First-last mile environmental life-cycle assessment of multimodal transit in Los Angeles

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Outline

- Project motivation
- Project overview and scope
- Project methodology & data
- Life cycle impacts (per passenger mile)
- Multimodal impacts (per passenger trip)
- Reducing 10% of system GHG impacts
Motivation in transportation

- There is a strong understanding of the environmental impacts from *unimodal* trips.
- There is limited knowledge of the environmental impacts from *multimodal* trips.
- Very limited knowledge of impacts from automobile access and egress with transit.

Sources: Chester et al. 2013, LA Metro
Project Overview

- Assess impacts generated from 10 LA transit systems and LA automobiles.

- Transit systems included:
  - Metro Light Rail Transit (LRT, 4 lines)
  - Metro Heavy Rail Transit (HRT, 1 line)
  - Commuter Rail Transit (CRT, 1 line)
  - Metro Local Bus
  - Metro Rapid Bus
  - Metro Express Bus
  - Bus Rapid Transit (BRT, 1 line)

- LA Auto:
  - 25 MPG sedan
Modal Split in LA

Modal Split

Auto, 82%
Non-Motorized, 14%

Transit Modal Split

Bus 73%
(Local/Rapid/Express)

Non-Motorized
Auto
Metro Transit
Other

Bus
Blue
Expo
Gold
BRT
Heavy Rail
Green

Estimate via California Household Travel Survey (Caltrans, 2013)
Estimate via LA Metro boardings (LA Metro, 2016)
Life-Cycle Assessment Scope

- Material and fuel extraction
- Vehicle operation & maintenance
- Infrastructure operation & maintenance
- Vehicle manufacturing
- Infrastructure construction
- Electricity production and generation

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<table>
<thead>
<tr>
<th>Life Cycle Grouping</th>
<th>Automobiles/Buses</th>
<th>Rail</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vehicle</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Manufacturing</td>
<td>▪ Vehicle Manufacturing</td>
<td>▪ Train</td>
</tr>
<tr>
<td></td>
<td>▪ Battery Manufacturing</td>
<td>▪ Transport to Point of Sale</td>
</tr>
<tr>
<td></td>
<td>▪ Transport to Point of Sale</td>
<td></td>
</tr>
<tr>
<td>Operation</td>
<td>▪ Propulsion</td>
<td>▪ Propulsion</td>
</tr>
<tr>
<td></td>
<td>▪ Idling</td>
<td>▪ Idling</td>
</tr>
<tr>
<td>Maintenance</td>
<td>▪ Typical Maintenance</td>
<td>▪ Typical Train Maintenance</td>
</tr>
<tr>
<td></td>
<td>▪ Tire Replacement</td>
<td>▪ Train Cleaning</td>
</tr>
<tr>
<td></td>
<td>▪ Battery Replacement</td>
<td>▪ Flooring Replacement</td>
</tr>
<tr>
<td>Infrastructure</td>
<td></td>
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<tr>
<td>Construction</td>
<td>▪ Roadway</td>
<td>▪ Track</td>
</tr>
<tr>
<td></td>
<td></td>
<td>▪ Station</td>
</tr>
<tr>
<td>Operation</td>
<td>▪ Roadway Lighting</td>
<td>▪ Track, Station, and Parking Lighting</td>
</tr>
<tr>
<td></td>
<td>▪ Herbicide Use</td>
<td>▪ Herbicide Use</td>
</tr>
<tr>
<td></td>
<td></td>
<td>▪ Train Control</td>
</tr>
<tr>
<td></td>
<td></td>
<td>▪ Miscellaneous (Escalators, Equipment)</td>
</tr>
<tr>
<td>Maintenance</td>
<td>▪ Roadway Maintenance</td>
<td>▪ Track and Station Maintenance</td>
</tr>
<tr>
<td>Parking</td>
<td>▪ Curbside Parking</td>
<td>▪ Dedicated Parking</td>
</tr>
<tr>
<td>Energy Production</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Extraction, Processing, &amp;</td>
<td>▪ Gasoline/Diesel/Natural Gas Extraction,</td>
<td>▪ Raw Fuel Extraction and Processing,</td>
</tr>
<tr>
<td>Distribution</td>
<td>Processing, &amp; Distribution</td>
<td>Electricity Generation, Transmission &amp;</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Distribution</td>
</tr>
</tbody>
</table>
Data & Tools

Trip data:
- California Household Travel Survey (CHTS, 2012-13)
- LA Metro On-board Surveys (2013 – current)

Transit operational data:
- Ridership & Operation Reports (2013 – current)
- Engineering design documents, Google Earth

Life-cycle Modeling:
- Modeling tools including SimaPro, GREET, CiRN-LCA, and other components
- EcoInvent and EIOLCA database and empirical studies
LA Metro Rail Energy Use

Yearly LA Rail System Energy Use vs System Passenger Miles Traveled (PMT)

- **Blue LRT**: 18% Coal, 40% Natural Gas, 28% Renewables, 21% Nuclear, 9% Unspecified
- **Red HRT**: 31% Coal, 39% Natural Gas, 21% Renewables, 26% Nuclear, 9% Unspecified
- **Green LRT**: 29% Coal, 41% Natural Gas, 21% Renewables, 28% Nuclear, 9% Unspecified
- **Gold LRT**: 34% Coal, 37% Natural Gas, 28% Renewables, 26% Nuclear, 9% Unspecified
- **Expo LRT**: 32% Coal, 37% Natural Gas, 26% Renewables, 28% Nuclear, 9% Unspecified

*Reflects 2013-2014 data*
Bus & Metrolink Drive Cycles

- Local, Express, and Rapid Bus drive cycles were estimated by matching similar empirically tested cycles in similar buses (excluding Orange BRT).

- Estimated system fuel consumption (based on mileage) was 4% lower for buses, and 7% lower than locomotives.

- Metrolink drive cycles developed from similar locomotive operation impacts from Fritz (1994).
Trip Characteristics (CHTS)

- Trip characteristics determined for each region/transit system.
- Aggregation at the zip code level, over 900 sub-regions.
- Auto trips are shorter distance than transit for same ODs.
Transit Access & Egress in LA

Access & Egress Modes (2012-13 CHTS)

- Metro Bus: 95%
- Metro Rail: 16%
- Other: 3%

Access Mode (2012-13 Metro Surveys)

- Metro Bus: 85%
- Metro Rail: 26%
- Other: 68%
Per Passenger-mile Impacts

<table>
<thead>
<tr>
<th>GHGs (g CO₂e/PMT)</th>
<th>Respiratory (mg PM₂.₅e/PMT)</th>
<th>Smog (g O₃e/PMT)</th>
</tr>
</thead>
</table>

Note that auto trips in LA are ~2 pax per trip
Auto occupancies may be lower when accessing or egressing transit.
GHGs per Passenger-Trip

GREENHOUSE GAS EMISSIONS (kg CO₂e per passenger trip)

Local Bus + Auto: Uncommon, high access distance

- Competing Auto
  - Local Bus
    - + Auto
  - Rapid Bus
    - + Auto
      - + Rail

Orange BRT
- Competing Auto
  - Orange BRT
    - + Auto
      - + Rail

Express Bus
- Competing Auto
  - Express Bus
    - + Auto
      - + Rail

Metrolink CRT
- Competing Auto
  - Metrolink CRT
    - + Auto
      - + Bus

Legend:
- Fuel Combustion
- Batteries
- Infrastructure Parking
- Propulsion Electricity
- Infrastructure Construction
- Infrastructure Operation
- Energy Production
- Vehicle Manufacturing
- Vehicle Maintenance
- Infrastructure Maintenance
Local vs Remote Impacts Per Passenger Trip

**GHG**
- **Metrolink**
  - Local: 91 g CO₂e
  - Remote: 36 g CO₂e
- **Metro Rail**
  - Local: 45 g CO₂e
  - Remote: 137 g CO₂e
- **Bus**
  - Local: 103 g CO₂e
  - Remote: 49 g CO₂e
- **Auto**
  - Local: 197 g CO₂e
  - Remote: 102 g CO₂e

**Respiratory**
- **Metrolink**
  - Local: 69 mg PM₂.₅e
  - Remote: 21 mg PM₂.₅e
- **Metro Rail**
  - Local: 5.6 mg PM₂.₅e
  - Remote: 61 mg PM₂.₅e
- **Bus**
  - Local: 3.1 mg PM₂.₅e
  - Remote: 20 mg PM₂.₅e
- **Auto**
  - Local: 17 mg PM₂.₅e
  - Remote: 75 mg PM₂.₅e

**Smog**
- **Metrolink**
  - Local: 39 g O₃e
  - Remote: 2.4 g O₃e
- **Metro Rail**
  - Local: 1.1 g O₃e
  - Remote: 3.4 g O₃e
- **Bus**
  - Local: 0.6 g O₃e
  - Remote: 2.3 g O₃e
- **Auto**
  - Local: 2.2 g O₃e
  - Remote: 8.6 g O₃e
Reducing 10% of GHG Impacts

Average GHG emissions per passenger trip vs auto shift

Percent shift required to achieve 10% reduction in system life-cycle GHG emissions.
la.transportationlca.org

REPORT and DATA

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GHGs per Passenger-Trip (Long Term)

Greenhouse Gas Emissions (kg CO$_2$e per passenger trip)

<table>
<thead>
<tr>
<th>Line</th>
<th>GHGs per Passenger-Trip</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gold LRT</td>
<td>Competing Auto Gold LRT + Auto + Bus</td>
</tr>
<tr>
<td>Expo LRT</td>
<td>Competing Auto Expo LRT + Auto + Bus</td>
</tr>
<tr>
<td>Green LRT</td>
<td>Competing Auto Green LRT + Auto + Bus</td>
</tr>
<tr>
<td>Blue LRT</td>
<td>Competing Auto Blue LRT + Auto + Bus</td>
</tr>
<tr>
<td>Red HRT</td>
<td>Competing Auto Red HRT + Auto + Bus</td>
</tr>
</tbody>
</table>

Legend:
- Fuel Combustion
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- Infrastructure Parking
- Propulsion Electricity
- Infrastructure Construction
- Infrastructure Operation
- Energy Production
- Vehicle Manufacturing
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- Infrastructure Maintenance
GHGs per Passenger-Trip (Long Term)

GREENHOUSE GAS EMISSIONS (kg CO₂e per passenger trip)

Local Bus + Auto: Uncommon, high access distance

GHG Emissions:
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