International Energy Agency
Materials Trends in Transport Workshop

8 March 2018

Rail Concrete and Steel Use from a Life Cycle Lens

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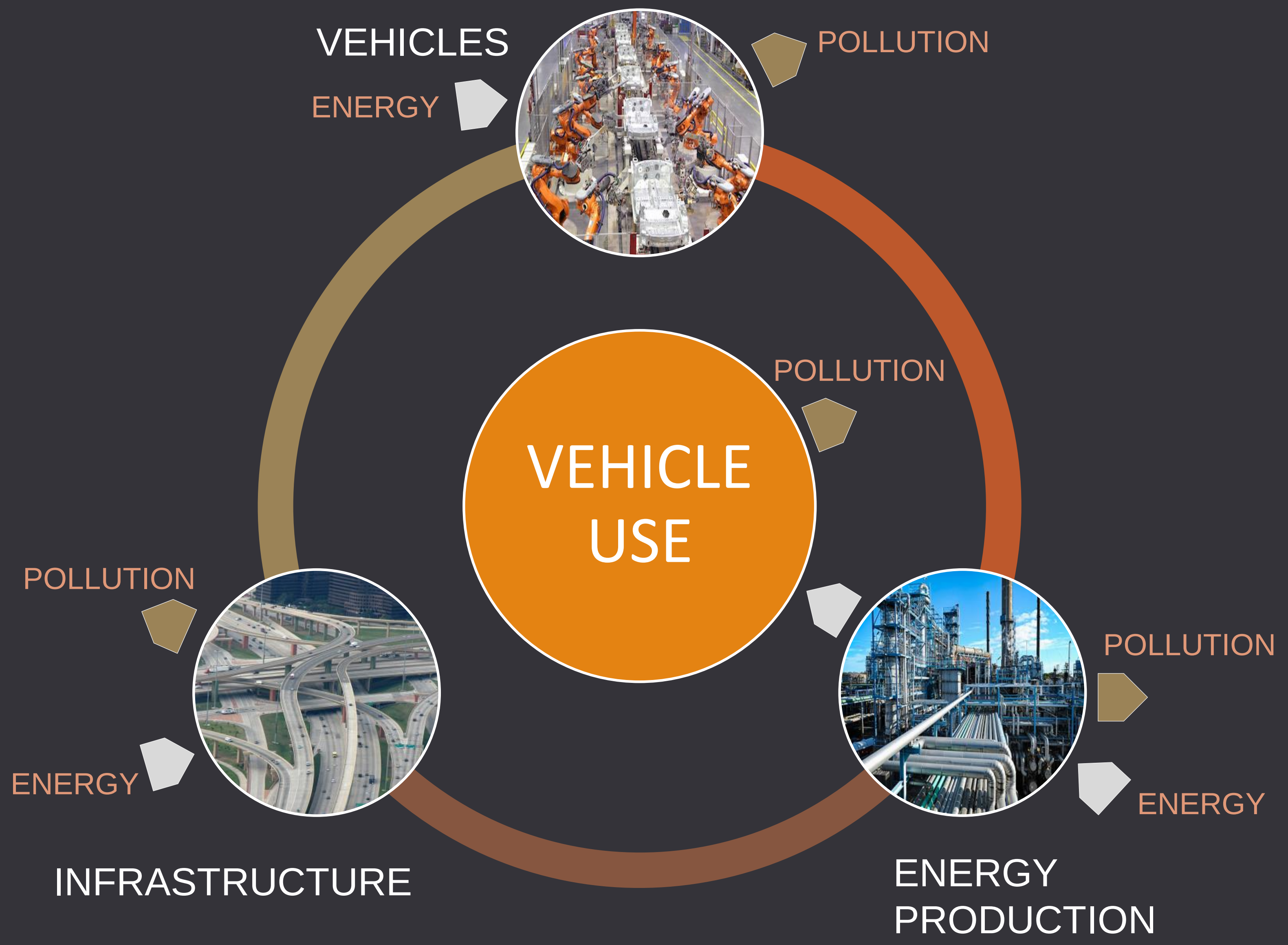


INTERDEPENDENCIES

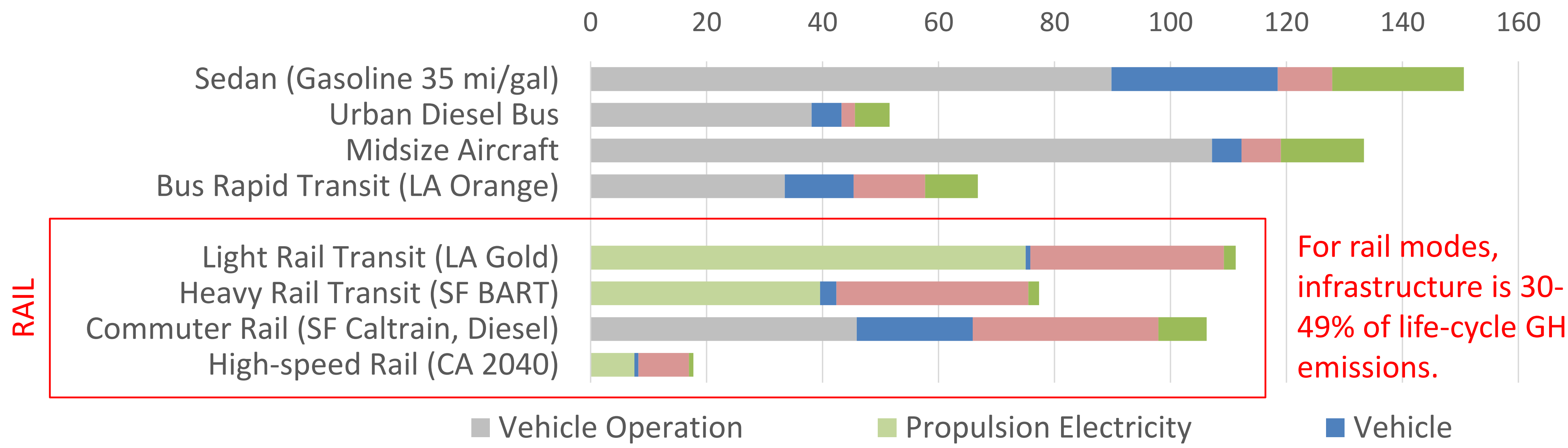
SUPPLY CHAINS

COMPLEXITY

	ONROAD	RAIL	AIR
VEHICLE			
Manufacturing	▪ Vehicle ▪ Transport to Point of Sale	▪ Train Manufacturing ▪ Transport to Point of Sale	▪ Aircraft ▪ Engine
Operation	▪ Propulsion ▪ Idling	▪ Propulsion + Auxiliaries ▪ Idling (Stops+Warm Running)	▪ Propulsion (Flight Stages) ▪ Idling
Maintenance	▪ Typical Sedan Maintenance ▪ Tire Replacement ▪ Battery Replacement	▪ Typical Train Maintenance ▪ Train Cleaning ▪ Flooring Replacement	▪ Typical Aircraft Maintenance ▪ Engine Maintenance and Replacement
Insurance	▪ Vehicle Liability	▪ Crew health and benefits ▪ Train liability	▪ Crew health and benefits ▪ Aircraft liability
INFRASTRUCTURE			
Construction	▪ Roadway construction	▪ Station construction ▪ Track construction	▪ Airport construction ▪ Runway/Taxiway/Tarmac construction
Operation	▪ Roadway lighting ▪ Herbicide spraying ▪ Roadway salting	▪ Station lighting ▪ Escalators ▪ Train control ▪ Station parking lighting ▪ Station miscellaneous (e.g., other electrical equipment)	▪ Runway lighting ▪ Deicing fluid production ▪ GSE operation
Maintenance	▪ Roadway maintenance	▪ Station maintenance ▪ Station cleaning	▪ Airport maintenance ▪ Runway/Taxiway/Tarmac maintenance
Parking	▪ Roadside, surface lot, and parking garage parking	▪ Station parking	▪ Airport parking
Insurance		▪ Non-crew health insurance and benefits ▪ Infrastructure liability insurance	▪ Non-crew health and benefits ▪ Infrastructure liability
ENERGY PRODUCTION			
Extraction, Processing, & Distribution	▪ Gasoline Extraction, Processing, & Distribution	▪ Diesel or Electricity Raw Fuel Extraction, Processing, Generation, Transmission, & Distribution	▪ Raw Fuel Extraction and Processing, Electricity Generation, Transmission & Distribution

LIFE-CYCLE GREENHOUSE GAS EMISSIONS

(grams CO_2e/Passenger Kilometer Traveled)



For rail modes, infrastructure is 30-49% of life-cycle GHG emissions.

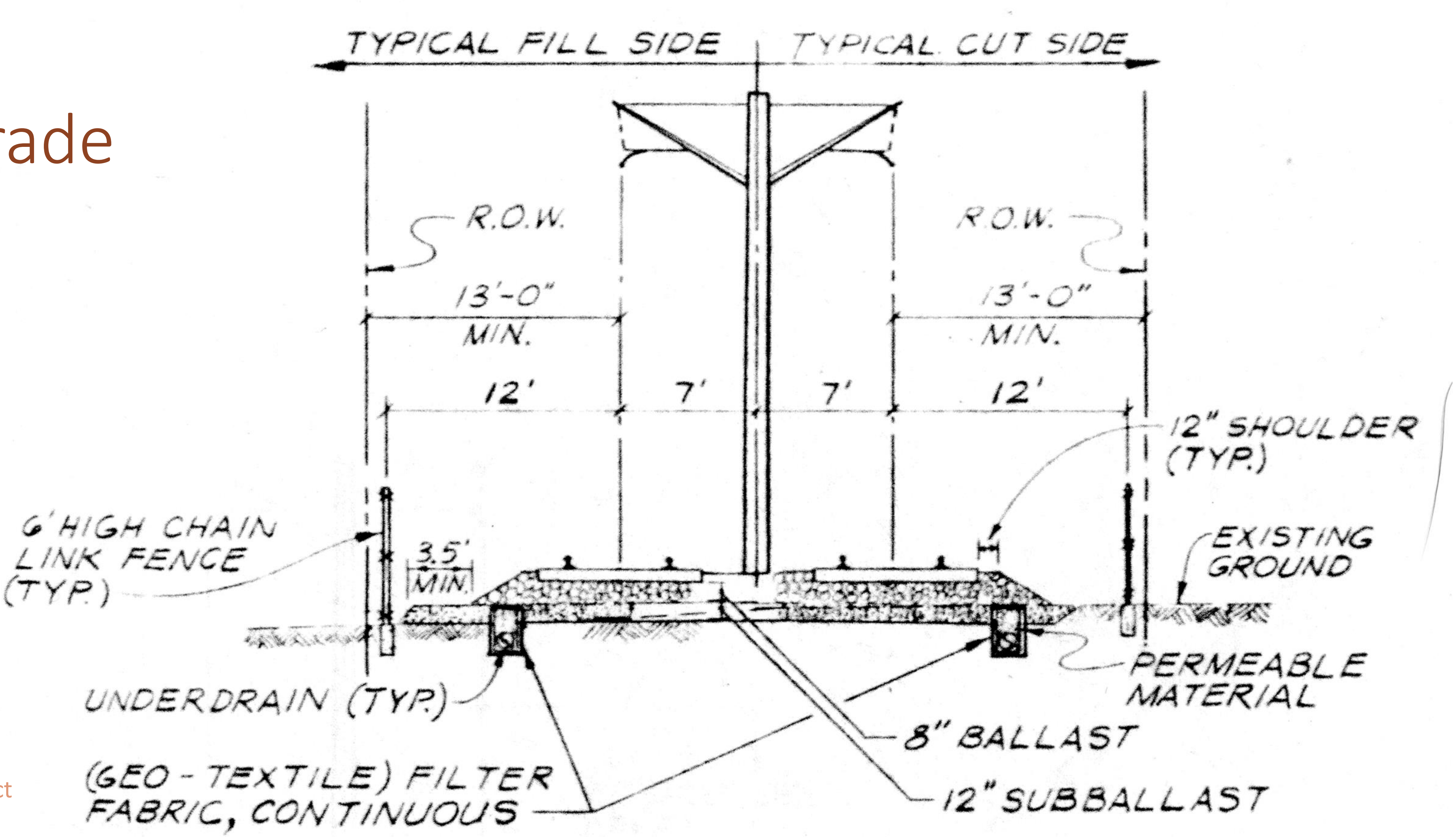
1) Environmental Assessment of Passenger Transportation Should Include Infrastructure and Supply Chains, Mikhail Chester and Arpad Horvath, Environmental Research Letters, 2009, 4(2), doi: 10.1088/1748-9326/4/2/024008.
2) High-speed Rail with Emerging Automobiles and Aircraft to Reduce Environmental Impacts in California's Future, Mikhail Chester and Arpad Horvath, Environmental Research Letters, 2012, 7(3), doi: 10.1088/1748-9326/7/3/034012.
3) Infrastructure and Automobile Shifts: Positioning Transit to Reduce Life-cycle Environmental Impacts for Urban Sustainability Goals, Mikhail Chester, Stephanie Pincetl, Zoe Elizabeth, William Eisenstein, and Juan Matute, Environmental Research Letters Focus Issue on Environmental Assessments and the Built Environment, 2013, 8(1), doi: 10.1088/1748-9326/8/1/015041.

There’s no one-size fits all approach when it comes to assessing transportation infrastructure, especially rail (diversity of systems, design conditions, etc).

Data points in life-cycle models are not necessarily representative.

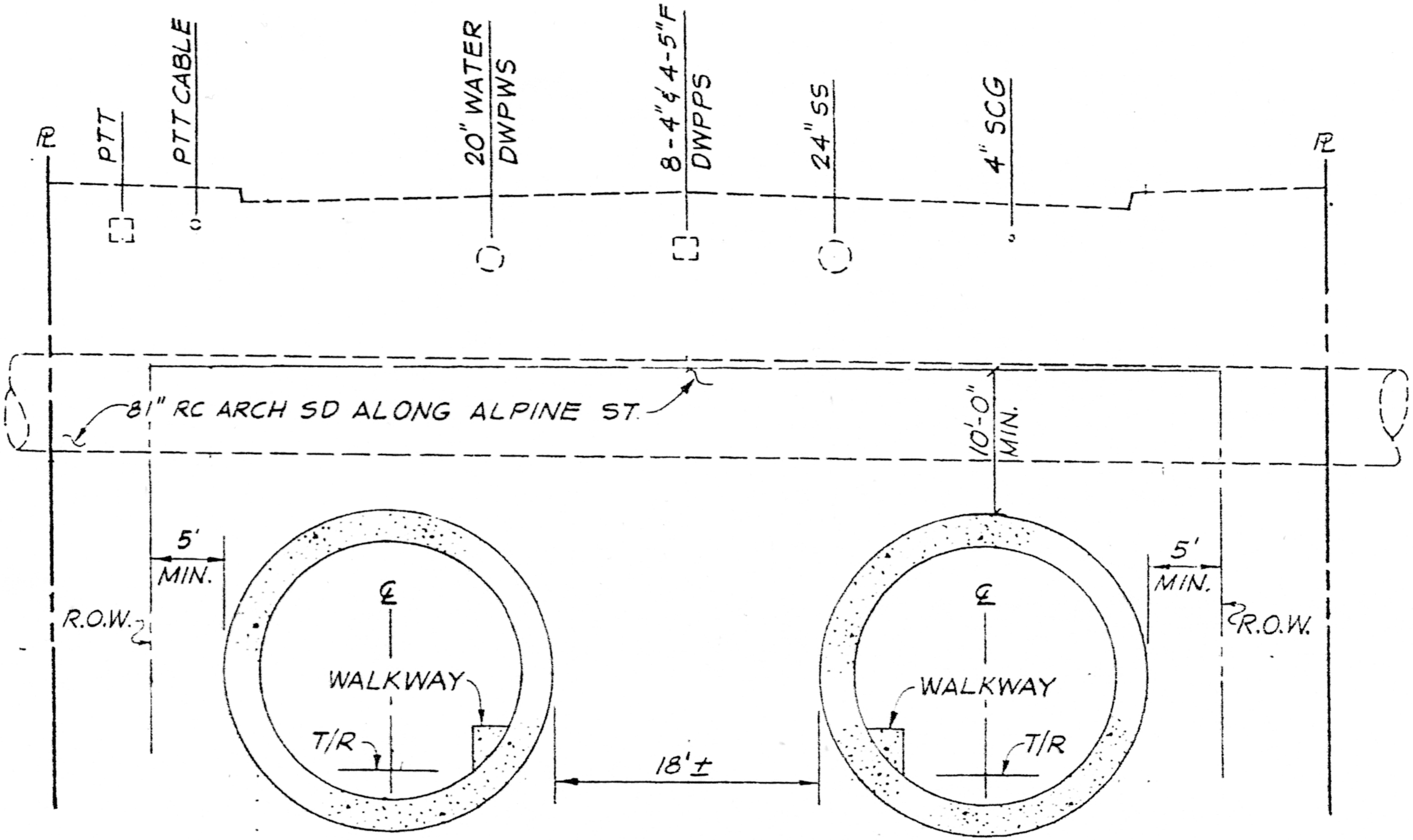
Chester/Horvath model continues to be the only bottom-up model for transportation infrastructure life-cycle modeling.

At-Grade



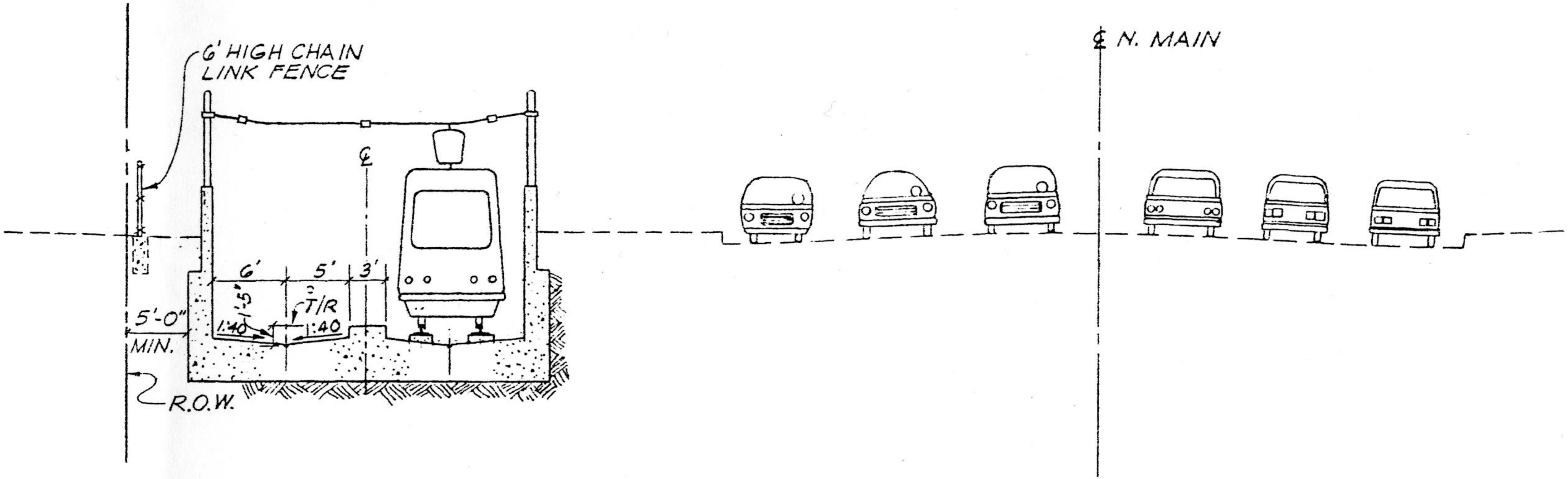
Los Angeles Metro,
Gold Line
Environmental Impact
Statement, 1988

Tunnel



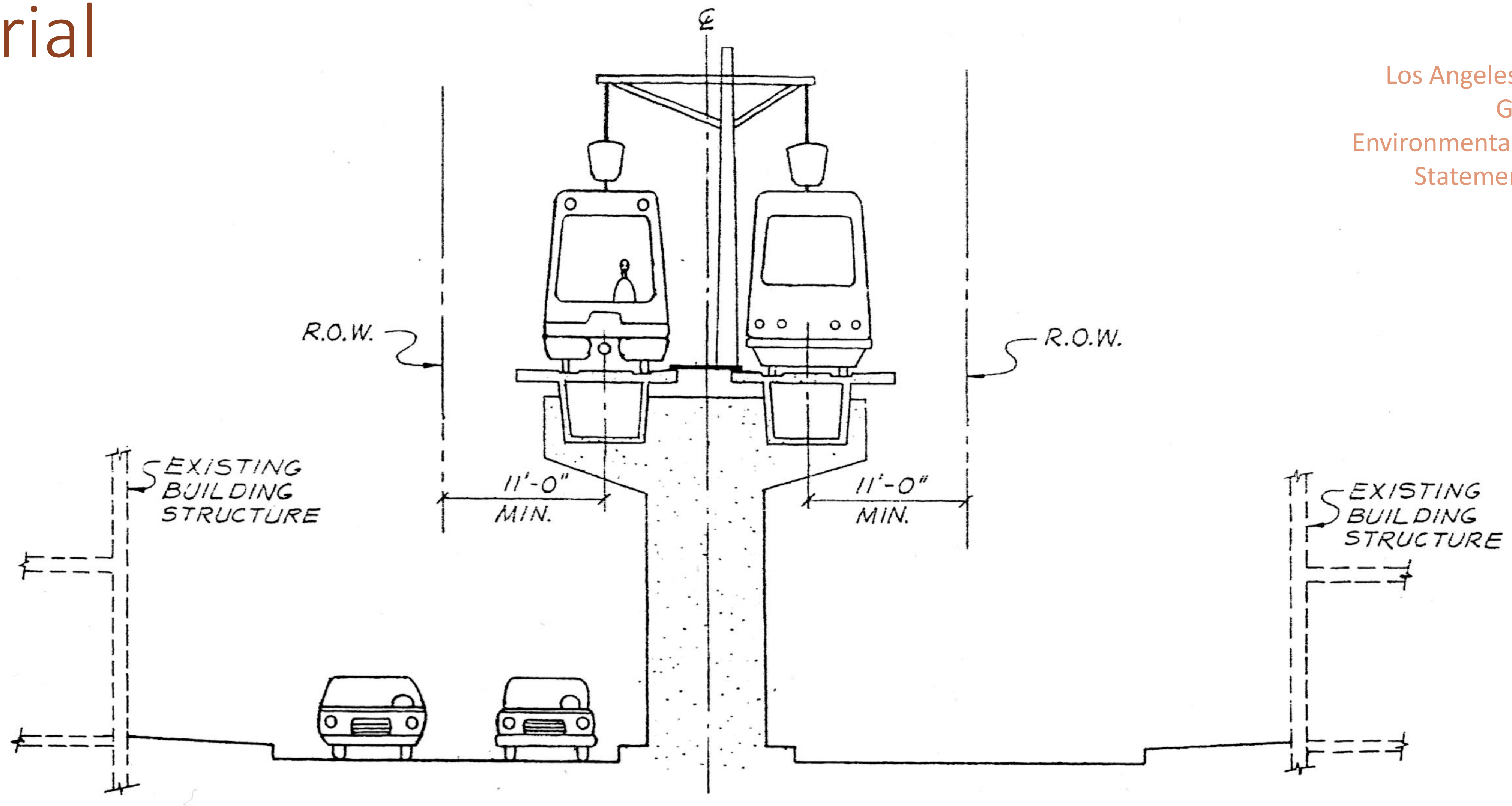
Los Angeles Metro, Gold Line Environmental Impact Statement, 1988

Below Grade



Los Angeles Metro, Gold Line
Environmental Impact Statement, 1988

Aerial



Los Angeles Metro, Gold Line Environmental Impact Statement, 1988

Legacy Infrastructure

Griest (1915), New York City

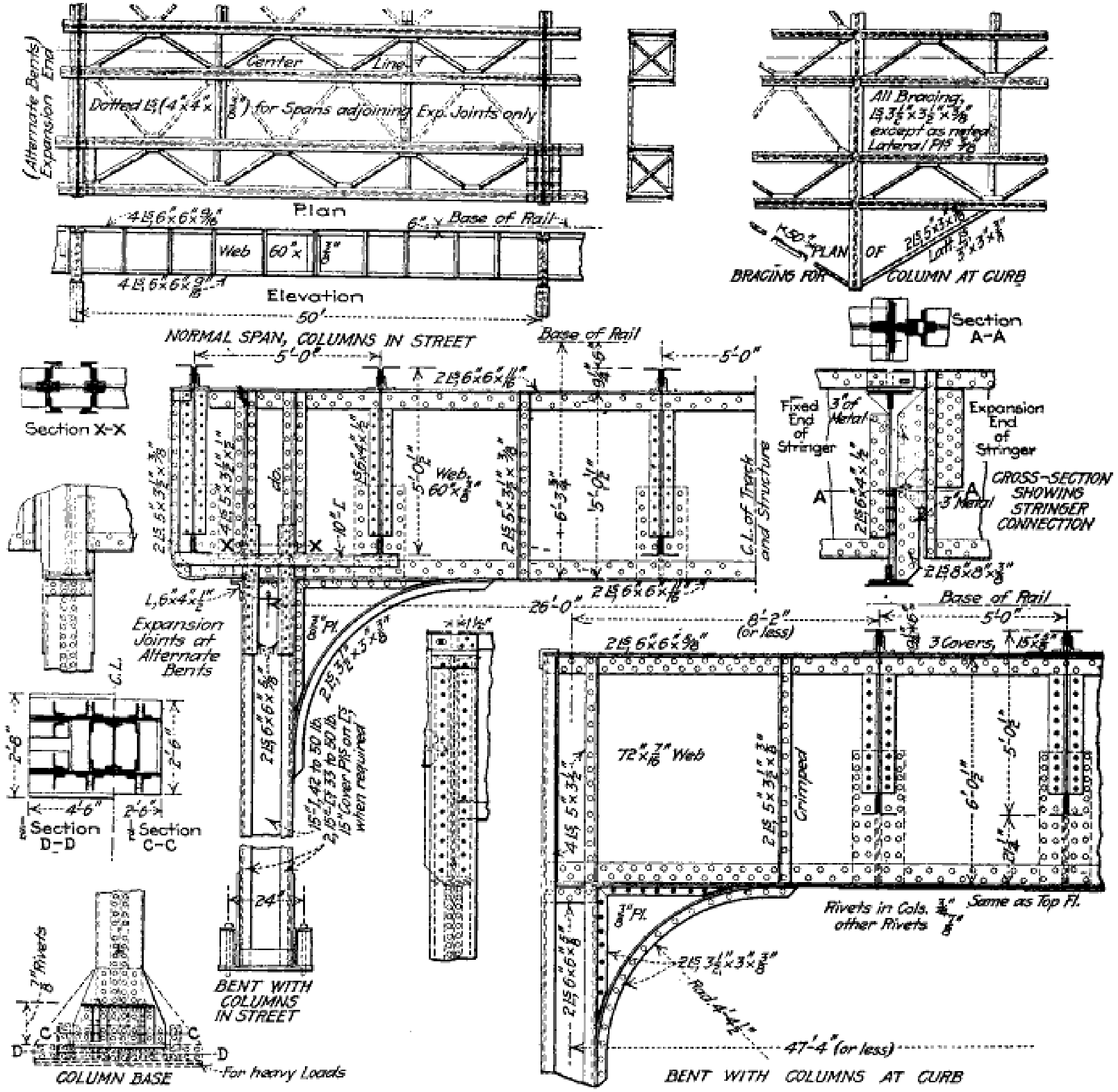
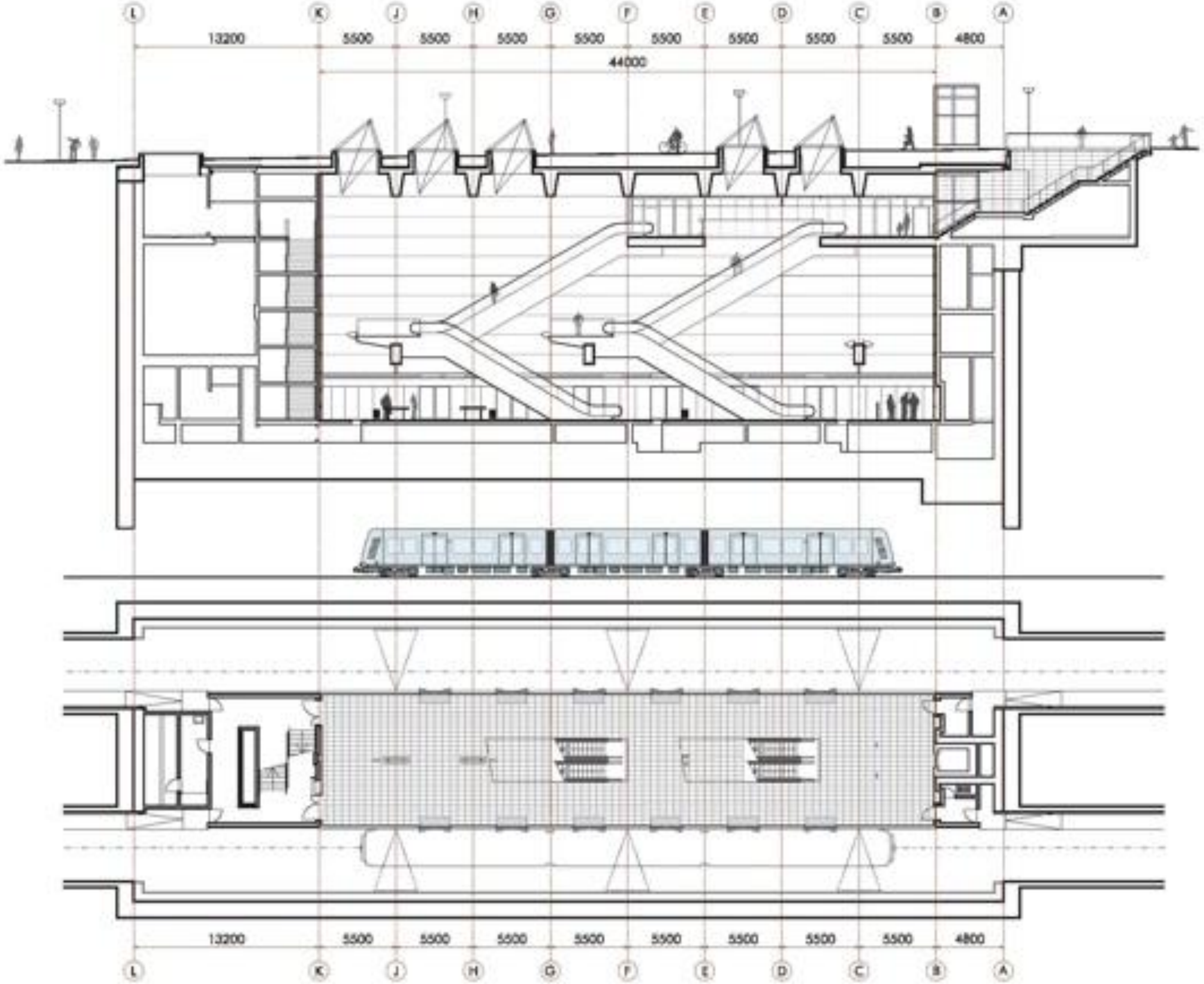


FIG. 93. DETAILS OF ELEVATED-RAILWAY CONSTRUCTION
(New city-built lines of dual rapid-transit system, New York City)

Stations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44000


Environmental assessment of passenger transportation should include infrastructure and supply chains

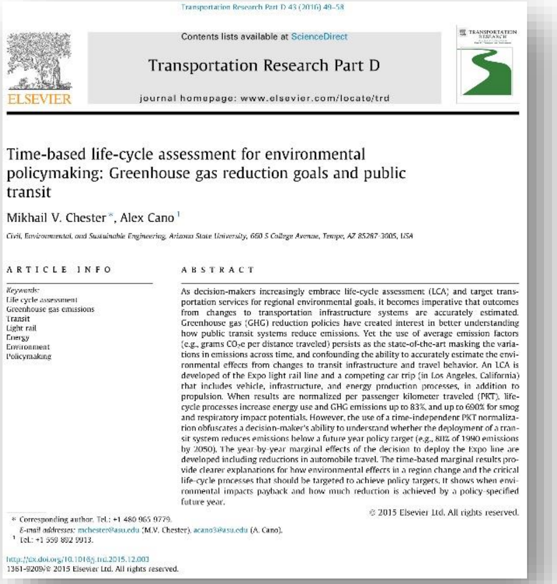
Mikhail V Chester and Arpad Horvath


Infrastructure and automobile shifts: positioning transit to reduce life-cycle environmental impacts for urban sustainability goals

Mikhail Chester, Stephanie Pincetl, Zoe Elizabeth, William Eisenstein and Juan Matute


High-speed rail with emerging automobiles and aircraft can reduce environmental impacts in California's future

Mikhail Chester and Arpad Horvath


Transportation Research Part D

Time-based life-cycle assessment for environmental policymaking: Greenhouse gas reduction goals and public transit

Mikhail V. Chester, Alex Cano


Transportation Research Part D

Greenhouse gas and air quality effects of auto first-last mile use with transit

Christopher G. Hoehne, Mikhail V. Chester

Light Rail, Heavy Rail, Commuter Rail, High-speed Rail

Passenger and Freight

Los Angeles, Chicago, New York, Boston, San Francisco, Phoenix, California, New England

Passenger Rail

Concrete & Steel

	CONCRETE	STEEL
STATIONS	Aerial (platforms, pier caps, columns, footings); Surface (platforms, footings); Elevated (platforms, footings); Underground (floor caps, roof caps, footings, walls).	Rebar; Structural steel; hardware (electrical and other housing); Fencing.
TRACKS	Surface (retaining walls, ground slab); Subway (walls); Aerial (supports, footings); Ties.	Gauge; Rebar for structural steel; Caternary lines and poles; substations; Electric third rail; Fencing.

Materials Comparison in Rail Infrastructure

Stations

SURFACE

- Concrete (m^3/station): 140 (street-level) to 1,700 (elevated); 12,000 for HSR
- Steel (kg/station): 36 (street-level) to 420 (elevated); 3,100 for HSR

AERIAL

- Concrete (m^3/station): 620 to 15,000
- Steel (kg/station): 160 to 3,700

UNDERGROUND

- Concrete (m^3/station): 8,600 to 22,000
- Steel (kg/station): 2,100 to 5,400

Materials Comparison in Rail Infrastructure

Tracks

SURFACE

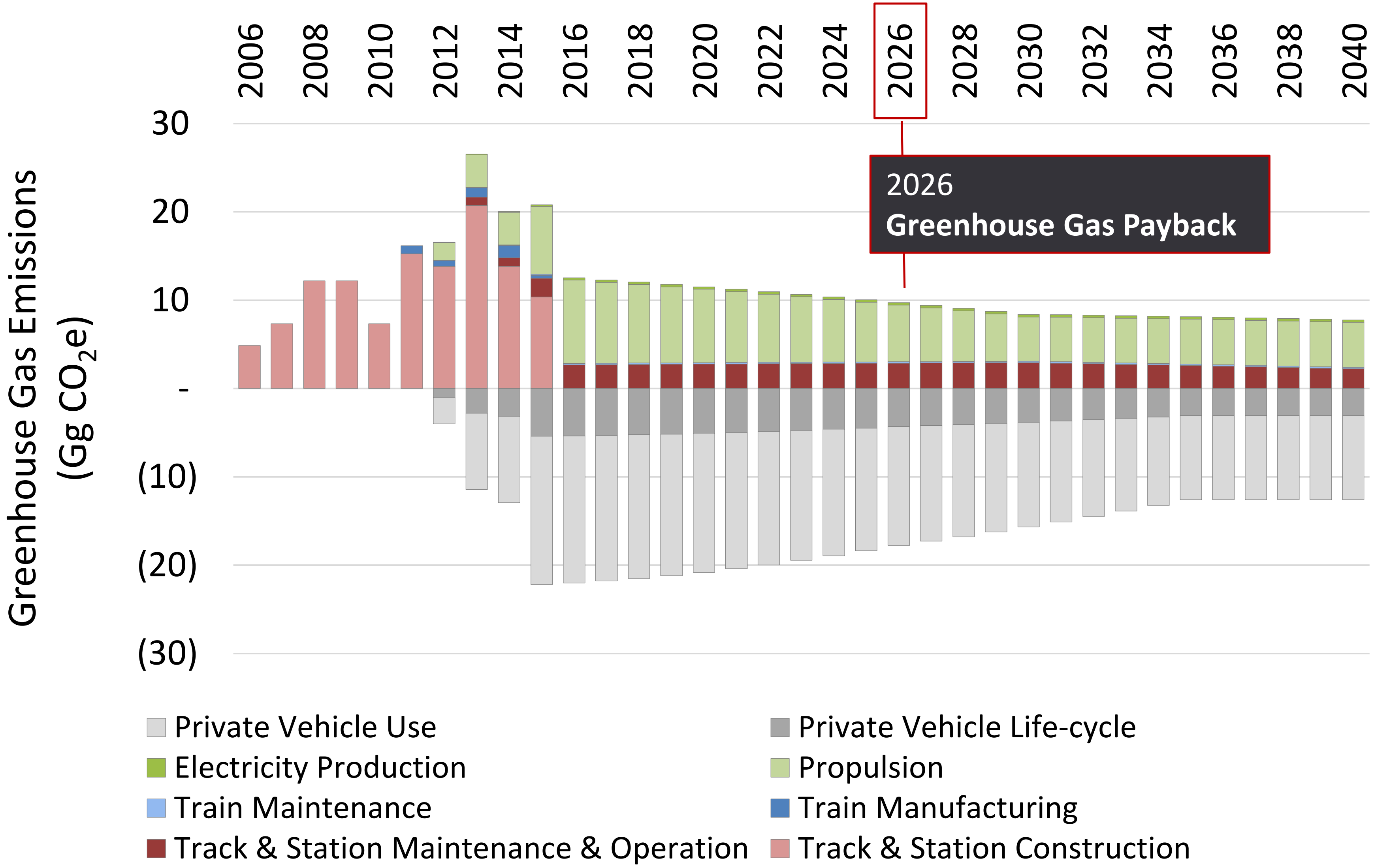
- Concrete (m^3/km): 140 to 560 (high of 4,800 for LA Expo with concrete for ballast)
- Steel (kg/km): 35 to 140 (high of 1,200 for LA Expo)

AERIAL

- Concrete (m3/km): 5,600 to 6,600 (high of 20,000 for LA Expo)
- Steel (kg/km): 1,400 to 1,600 (high of 5,000 for LA Expo)

UNDERGROUND

- Concrete (m3/km): 2,400
- Steel (kg/km): 590



Greenhouse Gas Payback

By 2026…

- Expo has added 267 Gg CO_2e
- Avoided automobile emissions are equivalent

Post 2026 Expo is reducing LA's GHG emissions.

Time-based Life-cycle Assessment for Environmental Policymaking: Greenhouse Gas Reduction Goals and Public Transit
Mikhail Chester and Alex Cano, Transportation Research Part D, 2016, 43, pp. 49-58, doi: 10.1016/j.trd.2015.12.003

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