Carbon Footprint Assessment in Road Construction Projects: Methods for Reducing Emissions

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Key Finding:

235,000
kg CO_2-eq/km
Sri Lanka OCH

3.01×
higher carbon intensity
Performance Gap (IPCC 2021 GWP100)

78,100
kg CO_2-eq/km
Italy A3 Motorway

Consistent across ReCiPe 2016 Midpoint (H) — ratios 2.81 to 3.58 — confirming a consistent performance difference under selected model assumptions

Introduction & Methodology

Background

The global construction sector contributes 39% of GHG emissions. Road infrastructure is a major contributor. No standardised ISO-compliant LCA methodology exists for Sri Lankan road construction, creating a gap in sustainable infrastructure planning and climate policy evidence.

Case Studies

	Sri Lanka OCH/E02	Italy A3
Pavement	Dense AC (50+100mm)	Porous + PMB
RAP	< 5%	25%
Electricity	40% coal, 40% hydro	34% renewable
Ecoinvent	RoW (adapted)	RER / IT

Research Aim

Phase 1 — Goal & Scope: Functional unit: 1 km two-lane road, modules A1–A5, cradle-to-gate, 20-year design life
Phase 2 — LCI Analysis: SimaPro 9.6.0.1 + Ecoinvent v3. Custom SL electricity grid (CEB 2023). RoW datasets adapted for cement, aggregates, freight
Phase 3 — LCIA: IPCC 2021 GWP100 V1.01 (primary) + ReCiPe 2016 Midpoint H (supplementary — 18 impact categories)
Phase 4 — Interpretation: OAT sensitivity analysis (4 parameters ±20%) + 5 emission reduction scenarios

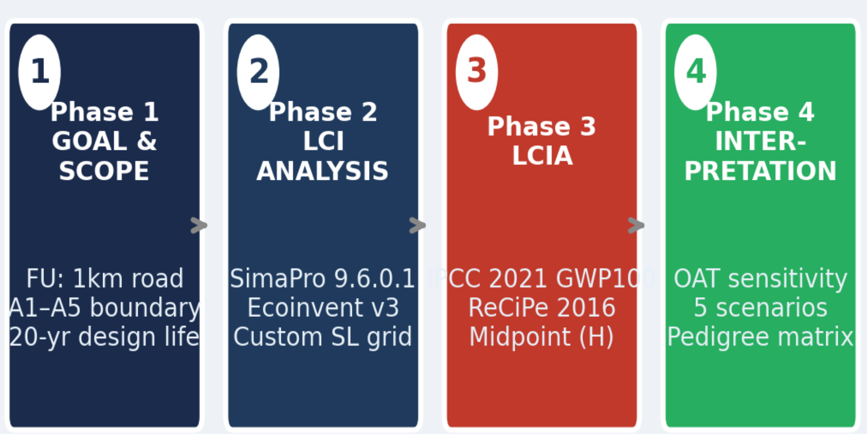
Methodology

- ISO 14044:2006 four-phase LCA
- SimaPro 9.6.0.1 + Ecoinvent v3 cut-off
- Functional unit: 1 km two-lane road, A1–A5
- IPCC 2021 GWP100 (primary indicator)
- ReCiPe 2016 Midpoint H (supplementary)
- Custom SL grid mix from CEB 2023 data
- OAT sensitivity analysis (Monte Carlo not available in Faculty version)

Sub-Process Contribution — Sri Lanka OCH

Base Course (32.8%)
Subbase & Earthwork (32.5%)
Binder Course (20.5%)
Wearing Course (10.2%)
Transport foreground (2.4%)
Equipment A5 (2.0%)

ISO 14044:2006 — Four-Phase LCA Framework Applied in This Study



Keywords

LCA • Carbon footprint • Road construction • SimaPro • Sri Lanka • ISO 14044 • GWP100 • Emission reduction • Supply chain optimisation

Results & Analysis

Sensitivity Analysis

One-at-a-time (OAT): each parameter varied ±20% while others held constant:

dist_agg +20% (55→66 km) — **+17% ★ DOMINANT PARAMETER**

dist_bitumen +20% (90→108 km) — +0.4%

diesel_L_hr +20% (18→21.6 L/h) — +0.4%

dist_cement −20% (75→60 km) — +0%

Scenario Analysis Results

SL Baseline (current) — 235k

IT Reference (A3) — 78.1k (−66.8%)

Sc.1 Warm-Mix Asphalt — 235k

Sc.2 RAP 20% — 235k

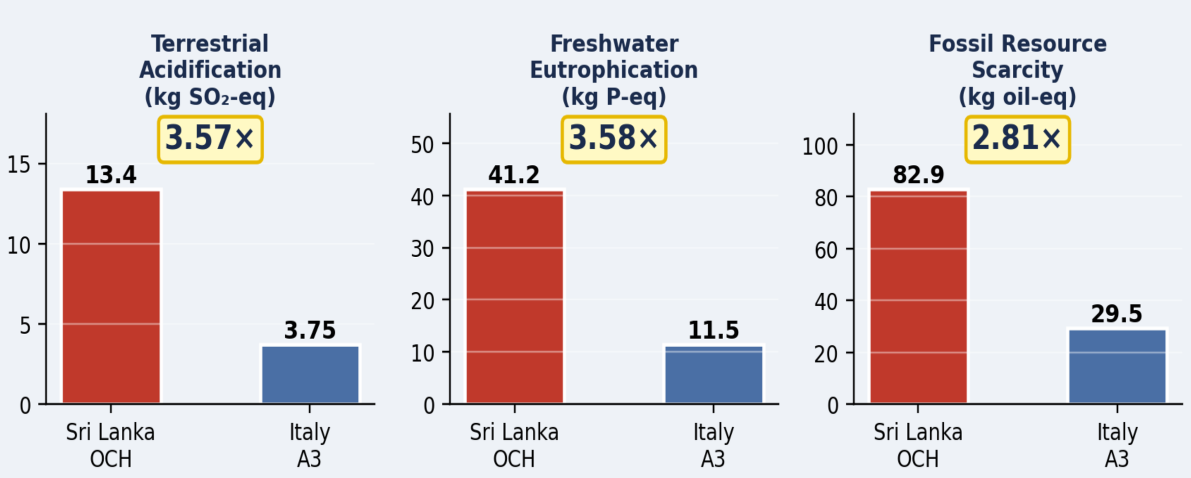
Sc.3 Local Sourcing −8% ★ — 172k (−26.8%)

Sc.4 Equipment Fleet — 235k

Sc.5 Integrated Best Practice — 171k (−27.2%)

Values ×000 kg CO_2-eq/km | ★ = highest leverage scenario | Sc.1, Sc.2, Sc.4 < 0.1% change

ReCiPe 2016 Midpoint (H) — Supplementary Impact Categories
Sri Lanka consistently higher across ALL 18 categories (ratios 2.81-3.58×)



KEY INSIGHT: WHY WMA & RAP SHOW < 0.1%

Aggregate haulage dominates the SL model so completely that a 25% energy saving in asphalt production (contributing 10–20% of total) yields only ~2.5% system-level saving — within the model rounding margin. WMA & RAP remain essential for institutional capacity and medium-term transition.

Summary of Key Quantitative Findings
(SimaPro 9.6.0.1 | IPCC 2021 GWP100 | ISO 14044:2006 | Modules A1–A5)

Finding	Sri Lanka OCH	Italy A3	Ratio
GWP100 (kg CO_2-eq/km)	235,000	78,100	3.01×
Dominant sub-process	Base+Subbase (65.3%)	Base stabilised (42.8%)	—
Equipment share (A5)	2.0%	3.9%	Low both
RAP content	< 5%	25%	Key gap
Best scenario result	171,000 (−27.2%)	78,100 (ref.)	2.19× still

Conclusions & Recommendations

Key Conclusions

C1 Sri Lanka road construction is 3.01× more carbon-intensive than Italy A3 (235,000 vs 78,100 kg CO_2-eq/km) — consistent across all impact categories (2.81–3.58).

C2 Gap driven by aggregate supply chain intensity and virgin material dependency. Construction equipment contributes only 2% of total emissions.

C3 Local sourcing optimisation (−26.8%) is the highest-leverage action — achievable through RDA procurement policy without new technology or capital investment.

C4 WMA and RAP show <0.1% system-level impact today due to aggregate haulage dominance — essential for medium-term institutional capacity building.

C5 Construction-phase interventions alone cannot close the full gap. Grid decarbonisation and structural changes required for residual 92,900 kg CO_2-eq/km.

C6 The SimaPro LCA framework provides a documented methodology adaptable for other Sri Lankan infrastructure projects and developing-country contexts.

Three-Pillar Emission Reduction Framework

1 — Supply Chain & Local Sourcing | Short term (1–3 yrs)
- National Aggregate Sourcing Strategy
- Max haul distance in procurement rules
- 3–4 RAP processing centres nationally

2 — Technology Adoption (WMA + RAP) | Medium term (3–5 yrs)
- Revise RDA SSCM to permit WMA
- Mandate 20–25% RAP incorporation
- Chemical surfactant WMA pilot programme

3 — Policy & Institutional Reform | Long term (5+ yrs)
- Mandatory carbon disclosure in procurement
- PAS 2080 adoption pilot
- Green bond financing for infrastructure
- National LCA database (cement first)

Expected Outcome

With all 3 pillars → Sri Lanka road construction can reach ~80,000 kg CO_2-eq/km by 2035–2040, approaching Italian A3 performance.
Aligned with Sri Lanka Carbon Net Zero 2050 Roadmap (Ministry of Environment, 2023).

FUTURE RESEARCH DIRECTIONS

1. Primary emission factor data from SL cement producers (SL Cement Corp., Tokyo Cement)
2. Extend boundary to cradle-to-grave — include use-stage rolling resistance and maintenance
3. Lifecycle cost analysis — cost per tonne CO_2-eq avoided for each scenario
4. Replicate for urban roads, bridges, rehabilitation projects in Sri Lanka
5. Formal Monte Carlo analysis using SimaPro Professional version