Quantifying Emissions Impacts of a Transportation Improvement Project involving Road Re-alignment and Conversion to a Multi-Lane Roundabout

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Outline

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Motivation

• On-road mobile sources of emissions account for 45% of total CO and 35% of total NO$_x$ in the United States

• Inconclusive results whether roundabouts reduce emissions

• Roundabouts are rarely installed in isolation

• Emission impacts of Transportation Improvement Projects (TIPs) are typically not validated by empirical “before and after” studies
Objectives

• Use empirical vehicle activity data to quantify emissions before and after a TIP, while accounting for joint simultaneous effects of all corridor-level changes
• Determine whether the installation of the multi-lane roundabout contributed to the change in environmental performance after the TIP.
Study Site - After

A

B

C
Methodology – Field Data

- Portable Emissions Measurement System
- GPS data
- On-board Diagnostics (OBD) data
Methodology - Vehicle Activity

Pre-TIP

Speed (mph)

Distance (mi)

Post-TIP

Speed (mph)

Distance (mi)

Woodburn Rd.  Oberlin Rd.  Pullen Rd.  Founders Dr.
Methodology - VSP Modal Approach

• Vehicle Specific Power (kW/ton) – instantaneous power per unit mass of vehicle

\[
VSP = v \left( 1.1a + 9.81 \left( \sin(\tan^{-1}(r)) \right) + 0.132 \right) + 3.02 \times 10^{-4} v^3
\]

\(v = \text{velocity (m/s)}; \ a = \text{acceleration (m/s}^2\); \ r = \text{road grade}\n
• 14 VSP bins – Frey et al. (2002)

• Average Modal Emission Factors for NO, HC, CO and CO\(_2\) -- PEMS data from 42 LDGVs

\[
\text{Total Emissions}_{ki} = \sum_{j=1}^{14} EF_{ij} \times t_{kj} \quad \text{for} \ i = 1,2,3,4
\]
Methodology - Study Design

• 4 turning movements
• 4 time periods
  • AM Off-peak (9.00am – 11.59am)
  • Lunch (12.00 noon – 12.59pm)
  • PM Off-peak (1.00pm – 4.29 pm; 6.00pm – 7.59am)
  • PM Peak (4.30 pm – 5.59pm)
• 2 levels of Analysis:
  • Corridor-level
  • Intersection-level
Results

• Corridor level results:

![Graph showing NO (mg/mi) for C to B, A to B, B to A, and B to C turning movements.]

• Intersection level results:

<table>
<thead>
<tr>
<th>Turning Movement (Fig 1)</th>
<th>NO</th>
<th>HC</th>
<th>CO</th>
<th>CO₂</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>mg/mi</td>
<td>mg/s</td>
<td>mg/mi</td>
<td>mg/s</td>
</tr>
<tr>
<td>C to B</td>
<td>-17%</td>
<td>4%</td>
<td>-24%</td>
<td>1%</td>
</tr>
<tr>
<td>B to C</td>
<td>-65%</td>
<td>49%</td>
<td>-69%</td>
<td>28%</td>
</tr>
</tbody>
</table>

Pre-TIP | Post-TIP
Conclusions

• At the corridor level the TIP improved the environmental performance of the site although in most cases, the improvement was not statistically significant.

• Direct comparison between 2 turning movements at the intersection level showed that emissions per unit distance were relatively lower after installation of the multi-lane roundabout.

• Empirical framework for comparison of emissions before and after TIPs involving roundabout retrofits.
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Thank you!

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