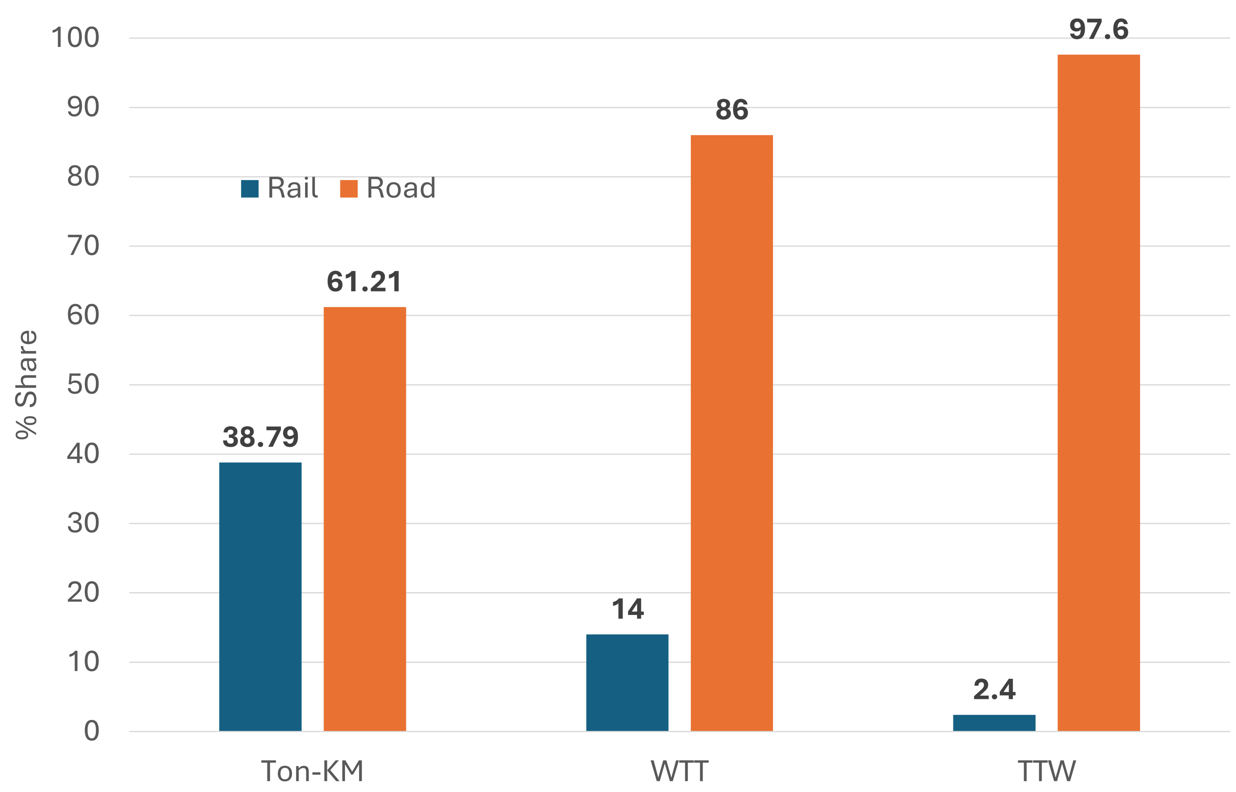

Figure 3: Share of rail and road freight in Ton-KM, WTT, and TTW emissions.

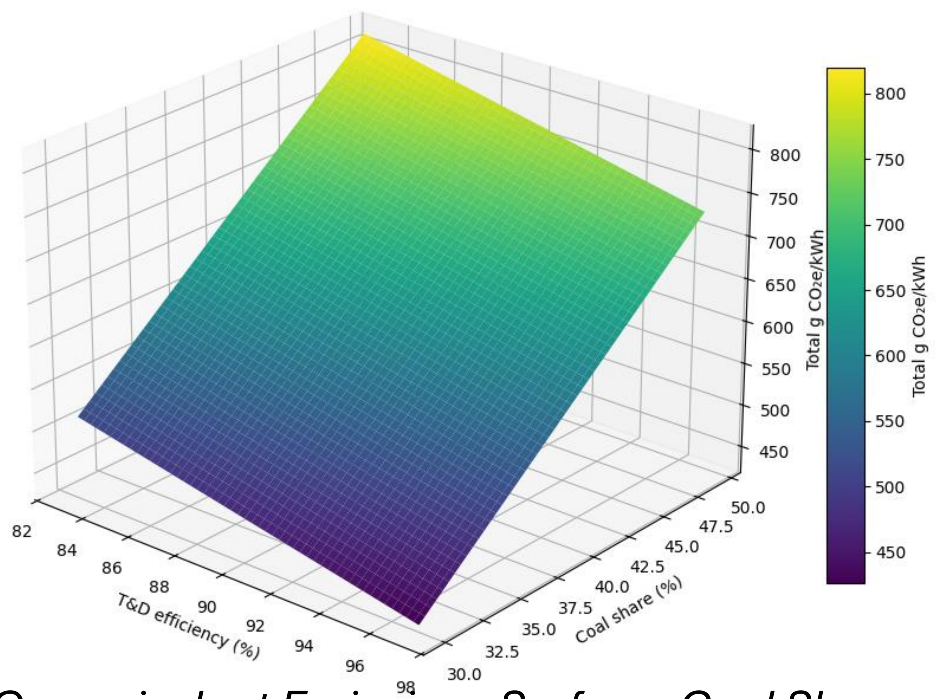

Figure 4: *CO_2-equivalent Emissions Surface: Coal Share vs. T&D Efficiency*

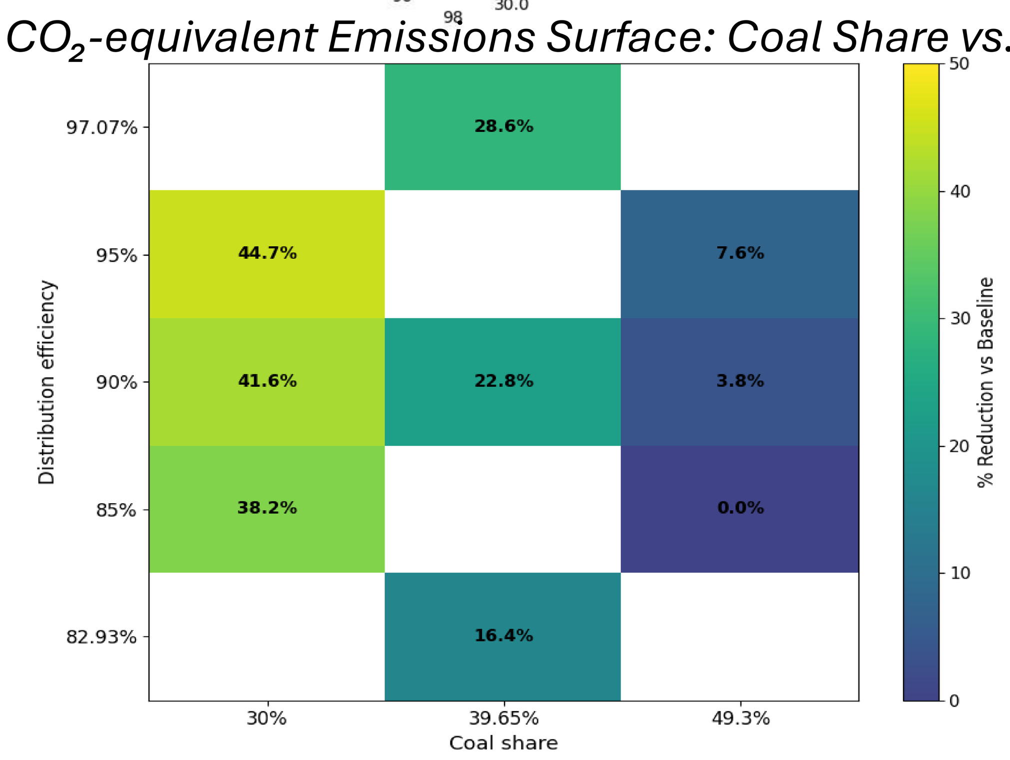

Figure 5: WTW impacts Reductions (%) vs Baseline Scenarios.