Infrastructure materials modelling

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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
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)

![Graph showing compressive strength versus total binder consumption.](image)

**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!