Infrastructure materials modelling

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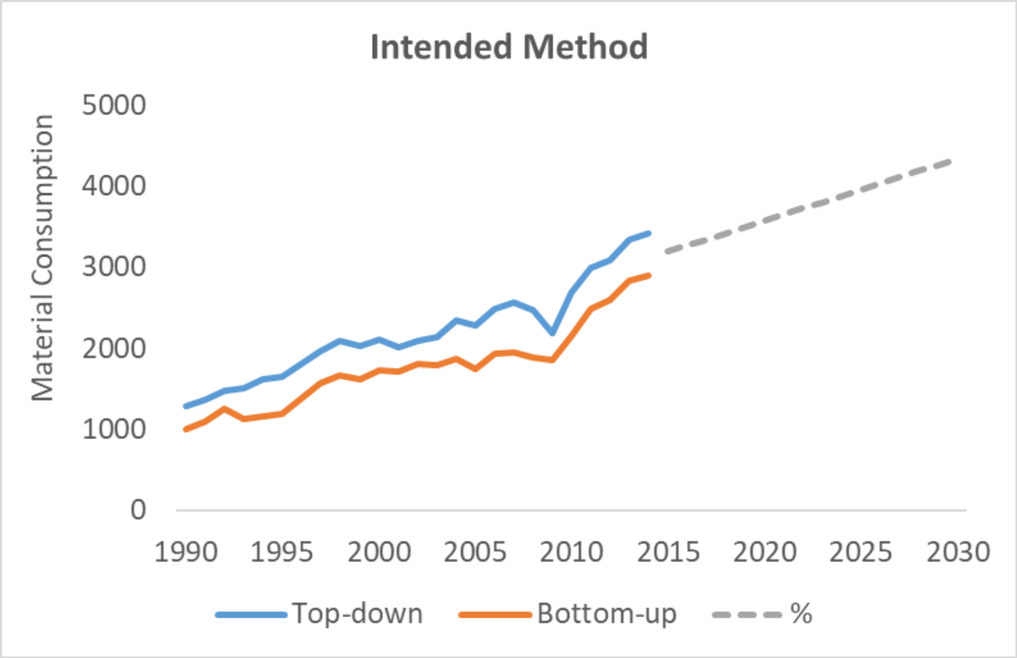
Experts' Dialogue on Material Trends in Transport CCM, 8 March 2018

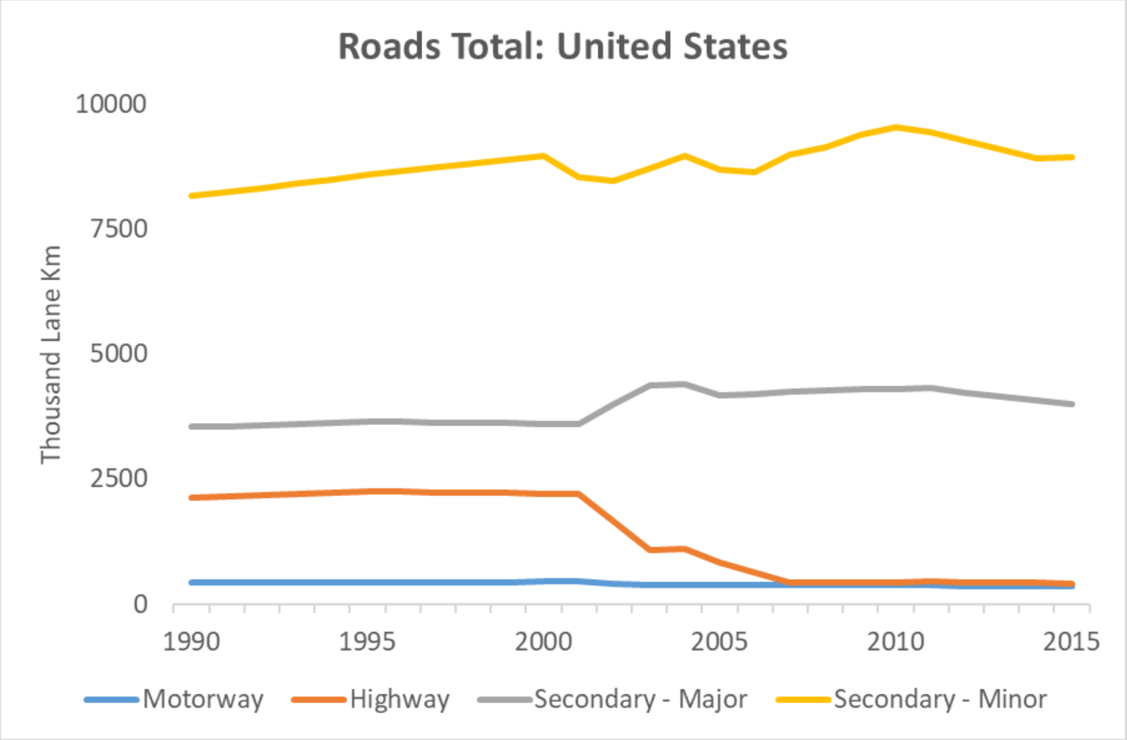
1) Objectives of Analysis

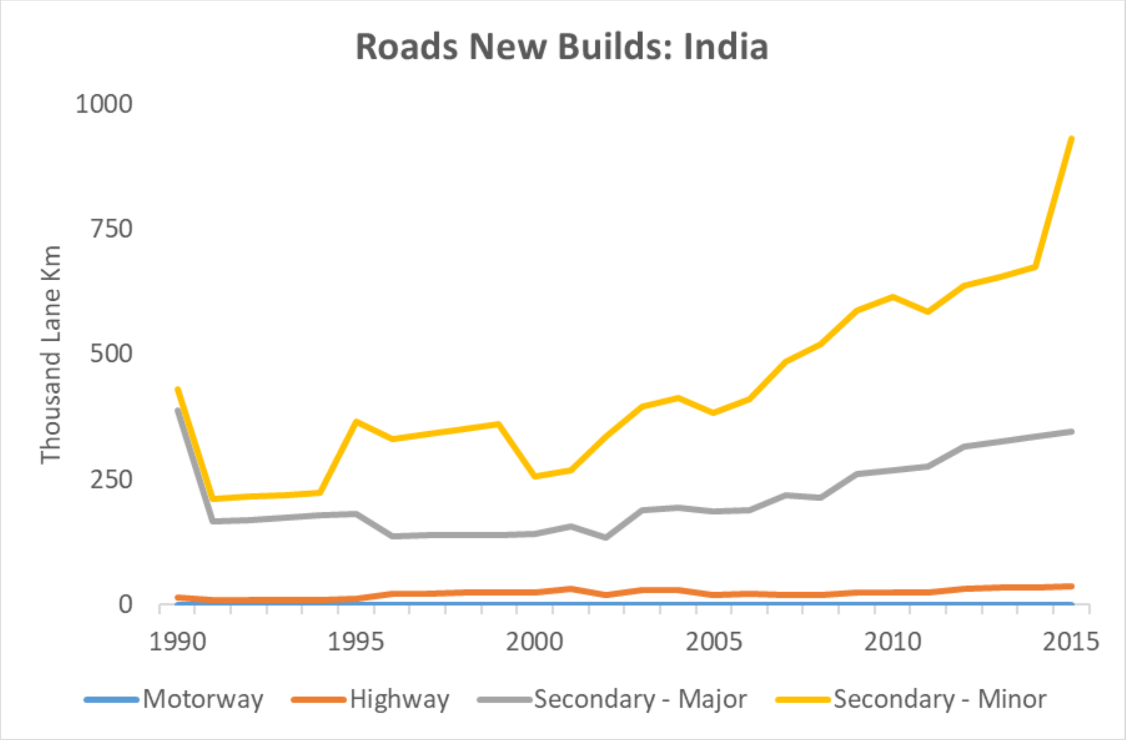
- **Scope**
  - Transport infrastructure: focus on roads and rail
  - Materials of focus: cement and steel
- **Method (recap from morning)**
  - Build historical bottom-up material demand curves & compare to top-down curves
  - Project material demand incorporating technological shifts & material efficiency strategies
  - Material curves feed into industry modelling, within global energy system model analysis



2) Bottom-Up Material Curves: Activity Levels

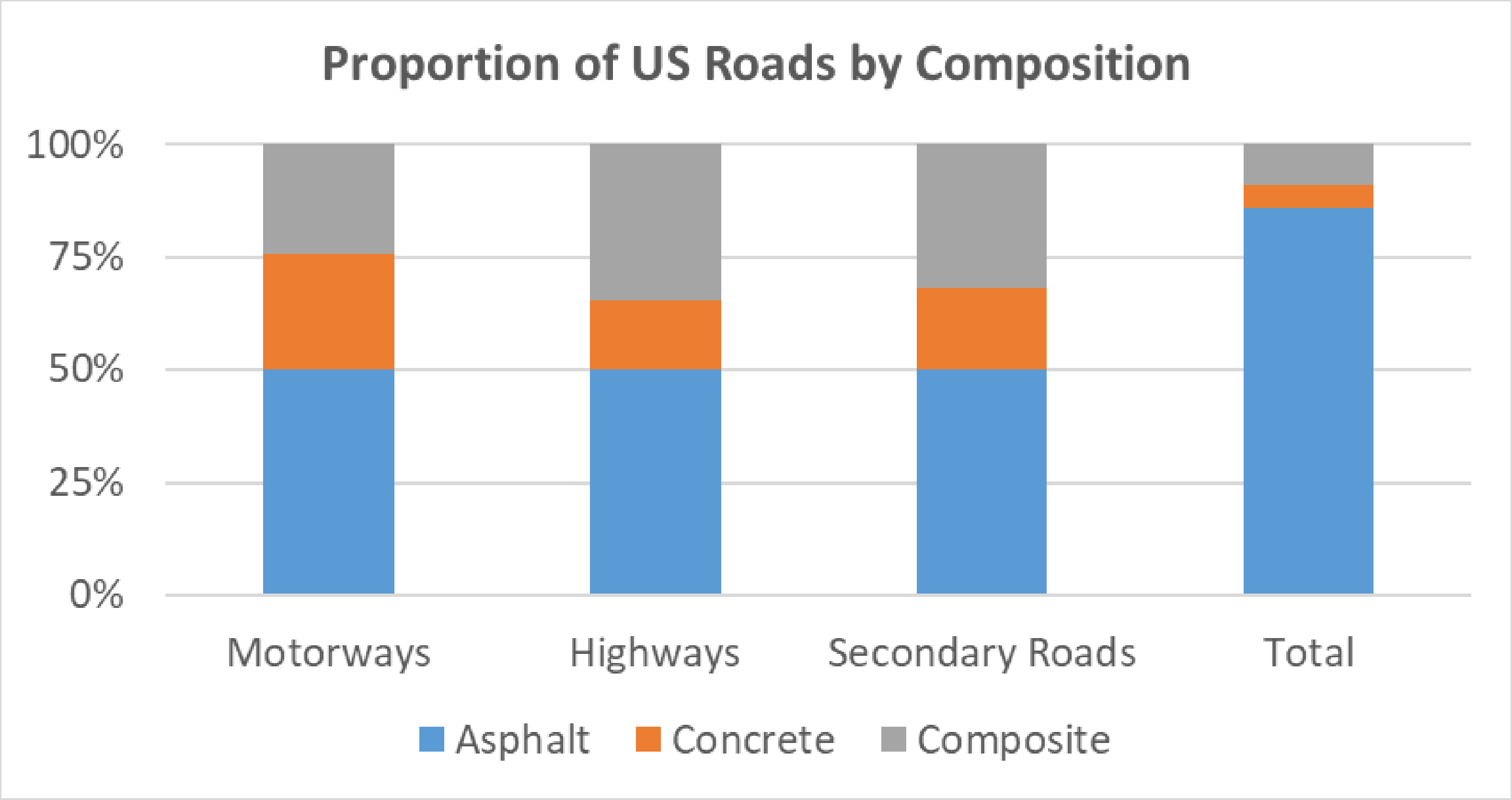
- **Road lane and rail track km assumptions:**
  - Data from International Road Federation (IRF), International Union of Railways (UIC) and Institute for Transportation and Development Policy (ITDP)
  - *Road categories*: motorway, highway, secondary major & minor
  - *Rail categories*: light rail, metro, inter-city rail & high-speed rail
  - Median lifetimes: concrete pavement roads = 45 years, rail = 40 years





2) Bottom-Up Material Curves: Material Intensities - Roads

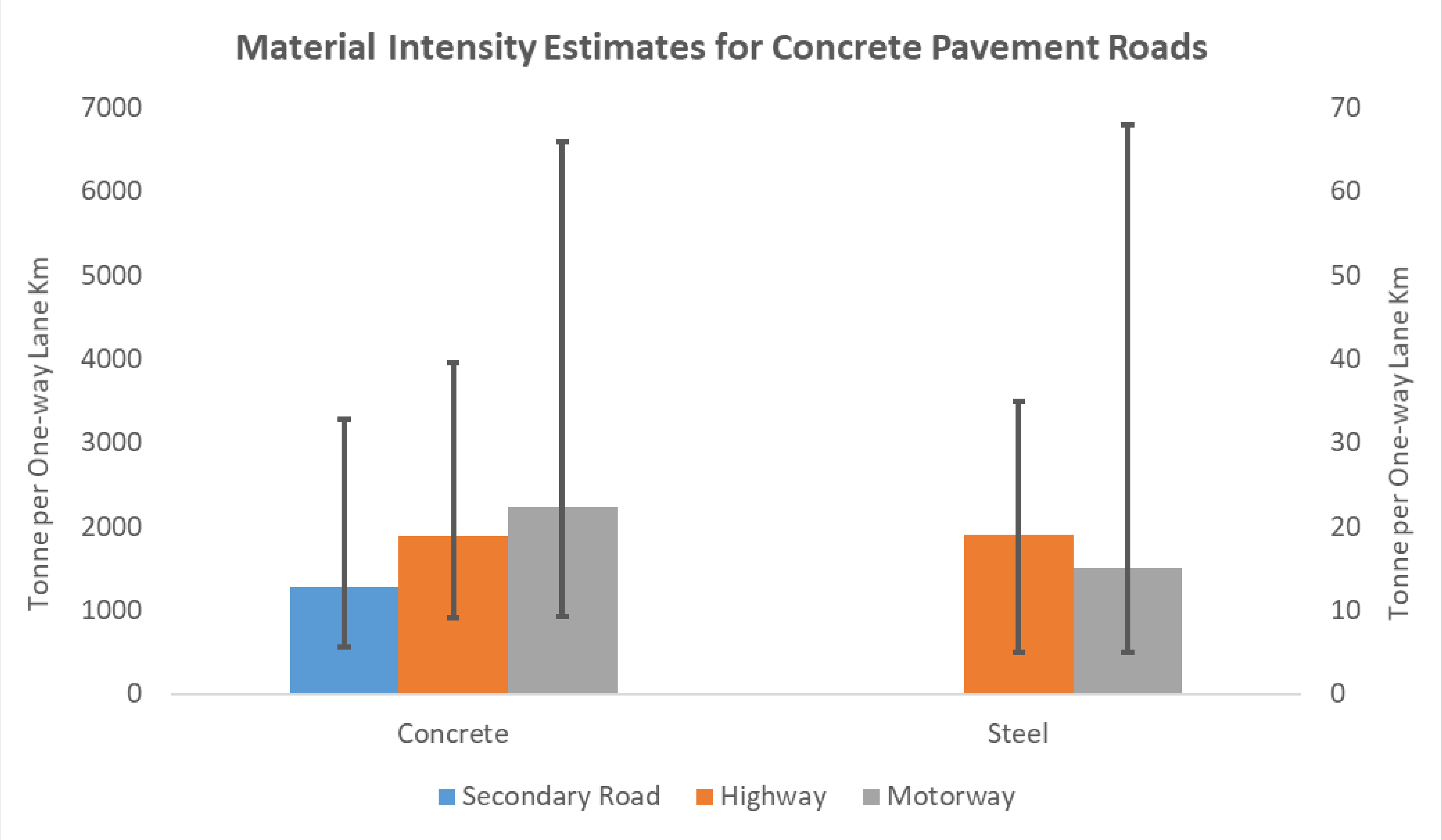
- **US Federal Highway Administration Statistics: Concrete plus Composite %**
  - Motorways: 47%
  - Highways: 27%
  - Secondary: 12%
  - **Total: 14%**
- **Drivers of road type:**
  - Economics?
  - Climate?
  - Other?



Proportion of roads by material composition is a key data gap

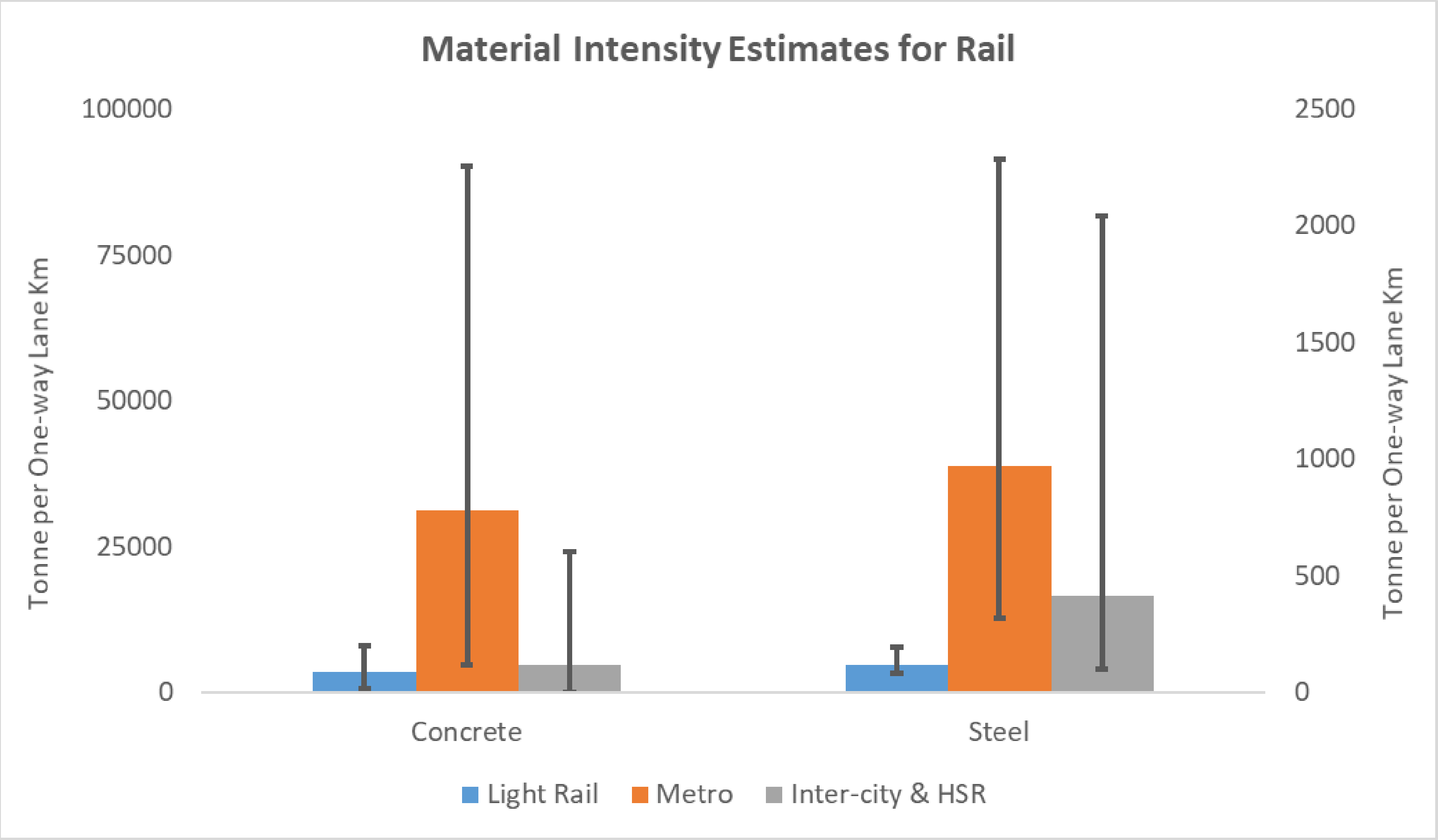
2) Bottom-Up Material Curves: Material Intensities - Roads

- **Cement proportion of concrete:**
  - Median: 13%
  - Range: 10 to 17%
- **Material intensities:**
  - Concrete use 100 to 150 times that of steel
  - Moderate range: 4 to 14 times differences between low and high values
- **Maintenance - % of surface repaired annually:**
  - Motorways/highways: 0.15%
  - Secondary: 9%



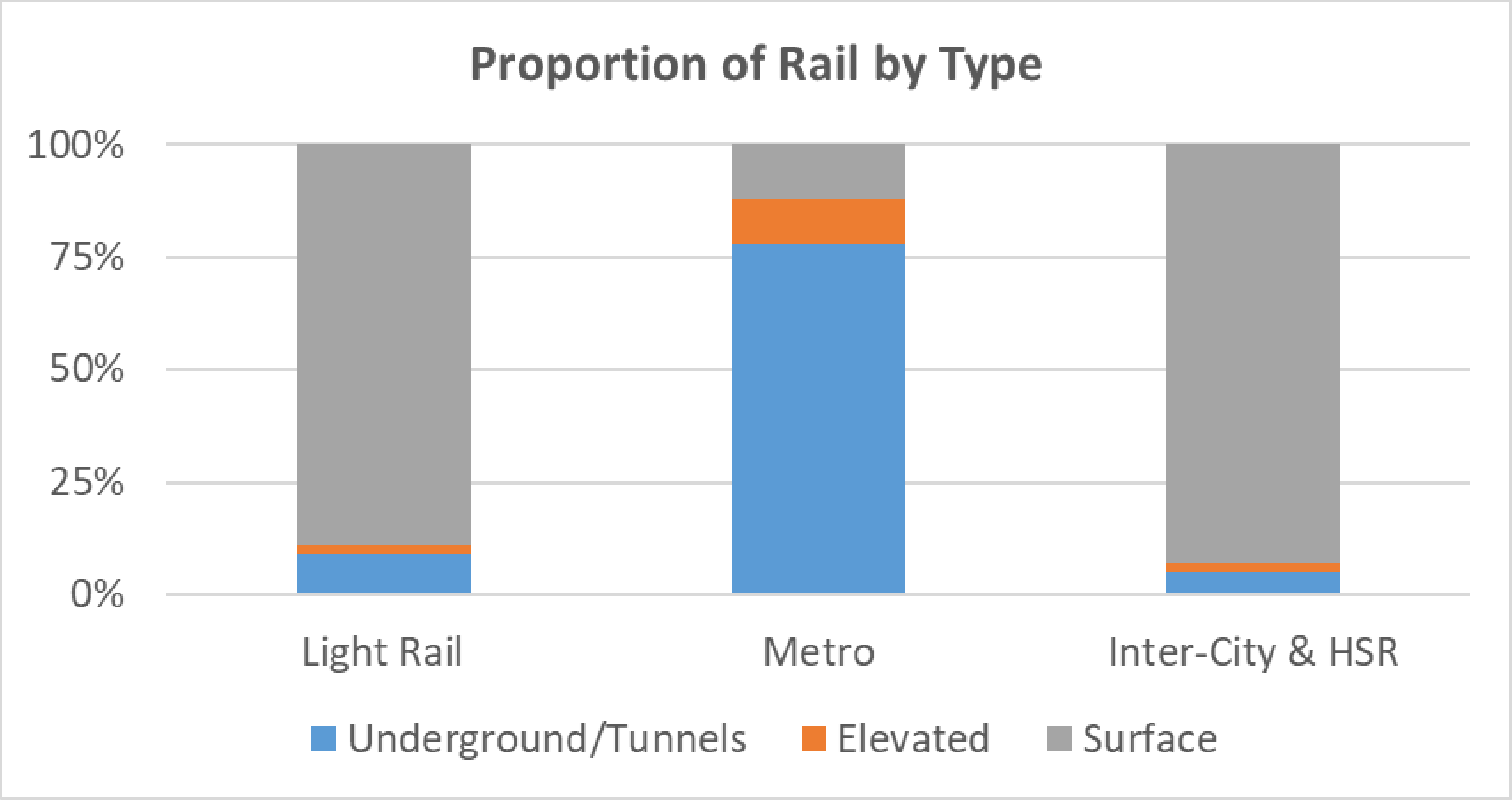
2) Bottom-Up Material Curves: Material Intensities - Rail

- **Cement proportion of concrete:**
  - Median: 10%
  - Range: 7 to 13%
- **Material intensities:**
  - Concrete use 10 to 30 times that of steel
  - Wide range: 2 to 250 times differences between low and high values
- **Maintenance - % of material replaced annually:**
  - All types: 3%



2) Bottom-Up Material Curves: Material Intensities - Rail

- **Adjusted material intensity values based on:**
  - Proportion of surface vs. elevated vs. underground (ITA 2004)
  - Estimates of material used for tunnels (Network Rail 2010)
- **Drivers of variation in rail placement:**
  - Economics?
  - Geography?
  - Other?



Material Intensities Vary Greatly for Surface vs. Elevated vs. Underground

2) Bottom-Up Material Curves: Regional Focus

- **Key data collected so far**
  - Roads: US, Canada, Sweden, India
  - Rail: US, Canada, Italy, Germany, Norway, UK, India, China
  - Key gaps: limited data for Latin America & Africa, as well as Asia and Australia
- **Moving from point data to regional trends**
  - No clear regional patterns so far
  - Trying to understand magnitude of regional differences

This map is without prejudice to the status of or sovereignty over any territory, to the delimitation of international frontiers and boundaries, and to the name of any territory, city or area.

Reporting regions

- North America
  - United States
- Central & South America
  - Brazil
- Europe
  - European Union
- Africa
  - South Africa
- Middle East
- Eurasia
  - Russia
- Asia Pacific
  - China
  - India
  - Japan
  - Southeast Asia

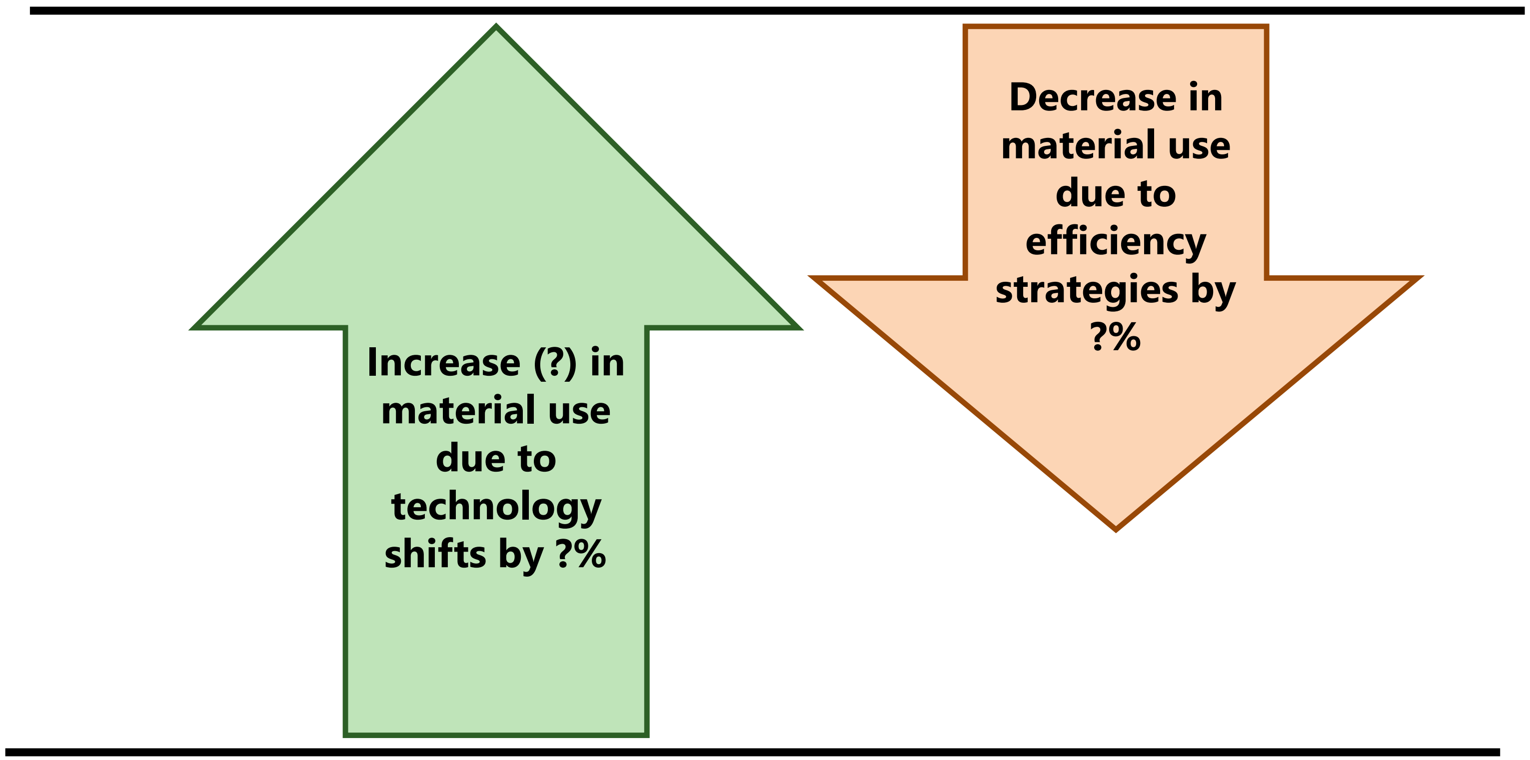
3) Future materials use: 2 levers of interest

1) Impact of technological shifts

- Related to future activity levels in a 2DS scenario

2) Impact of material use efficiency strategies

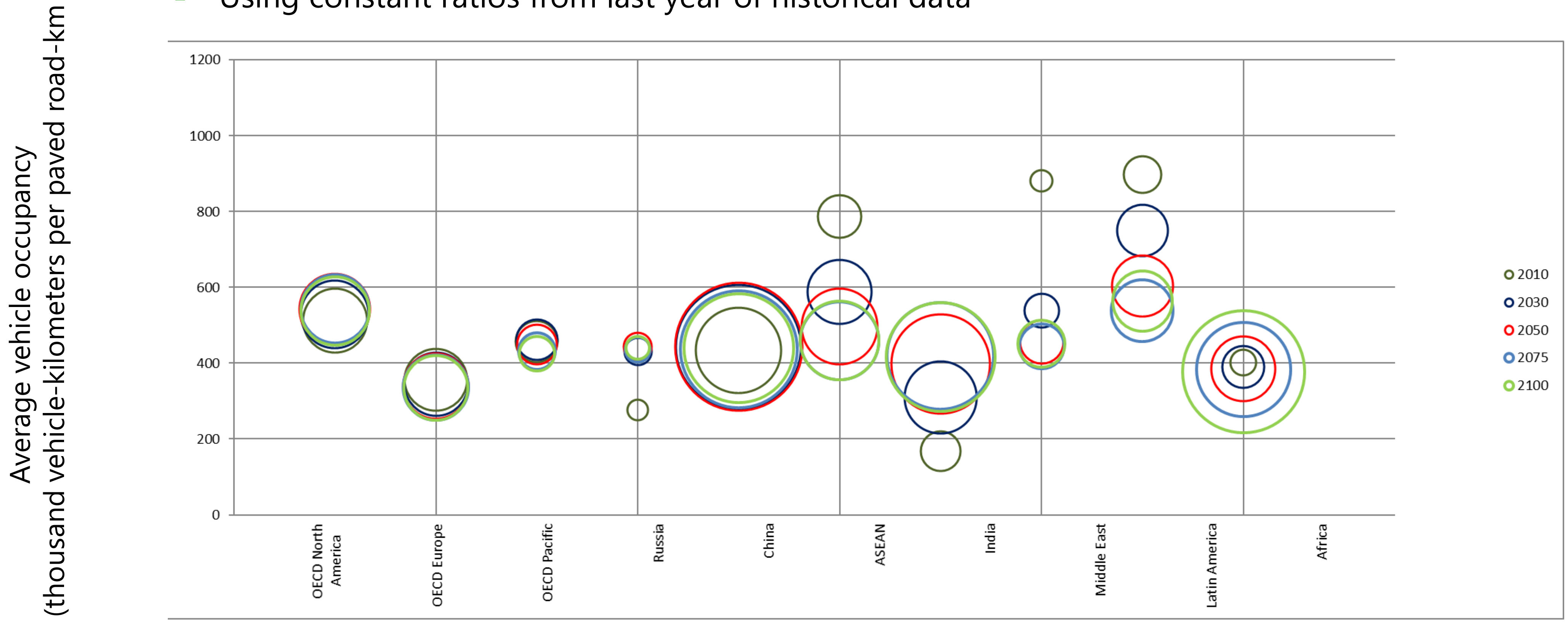
- Related to material intensities



Infrastructure Material Demand in 2DS

3) Future materials use: Projecting Activity Levels

- **Total road and rail kilometers**
  - Based on activity projections
  - Low-carbon scenarios incorporate uptake of ‘avoid-shift’ policies
  - Infrastructure utilization assumed to converge to levels in developed countries
- **Split between types of road and rail**
  - Using constant ratios from last year of historical data



3) Future materials use: Projecting Materials Intensities

- **Impact of maximizing material efficiency strategies**
  - Design of infrastructure favoring reuse, modularity, reduced material use, longer-lifetimes
  - Minimize losses during manufacturing & construction phases
  - Demolition techniques favoring scrap collection
  - Re-use and recycling maximized
- **Literature suggests potential for significant improvements in material use efficiency**
  - Wide variability among individual LCAs suggests potential to provide similar service using different quantities of materials
  - Various methods to improve material efficiency and reduce wastage
- **Steel**
  - **Steel use efficiency improvements**
    - Average utilization of structural steel in some buildings may be up to 50% below their capacity, suggesting at least some degree of reduction potential without reducing safety or service (Moynihan & Allwood 2014)
  - **Steel waste reductions**
    - Steel reinforcement wastage rate: median of 11%, minimum of 4% (Formoso et al. 2002)

3) Future materials use: Projecting Materials Intensities

- **Cement use efficiency improvements**
  - Improvement methods (Damineli et al. 2010):
    - Use of dispersants
    - More efficient packing of particles
    - Increase in compressive strength
    - Structural design
  - Active binder efficiency: 44% difference between minimum and average binder intensity for concrete of 30 MPa compressive strength (UNEP 2016)
  - WWF-Lafarge Report sets objective of 15% consumption reduction through efficiency by 2050
- **Cement waste reductions**
  - On-site mixing leads to more wastage than ready-mix concretes
  - Increased industrialised production of concrete could reduce overall cement consumption by 10% (UNEP 2016)

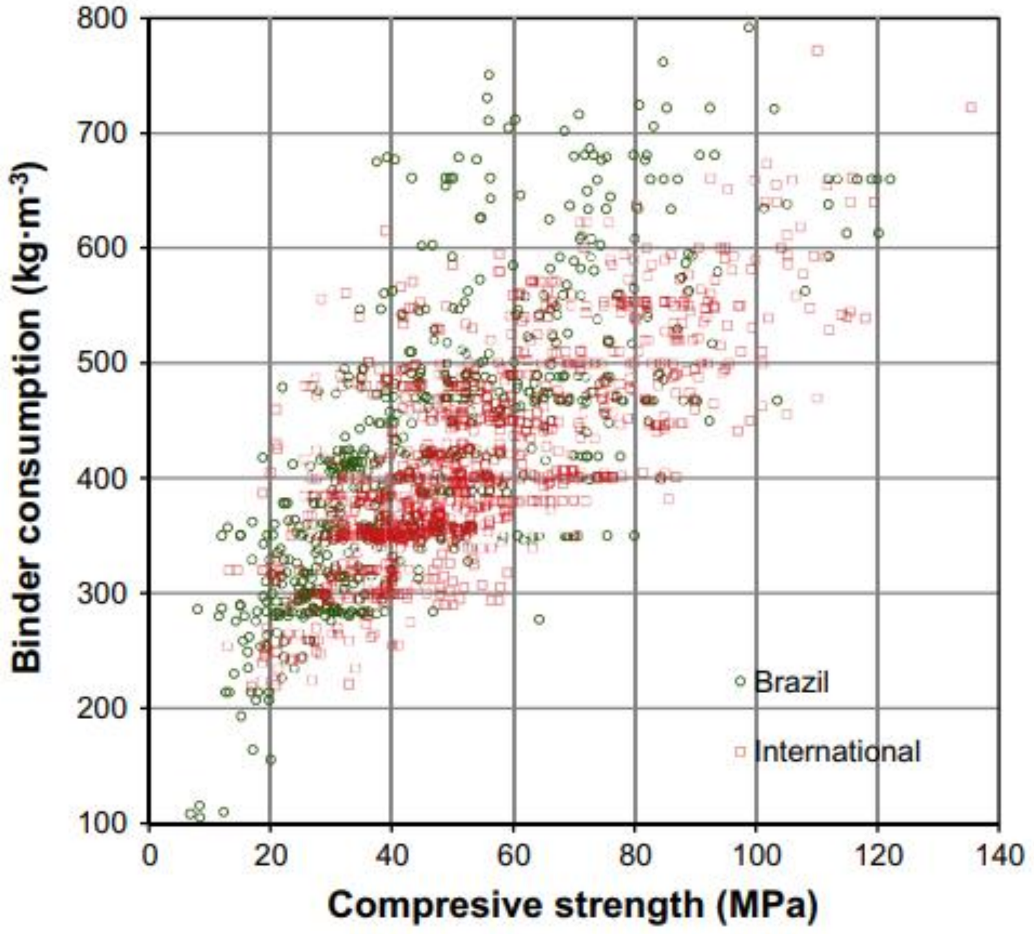


Fig. 1. Compressive strength *versus* total binder consumption. There are 604 results from Brazil (circles) and 981 international (squares).

Source: Damineli et al. (2010), Measuring the eco-efficiency of cement use

4) Conclusions and Next Steps

- **Objective: to estimate global material use (historically and in future)**
  - Initial top-down bottom-up comparisons are within the correct order of magnitude
  - Many data gaps and uncertainties exist
    - Roads: asphalt vs. concrete vs. composite
    - Rail: underground vs. elevated vs. surface
    - Regional variation
  - Challenges of extrapolating from precise individual LCAs to broader trends
  - Future assumptions have even greater uncertainty

- **Next steps: continued data collection and refinement**
  - Any additional data and feedback are welcome!