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Identification and Characterization of Pollutant Hot Spots Integrating Probe Vehicle, Traffic and Land Use Data

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Identification and Characterization of Pollutant Hot Spots
Integrating Probe Vehicle, Traffic and Land Use Data

By
Katherine E. Bell, P.E.
Miguel A Figliozzi, Ph.D.

FRIDAY SEMINAR
January 17, 2014
OUTLINE

I. Introduction & Background

II. Available and Collected Data

III. Statistical Analysis

IV. Conclusions & Future Research
BACKGROUND

• Motor Vehicle Emissions – CO2, CO, HC, NOX, MSATs

• Fine Particulate Matter (PM$_{2.5}$) – noncombustion & combustion
  - Carcinogenic
  - Heart problems
  - Respiratory problems

• Volatile Organic Compounds (VOC) – ozone precursors, carcinogens

• **HOT SPOT:** Subsection of corridor that consistently has an average pollutant concentration above the 85$^{th}$ percentile when compared to all other subsections on the corridor.
STUDY AREA – SE Powell Boulevard

- 4.6 miles – SE 7th Ave to I-205
- Multi-modal
- 2-lanes each direction
- Variety of land uses
OBJECTIVES

• Develop an **efficient** method to identify hot spot locations
  
  o **Better understand which variables are most related to variability in pollutant levels**
  
  o **Better understand the variability of exposure levels along a corridor**
  
• **Long-term**: Better inform personal exposure models and health analyses
LITERATURE REVIEW

1) Air Quality Health and Environmental Concerns
2) Air Quality Modeling and Measurements
3) Powell Boulevard Research
4) Land Use Regression
LITERATURE REVIEW

1) Air Quality Health and Environmental Concerns

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LITERATURE REVIEW

1) Air Quality Health and Environmental Concerns
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4) Land Use Regression
AVAILABLE & COLLECTED DATA

Probe Vehicle Data

Traffic Data

Land Use Data

Meteorology

PM$_{2.5}$ Concentrations
DATA COLLECTION

Probe Vehicle

<table>
<thead>
<tr>
<th>Data Type</th>
<th>Equipment</th>
<th>Description</th>
<th>Measurement Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>GPS Data</td>
<td>iPhone 4 - &quot;MyTracks&quot; Application</td>
<td>Location of probe vehicle</td>
<td>1 second</td>
</tr>
<tr>
<td>Video Footage</td>
<td>4 CountingCars digital video cameras</td>
<td>Front, Right, Left and Rear of Probe Vehicle</td>
<td>Continuous</td>
</tr>
<tr>
<td>PM$_{2.5}$ (µg/m$^3$)</td>
<td>2 DustTrak DRX Aerosol Monitors (TSI Model 8533)</td>
<td>Outside probe vehicle passenger windows, left and right</td>
<td>1 second</td>
</tr>
<tr>
<td>VOC (ppb)</td>
<td>2 Ion-Science PhoCheck Tiger devices</td>
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<td>1 second</td>
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AVAILABLE DATA

**Data Source Table**

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<td>Traffic</td>
<td>Wavetronix</td>
<td>10 seconds</td>
</tr>
<tr>
<td></td>
<td>SCATS</td>
<td>15 minutes</td>
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<tr>
<td>Land Use</td>
<td>PortlandMaps</td>
<td>n/a</td>
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<tr>
<td></td>
<td>Portland Metro RLIS*</td>
<td>n/a</td>
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</table>
Multiple Regression – ALL DAY

Data
- Linear Model: Adjusted $R^2 = 36\%$
- Log-Linear Model: Adjusted $R^2 = 52\%$

![Graph showing the percentage average contribution to baseline for various factors such as Mean Temp, # of High Emitters, Time with Queue Adjacent, Traffic Volume, % Residential Zoning, Distance to Gas Station.](Image)
CONCLUSIONS

• Hot Spot Identification
  • Consistency, magnitude and distance impacted
  • AM vs. PM: analyze together AND separately

• Statistical Analysis
  • Strongest (+) Relationships: Relative Humidity, Background PM$_{2.5}$ Concentrations, Presence of “High Emitters”
  • Strongest (-) Relationships: Temperature, Wind Speed, Traffic Speed
  • Land Use variables also have statistically significant relationships with PM$_{2.5}$ concentrations
  • Multiple Regression models can be adjusted depending on data available

• Mobile Outside Vehicle Measurements + Land Use Regression
  • Valuable tool to better understand relationships between hot spot locations and other variables
FUTURE RESEARCH

• **Cold Spots** – study potential predictors
• **VOC** – perform regression analysis
• **Predictors of Hot Spot Frequency**
• **Study “outliers”**
• **Other variables**
  o **Construction**
  o **Underpasses**
  o **Vehicle Classifications (more detailed)**
ACKNOWLEDGEMENTS

Oregon Transportation Research and Education Consortium (OTREC) & National Institute for Transportation and Communities (NITC)

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Thesis Committee: Dr. Miguel Figliozzi, Dr. Robert Bertini and Dr. Chris Monsere

Alex Bigazzi, Adam Moore (PSU)
QUESTIONS

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Portland State University

Related Masters Thesis will be available at http://www.its.pdx.edu/publications.php
Data

• Pollutant Concentration – $PM_{2.5}$ and VOC

• Probe Vehicle Behavior – Location, Speed, Standard deviation of speed, Percent time accelerating, Stopped time

• Traffic – Queue length, Queue adjacent, Volume, Distance to major intersection, # of high emitters

• Meteorological – Wind Speed/Direction, Background $PM_{2.5}$, Relative humidity, Temperature

• Zoning – Commercial, Residential, Industrial, Open-space

• Buildings & Businesses – Drive-through business (i.e., McDonalds) Gas station, Building height, Building footprints

• Elevation Changes – Flat, Uphill, Downhill, High point, Low point
AVAILABLE DATA

- **Traffic** – *Wavetronix & SCATS*
- **Land Use** – *PortlandMaps & RLIS*
- **Meteorological** – *DEQ Air Quality Monitoring Station*
STATISTICAL ANALYSIS

1) Mann-Whitney-Wilcoxon Test
2) Simple Regression Analysis
3) Multiple Regression Analysis

Measured PM2.5 (μg/m³)
25 breaks

Skewed distribution
Time-Space-Air Quality Diagram

PM2.5 (ug/m³)
- 0.4
- ≥4.8
- ≥8.12
- ≥12.16
- ≥16.20
- ≥20

* Above Primary NAAQS (for annual mean, averaged over 3 years)
Simple Regression - Traffic

- Time of Day
- Mean Speed
- Stddev Speed
- Stopped Time
- Queue Length
- Queue Adjacent
- Traffic Volume
- Distance to Major Intx
- # Of High Emitters

R-square and correlation sign

-40% -30% -20% -10% 0% 10% 20%

AM Only
PM Only
AM & PM

Introduction  Literature Review  Data  Analysis  Conclusions
Simple Regression

Meteorology
- Temperature
- Wind Speed
- Wind Direction Sin
- Wind Direction Cos
- Background PM2.5
- Relative Humidity
- Time of Day

Traffic
- Mean Speed
- # Of High Emitters
- Queue Adjacent

R-square and correlation sign

Legend:
- AM Only
- PM Only
- AM & PM
Simple Regression

Zoning
- Industrial
- Residential
- Commercial

Buildings
- Frontage Profile Height
- Building Height
- Building Footprint
- Distance to Gas Station (Far Side)
- Distance to Gas Station
- Distance to Drive Through (i.e., McD's)
- Mostly Flat
- Mostly Uphill
- Temperature
- Mean Speed

R-square and correlation sign

Legend:
- AM Only
- PM Only
- AM & PM
Simple Regression - Traffic

- Time of Day
- Mean Speed
- Stdev Speed
- Stopped Time
- Queue Length
- Queue Adjacent
- Traffic Volume
- Distance to Major Intx
- # Of High Emitters

R-square and correlation sign

AM Only
PM Only
AM & PM
Simple Regression

Meteorology
- Temperature
- Wind Speed
- Wind Direction Sin
- Wind Direction Cos
- Background PM2.5
- Relative Humidity
- Time of Day

Traffic
- Mean Speed
- # Of High Emitters
- Queue Adjacent

R-square and correlation sign

-40% -30% -20% -10% 0% 10% 20% 30%

AM Only
PM Only
AM & PM
Simple Regression

### Zoning
- Industrial
- Residential
- Commercial

### Buildings
- Frontage Profile Height
- Building Height
- Building Footprint
- Distance to Gas Station (Far Side)
- Distance to Gas Station
- Distance to Drive Through (i.e., McD's)
- Mostly Flat
- Mostly Uphill
- Temperature
- Mean Speed

---

**R-square and correlation sign**

- AM Only
- PM Only
- AM & PM

---

**Data**

- Introduction
- Literature Review
- Data
- Analysis
- Conclusions
Multiple Regression - % Contribution to Baseline

All Day Model - Example

\[ Y = 18.14 - 0.21(\text{Temperature}) + 2.00[\sin(\text{Wind Direction})] + 0.22(\# \text{ of high emitters}) + 1.41(\text{Time w queue adjacent}) - 0.01(\% \text{ Residential zoning}) - 0.12(\text{Distance to gas station}) \]

Baseline

+6.5%  
+7.2%  
+3.5%  
-4.6%  
-3.1%
Multiple Regression

\[ Y_i = \beta_0 + \beta_1 X_{1i} + \ldots + \beta_k X_{ki} + \varepsilon \]

- R Step() function – *uses AIC criteria*
- p-value < 0.05
- Variance inflation factor (VIF) < 5

\[ VIF_j = \frac{1}{1 - R^2_j} \]

- Correlations
- Log-linear Models
## Correlations

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<th>$R^2$</th>
<th>ResTotal</th>
<th>ResNear</th>
<th>GasDistFar</th>
<th>H200AvgTotal</th>
<th>ResFar</th>
<th>GasDistAll</th>
<th>H200AvgNear</th>
<th>IndTotal</th>
<th>H200Total</th>
<th>IndNear</th>
<th>IndFar</th>
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## Simple Regression

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<tr>
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### Simple Regression

**Introduction**

**Literature Review**

**Data**

**Analysis**

**Conclusions**

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