# MOVES Regional Level Sensitivity Analysis

Presented By:
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# Introduction

- MOVES 2010a Released in April of 2010 as minor update to MOVES 2010, released in December of 2009.
- During the original 2 year grace period FHWA received numerous requests from it's air practitioner customer base for assistance in meeting regional conformity requirements using MOVES.
- At the urging of State DOTs and MPOs, USEPA extends grace period for MOVES use in Regional conformity for an additional year.

# Introduction cont.

- The MOVES Regional Level Sensitivity Analysis was initiated by the Federal Highway Administration in October of 2011 with technical assistance from the Volpe National Transportation Systems Center.

- Partial results of the study have been presented to the following organizations:

  - 2012 Transportation Research Board Annual Meeting
  - 2012 Air and Waste Management Association Annual Meeting
  - 2012 Transportation Research Board Summer Meeting

# Purpose of the Analysis

- The MOVES Regional Level Sensitivity Analysis was conducted to increase understanding of the operations of the MOVES Model in regional emissions analysis and to highlight the following:
  - the relative sensitivity of selected MOVES Model input parameters when compared to national default values.
  - relationships between specific variables and their effects on emission rate calculations for specific pollutants.
  - areas where air quality practitioners can most wisely focus scarce resources in order to refine their MOVES model inputs.

# Acknowledgements

For significant contribution to the MOVES Regional Level Sensitivity Analysis:

Emily Biondi – USDOT, Federal Highway Administration

Michael Claggett – USDOT, Federal Highway Administration

John Byun – USDOT, Federal Highway Administration

Paul Heishman – USDOT, Federal Highway Administration

# Evaluation Parameters

- Sensitivity Analysis of MOVES
  - Conducted for Regional/County Scale
  - Focused on the running emissions process for CO, PM2.5, NOX, and VOCs
  - Temperature effects for Start and Evaporative emissions also included
  - Analysis results report the sensitivity of selected input parameters on predicted emissions rates by vehicle type

- MOVES Input Parameters Evaluated
  - Temperature
  - Humidity
  - Ramp Fraction
  - Analysis Year
  - Age Distribution
  - Average Speed Distribution

# EPA Sensitivity Analysis

- *"MOVES Sensitivity Analysis: The Impacts of Temperature and Humidity of Emissions"*

- Focused on Temperature and Humidity
  - Included more temperature ranges for humidity sensitivity

- Analyzed impacts by fuel type (gasoline and diesel) and analysis year

- Majority of Sensitivity Analysis results showed the same trends as EPA analysis for temperature and humidity
  - Only difference was with CO and VOC results for diesel vehicle types

# Comparison to Baseline Case

- A ‘Baseline Case’ Developed For Comparison and For Efficiency of Analysis
  - Represents a regional (county level) scale analysis

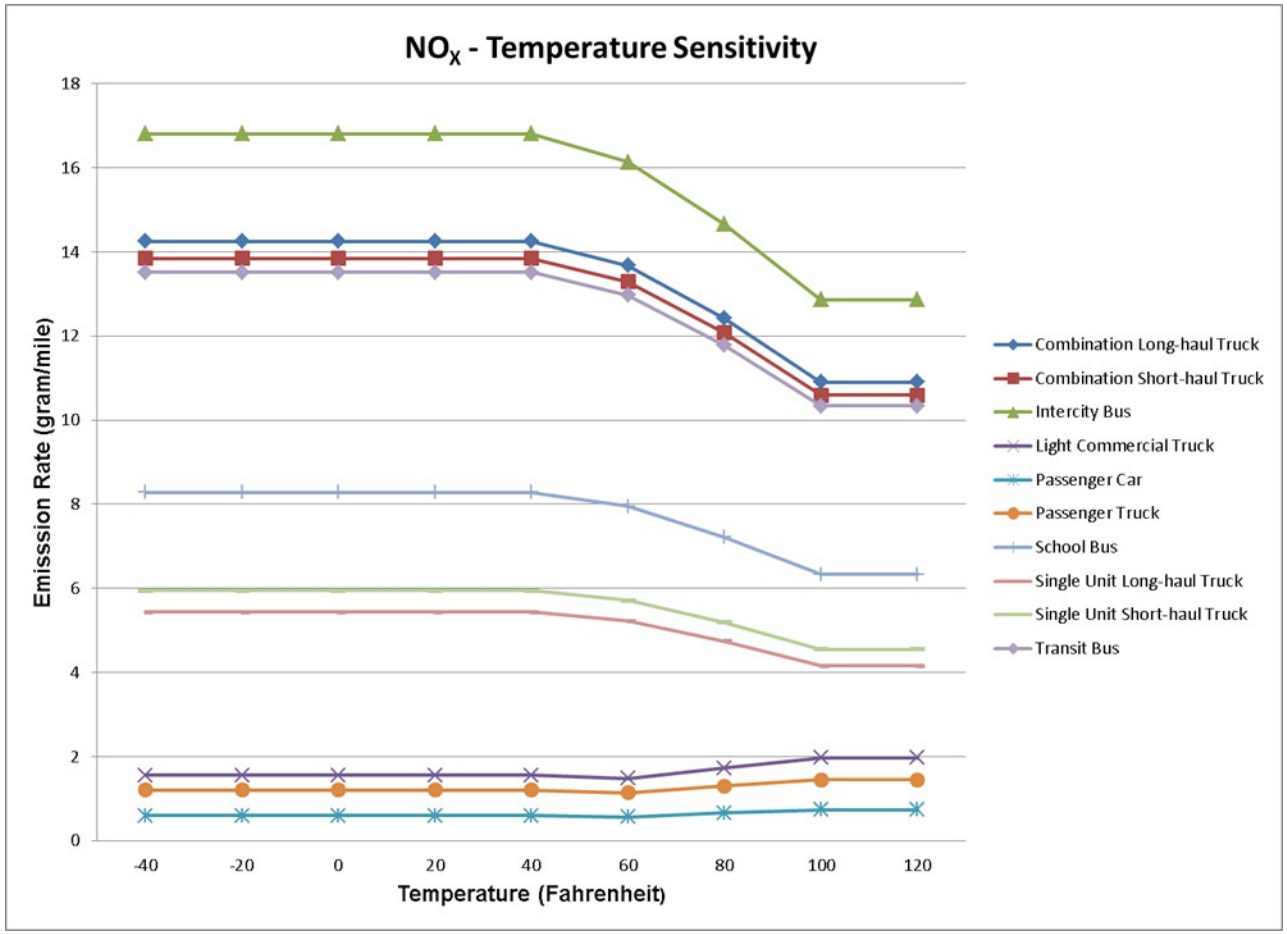
- Utilized a Single Hour of Execution (run time consideration)
  - 8 AM Hour (morning peak)
  - 60º Fahrenheit*
  - 50% Relative Humidity*
    - * also evaluated

- National Defaults Utilized for General Input Parameters Required in Data Manager

# Input Parameters Analyzed

| Input Parameter | Parameter Values/Description |
|---|---|
| Temperature (Fahrenheit) includes starts and evaporative | -40º, -20º, 0º, 20º, 40º, 60º, 80º, 100º, 120º F |
| Humidity | 0%, 20%, 40%, 50%, 60%, 80%, 100% (60º F and 80º F) |
| Ramp Fraction | 0, 0.02, 0.04, 0.06, 0.10, 0.12 0.16, 0.20 |
| Analysis Year | 2010, 2020, 2030, 2040, 2050 |
| Age Distribution | Group 1 = 0-10 years old<br>Group 2 = 11-20 years old<br>Group 3 = 21-30 years old |
| Average Speed Distribution - Urban Restricted Access - FC 11 Urban Interstate | LOS B,C,D,E,F |
| Average Speed Distribution - Urban Unrestricted Access - FC 12 Urban Principal Arterial Freeway | LOS C,D,E |
| Average Speed Distribution - Urban Restricted Access - FC 14 Urban Principal Arterial Other | LOS B,C,F |

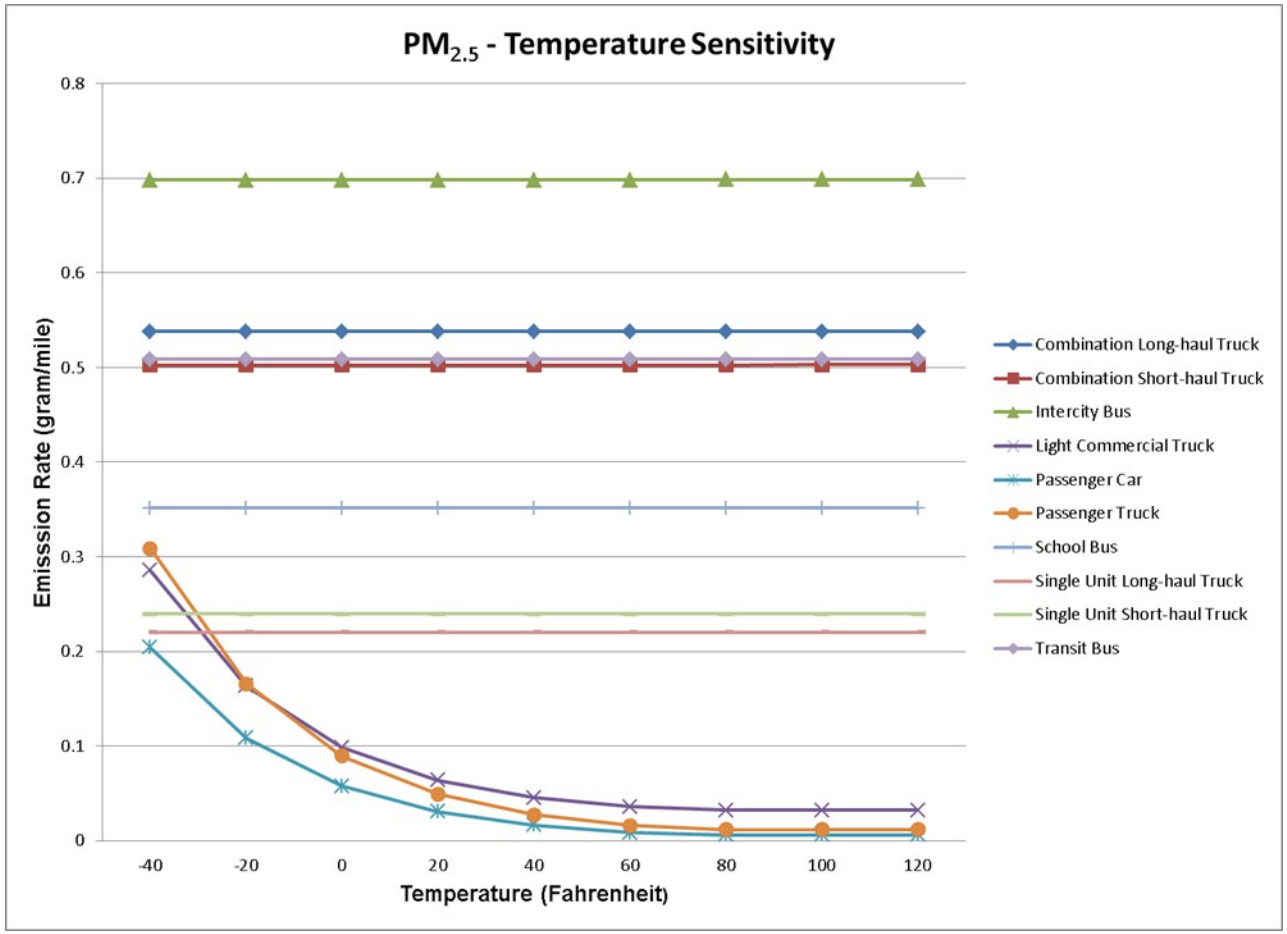
# NOX – Temperature Sensitivity



# NOX – Temperature Sensitivity

| Temperature (Fahrenheit) | Passenger Car | | Passenger Truck | | Single Unit Short-haul Truck | | Combination Long-haul Truck | |
|---|---|---|---|---|---|---|---|---|
| | Emission Rate (gram/mile) | % difference | Emission Rate (gram/mile) | % difference | Emission Rate (gram/mile) | % difference | Emission Rate (gram/mile) | % difference |
| -40 | 0.593 | 6% | 1.203 | 6% | 5.947 | 4% | 14.244 | 4% |
| -20 | 0.593 | 6% | 1.203 | 6% | 5.947 | 4% | 14.244 | 4% |
| 0 | 0.593 | 6% | 1.203 | 6% | 5.947 | 4% | 14.244 | 4% |
| 20 | 0.593 | 6% | 1.203 | 6% | 5.947 | 4% | 14.244 | 4% |
| 40 | 0.593 | 6% | 1.203 | 6% | 5.947 | 4% | 14.244 | 4% |
| 60 | 0.561 | 0% | 1.137 | 0% | 5.708 | 0% | 13.673 | 0% |
| 80 | 0.657 | 17% | 1.306 | 15% | 5.185 | -9% | 12.42 | -9% |
| 100 | 0.739 | 32% | 1.449 | 27% | 4.55 | -20% | 10.899 | -20% |
| 120 | 0.739 | 32% | 1.449 | 27% | 4.55 | -20% | 10.899 | -20% |

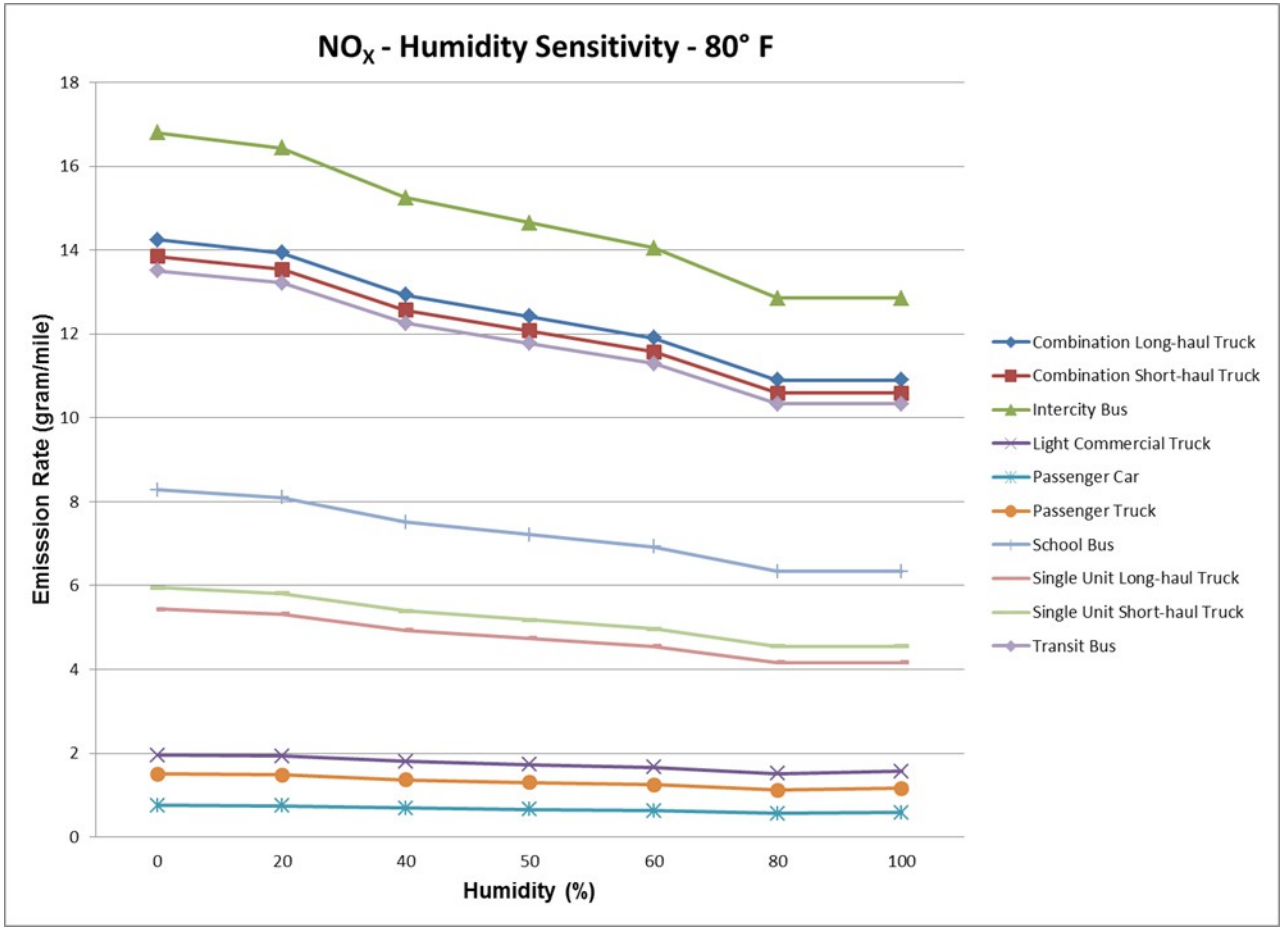
# PM2.5 – Temperature Sensitivity



# PM2.5 – Temperature Sensitivity

| Temperature (Fahrenheit) | Passenger Car | | Passenger Truck | | Single Unit Short-haul Truck | | Combination Long-haul Truck | |
|---|---|---|---|---|---|---|---|---|
| | Emission Rate (gram/mile) | % difference | Emission Rate (gram/mile) | % difference | Emission Rate (gram/mile) | % difference | Emission Rate (gram/mile) | % difference |
| -40 | 0.2039 | 2225% | 0.3087 | 1794% | 0.2397 | 0.00% | 0.5378 | 0.00% |
| -20 | 0.1085 | 1137% | 0.1657 | 916% | 0.2397 | 0.00% | 0.5378 | 0.00% |
| 0 | 0.0577 | 558% | 0.0896 | 450% | 0.2397 | 0.00% | 0.5378 | 0.00% |
| 20 | 0.0307 | 250% | 0.0492 | 202% | 0.2397 | 0.00% | 0.5378 | 0.00% |
| 40 | 0.0164 | 87% | 0.0277 | 70% | 0.2397 | 0.00% | 0.5378 | 0.00% |
| 60 | 0.0088 | 0% | 0.0163 | 0% | 0.2397 | 0.00% | 0.5378 | 0.00% |
| 80 | 0.006 | -32% | 0.0121 | -26% | 0.2397 | 0.02% | 0.5379 | 0.01% |
| 100 | 0.006 | -32% | 0.0121 | -26% | 0.2398 | 0.04% | 0.5379 | 0.03% |
| 120 | 0.006 | -32% | 0.0121 | -26% | 0.2398 | 0.04% | 0.5379 | 0.03% |

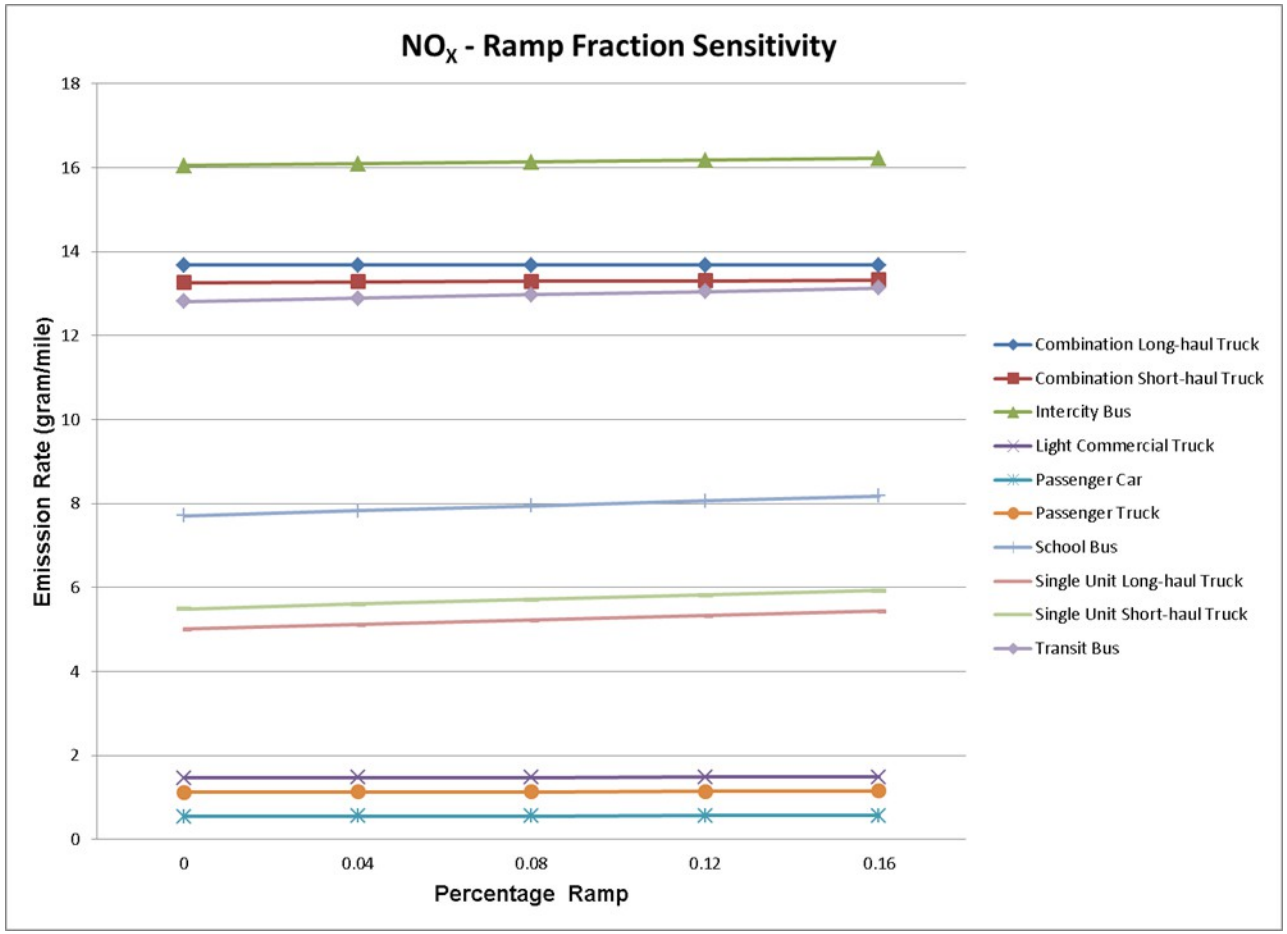
# NOX – Humidity Sensitivity



# NOX – Humidity Sensitivity

| Humidity | Passenger Car | | Passenger Truck | | Single Unit Short-haul Truck | | Combination Long-haul Truck | |
|---|---|---|---|---|---|---|---|---|
| | Emission Rate (gram/mile) | % difference | Emission Rate (gram/mile) | % difference | Emission Rate (gram/mile) | % difference | Emission Rate (gram/mile) | % difference |
| 0 | 0.7538 | 14.76% | 1.5 | 14.86% | 5.9465 | 15% | 13.8455 | 15% |
| 20 | 0.7453 | 13.46% | 1.4817 | 13.46% | 5.8171 | 12% | 13.5442 | 12% |
| 40 | 0.6867 | 4.55% | 1.3652 | 4.54% | 5.3971 | 4% | 12.5663 | 4% |
| 50 | 0.6569 | 0.00% | 1.3059 | 0.00% | 5.1848 | 0% | 12.0721 | 0% |
| 60 | 0.6264 | -4.64% | 1.2454 | -4.63% | 4.9711 | -4% | 11.5744 | -4% |
| 80 | 0.5648 | -14.02% | 1.1237 | -13.96% | 4.5501 | -12% | 10.5942 | -12% |
| 100 | 0.5844 | -11.03% | 1.1603 | -11.15% | 4.5501 | -12% | 10.5942 | -12% |

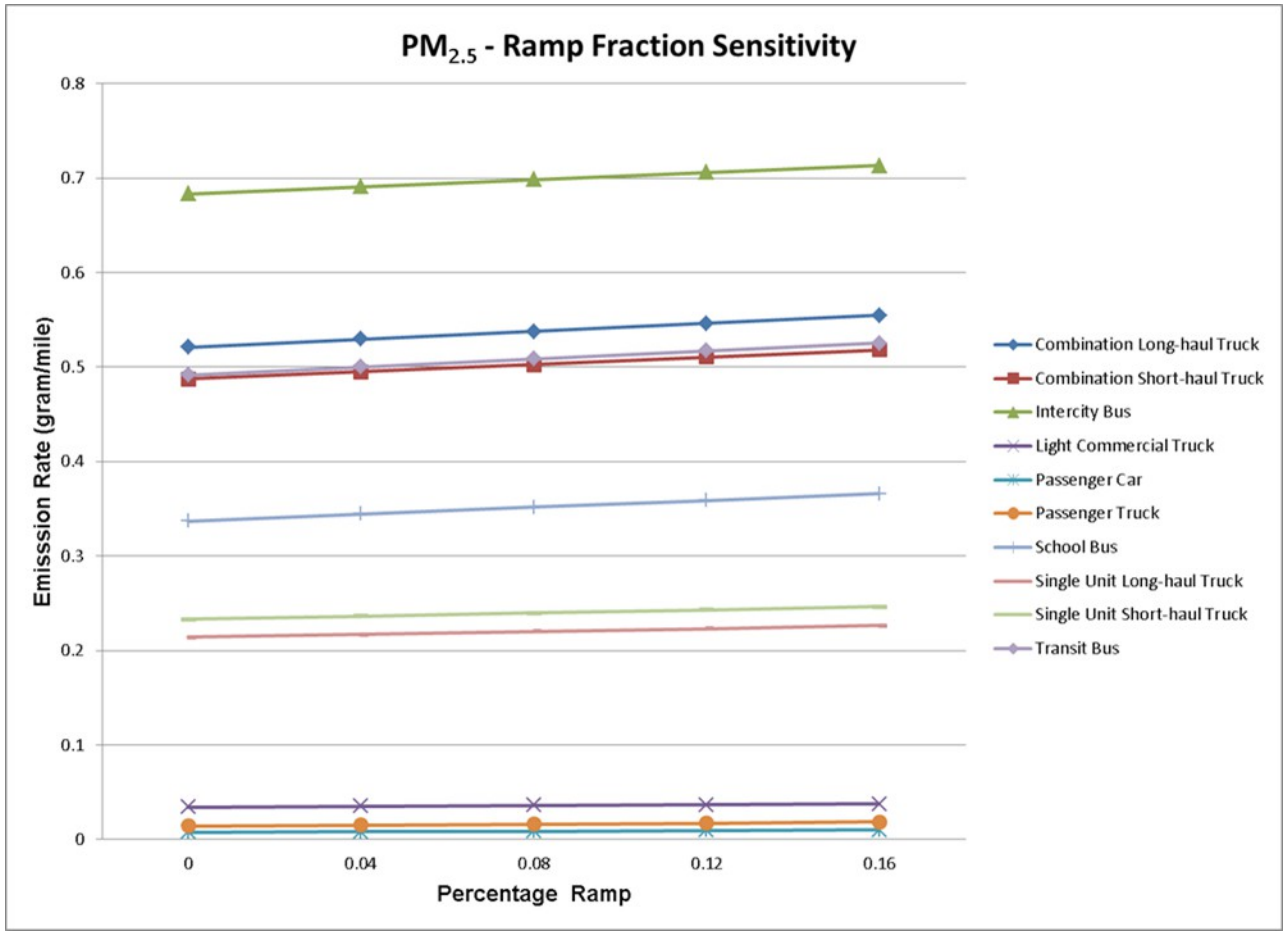
# NOX – Ramp Fraction Sensitivity



# NOX – Ramp Fraction Sensitivity

| Ramp Fraction | Passenger Car | | Passenger Truck | | Single Unit Short-haul Truck | | Combination Long-haul Truck | |
|---|---|---|---|---|---|---|---|---|
| | Emission Rate (gram/mile) | % difference | Emission Rate (gram/mile) | % difference | Emission Rate (gram/mile) | % difference | Emission Rate (gram/mile) | % difference |
| 0 | 0.549 | -2% | 1.125 | -1% | 5.492 | -3.80% | 13.674 | 0.00% |
| 0.02 | 0.552 | -2% | 1.128 | -1% | 5.546 | -2.80% | 13.673 | 0.00% |
| 0.04 | 0.555 | -1% | 1.131 | -1% | 5.6 | -1.90% | 13.673 | 0.00% |
| 0.06 | 0.558 | -1% | 1.134 | 0% | 5.654 | -0.90% | 13.673 | 0.00% |
| 0.08 | 0.561 | 0% | 1.137 | 0% | 5.708 | 0.00% | 13.673 | 0.00% |
| 0.1 | 0.564 | 1% | 1.14 | 0% | 5.762 | 0.90% | 13.673 | 0.00% |
| 0.12 | 0.566 | 1% | 1.143 | 1% | 5.816 | 1.90% | 13.673 | 0.00% |
| 0.16 | 0.572 | 2% | 1.149 | 1% | 5.924 | 3.80% | 13.673 | 0.00% |
| 0.2 | 0.578 | 3% | 1.155 | 2% | 6.032 | 5.70% | 13.673 | 0.00% |

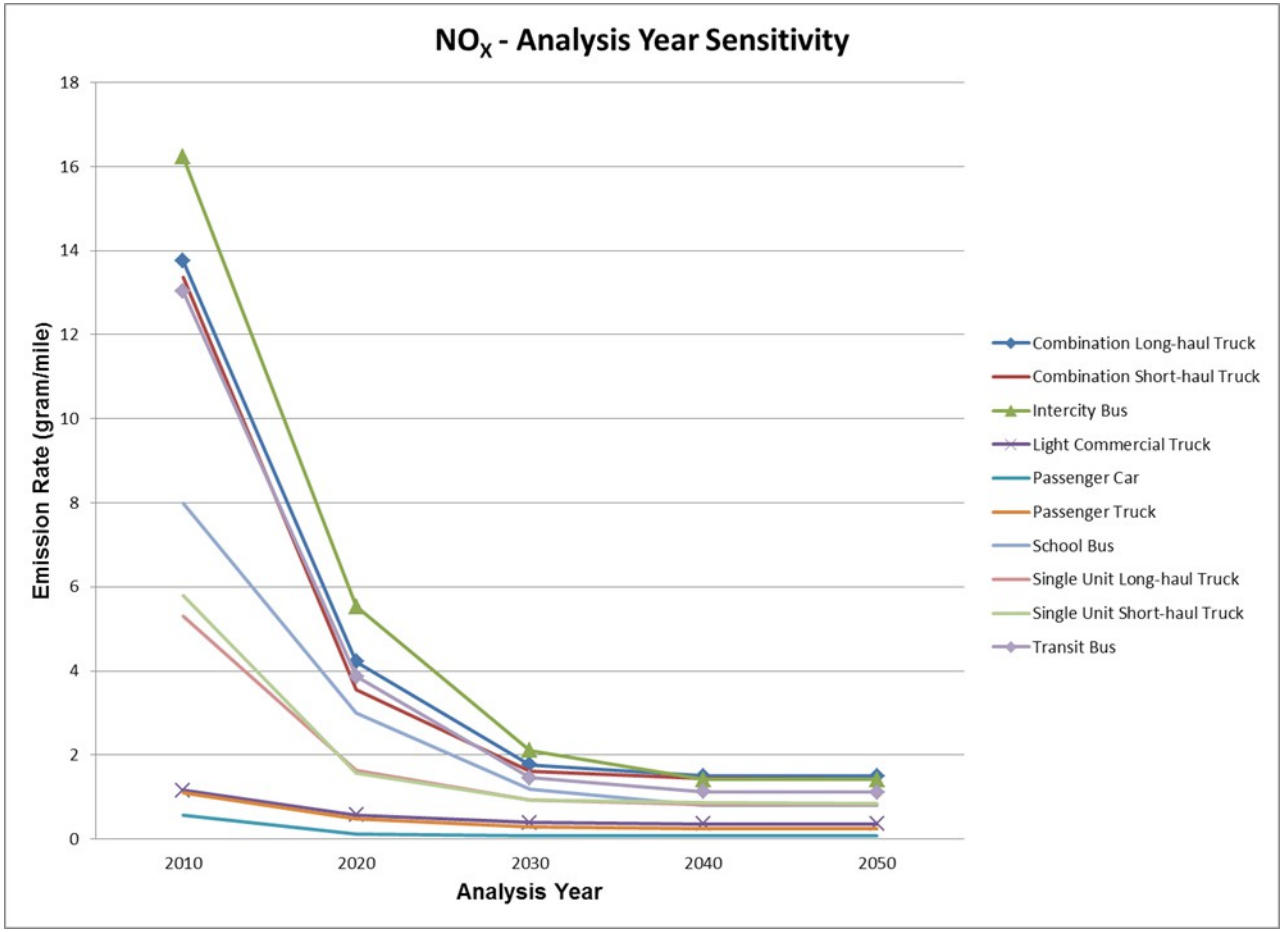
# PM2.5 – Ramp Fraction Sensitivity



# PM2.5 – Ramp Fraction Sensitivity

| Ramp Fraction | Passenger Car | | Passenger Truck | | Single Unit Short-haul Truck | | Combination Long-haul Truck | |
|---|---|---|---|---|---|---|---|---|
| | Emission Rate (gram/mile) | % difference | Emission Rate (gram/mile) | % difference | Emission Rate (gram/mile) | % difference | Emission Rate (gram/mile) | % difference |
| 0 | 0.00749 | -15% | 0.01426 | -12% | 0.233 | -2.70% | 0.521 | -3.10% |
| 0.02 | 0.00781 | -11% | 0.01477 | -9% | 0.235 | -2.00% | 0.525 | -2.40% |
| 0.04 | 0.00813 | -7% | 0.01528 | -6% | 0.236 | -1.40% | 0.529 | -1.60% |
| 0.06 | 0.00845 | -4% | 0.01579 | -3% | 0.238 | -0.70% | 0.534 | -0.80% |
| 0.08 | 0.00877 | 0% | 0.0163 | 0% | 0.24 | 0.00% | 0.538 | 0.00% |
| 0.1 | 0.00909 | 4% | 0.01681 | 3% | 0.241 | 0.70% | 0.542 | 0.80% |
| 0.12 | 0.00941 | 7% | 0.01732 | 6% | 0.243 | 1.40% | 0.546 | 1.60% |
| 0.16 | 0.01005 | 15% | 0.01834 | 12% | 0.246 | 2.70% | 0.555 | 3.10% |
| 0.2 | 0.01069 | 22% | 0.01936 | 19% | 0.249 | 4.10% | 0.563 | 4.70% |

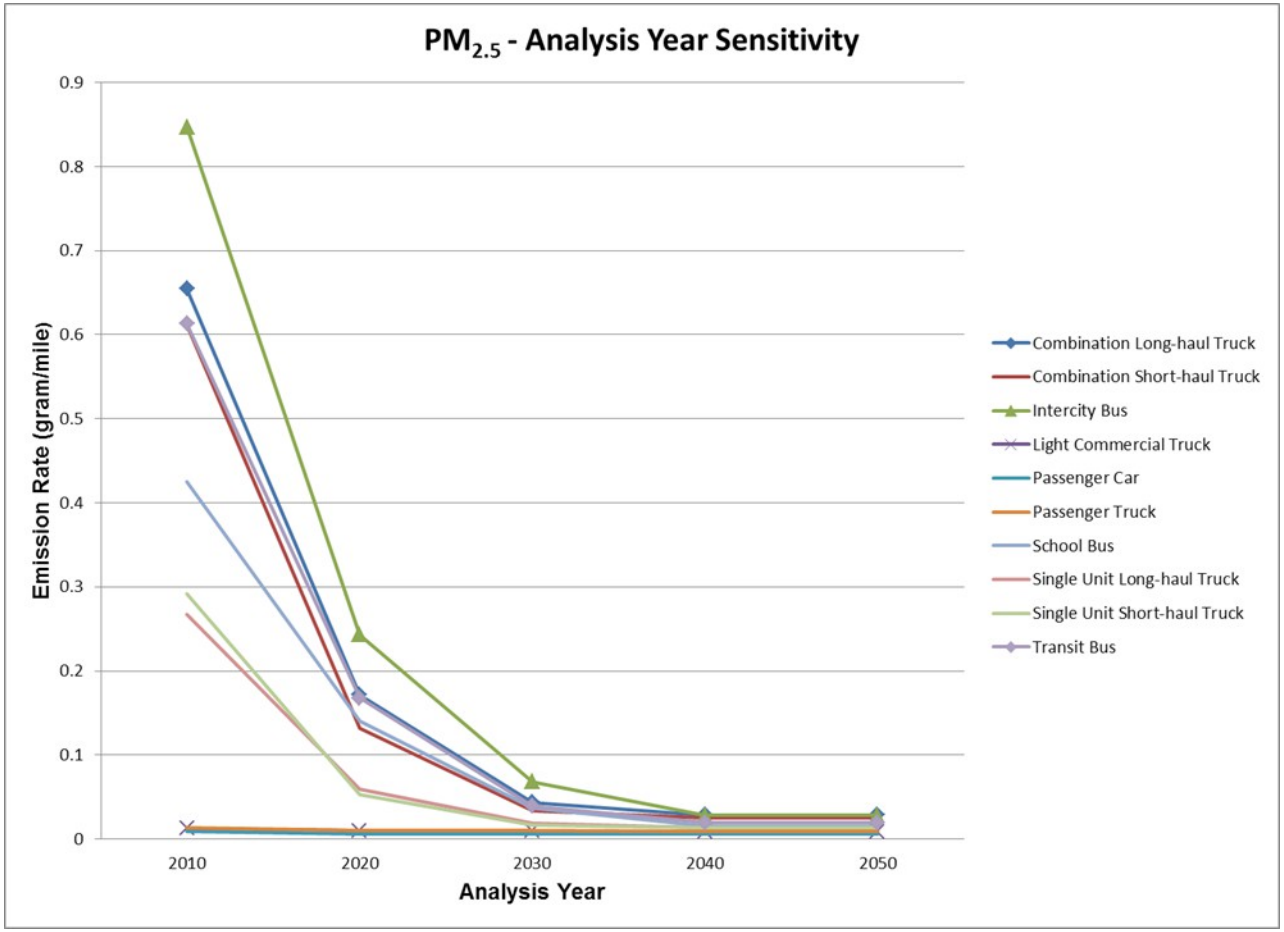
# NOX – Analysis Year Sensitivity



# NOX – Analysis Year Sensitivity

| Analysis Year | Passenger Car | | Passenger Truck | | Single Unit Short-haul Truck | | Combination Long-haul Truck | |
|---|---|---|---|---|---|---|---|---|
| | Emission Rate (gram/mile) | % difference | Emission Rate (gram/mile) | % difference | Emission Rate (gram/mile) | % difference | Emission Rate (gram/mile) | % difference |
| 2010 | 0.5598 | 0.00% | 1.0943 | 0.00% | 13.2825 | 0% | 7.2077 | 0% |
| 2020 | 0.1117 | -80.10% | 0.4786 | -56.30% | 3.4577 | -74.00% | 2.6163 | -63.70% |
| 2030 | 0.0786 | -86.00% | 0.2794 | -74.50% | 1.4534 | -89.10% | 1.3025 | -81.90% |
| 2040 | 0.0789 | -85.90% | 0.2479 | -77.30% | 1.301 | -90.20% | 0.9583 | -86.70% |
| 2050 | 0.0791 | -85.90% | 0.2469 | -77.40% | 1.3003 | -90.20% | 0.9562 | -86.70% |

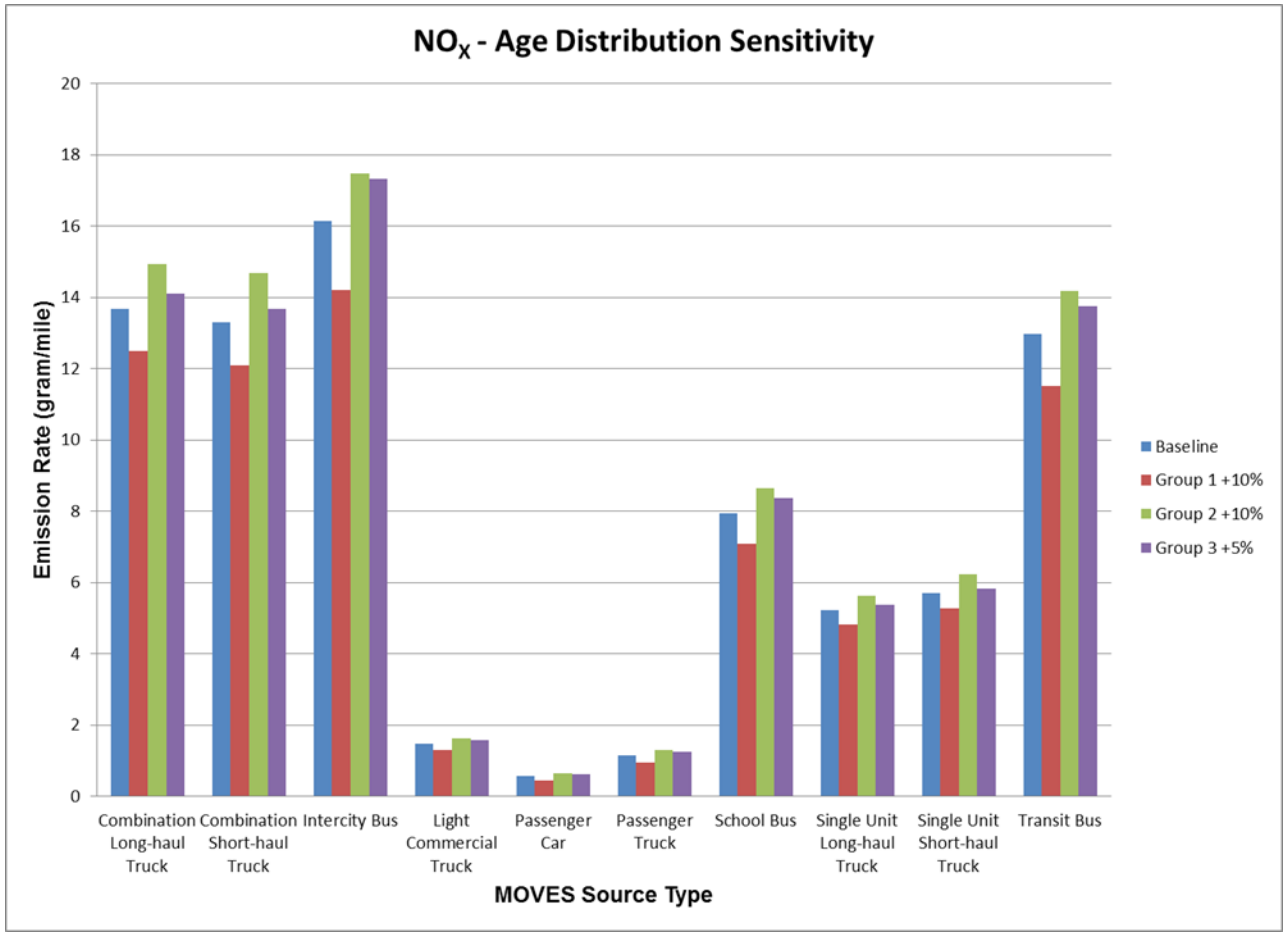
# PM2.5 – Analysis Year Sensitivity



# PM2.5 – Analysis Year Sensitivity

| Analysis Year | Passenger Car | | Passenger Truck | | Single Unit Short-haul Truck | | Combination Long-haul Truck | |
|---|---|---|---|---|---|---|---|---|
| | Emission Rate (gram/mile) | % difference | Emission Rate (gram/mile) | % difference | Emission Rate (gram/mile) | % difference | Emission Rate (gram/mile) | % difference |
| 2010 | 0.0088 | 0.00% | 0.0133 | 0.00% | 0.5607 | 0% | 0.3035 | 0% |
| 2020 | 0.0055 | -37.40% | 0.0104 | -21.70% | 0.1234 | -78.00% | 0.0897 | -70.40% |
| 2030 | 0.0055 | -37.60% | 0.0096 | -28.00% | 0.033 | -94.10% | 0.0275 | -90.90% |
| 2040 | 0.0056 | -36.30% | 0.0093 | -30.20% | 0.0254 | -95.50% | 0.013 | -95.70% |
| 2050 | 0.0056 | -36.00% | 0.0092 | -30.90% | 0.0254 | -95.50% | 0.0129 | -95.70% |

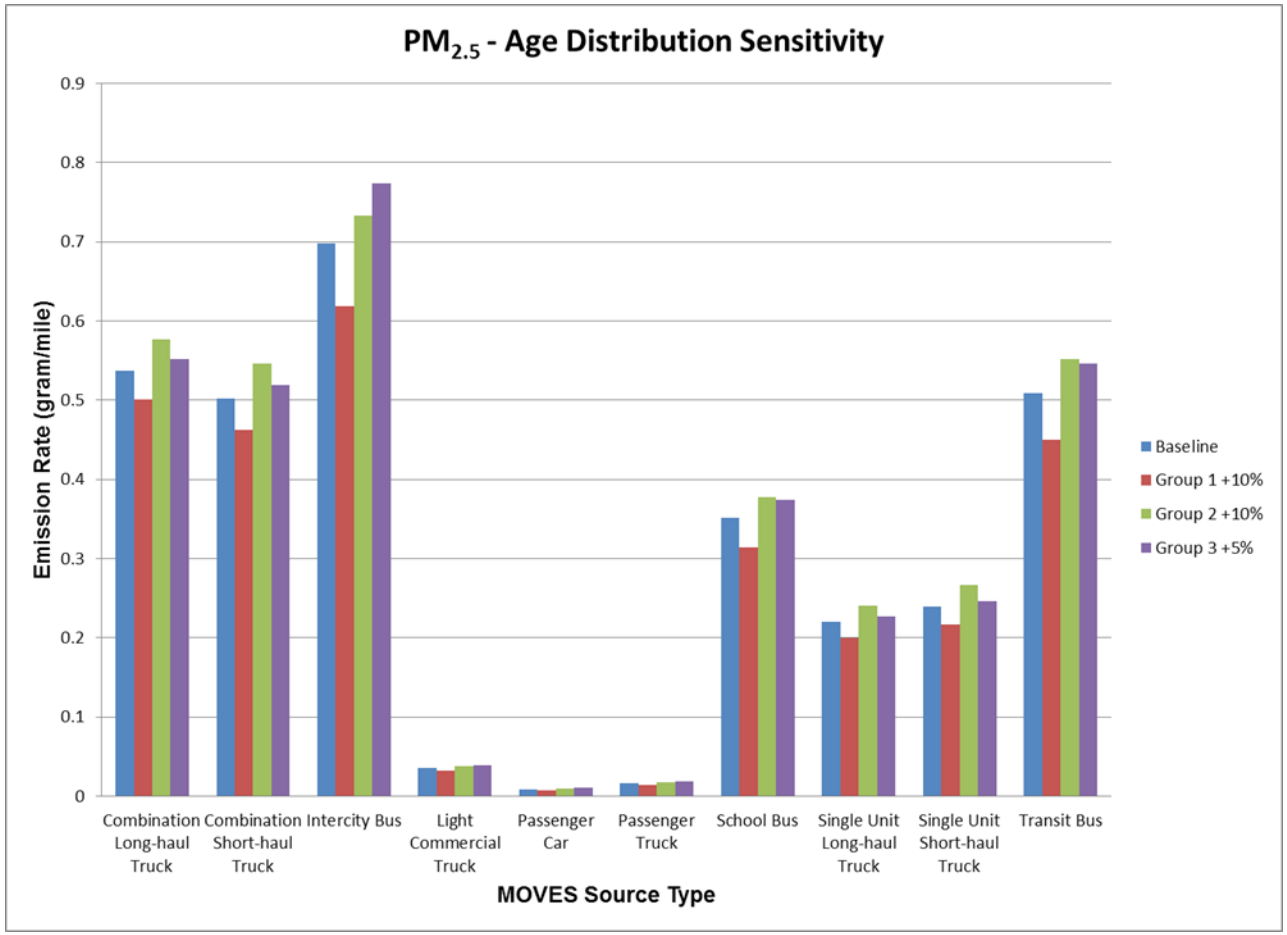
# NOX – Age Distribution Sensitivity



# NOX – Age Distribution Sensitivity

| Age Distribution | Passenger Car | | Passenger Truck | | Single Unit Short-haul Truck | | Combination Long-haul Truck | |
|---|---|---|---|---|---|---|---|---|
| | Emission Rate (gram/mile) | % difference | Emission Rate (gram/mile) | % difference | Emission Rate (gram/mile) | % difference | Emission Rate (gram/mile) | % difference |
| Baseline | 0.561 | 0% | 1.137 | 0% | 5.708 | 0% | 13.673 | 0% |
| Group 1 +10% (0-10 years) | 0.451 | -19.60% | 0.942 | -17.20% | 5.274 | -7.60% | 12.49 | -8.70% |
| Group 2 +10% (11-20 years) | 0.653 | 16.40% | 1.295 | 13.90% | 6.226 | 9.10% | 14.936 | 9.20% |
| Group 3 +5% (21-30 years) | 0.619 | 10.40% | 1.249 | 9.80% | 5.832 | 2.20% | 14.111 | 3.20% |

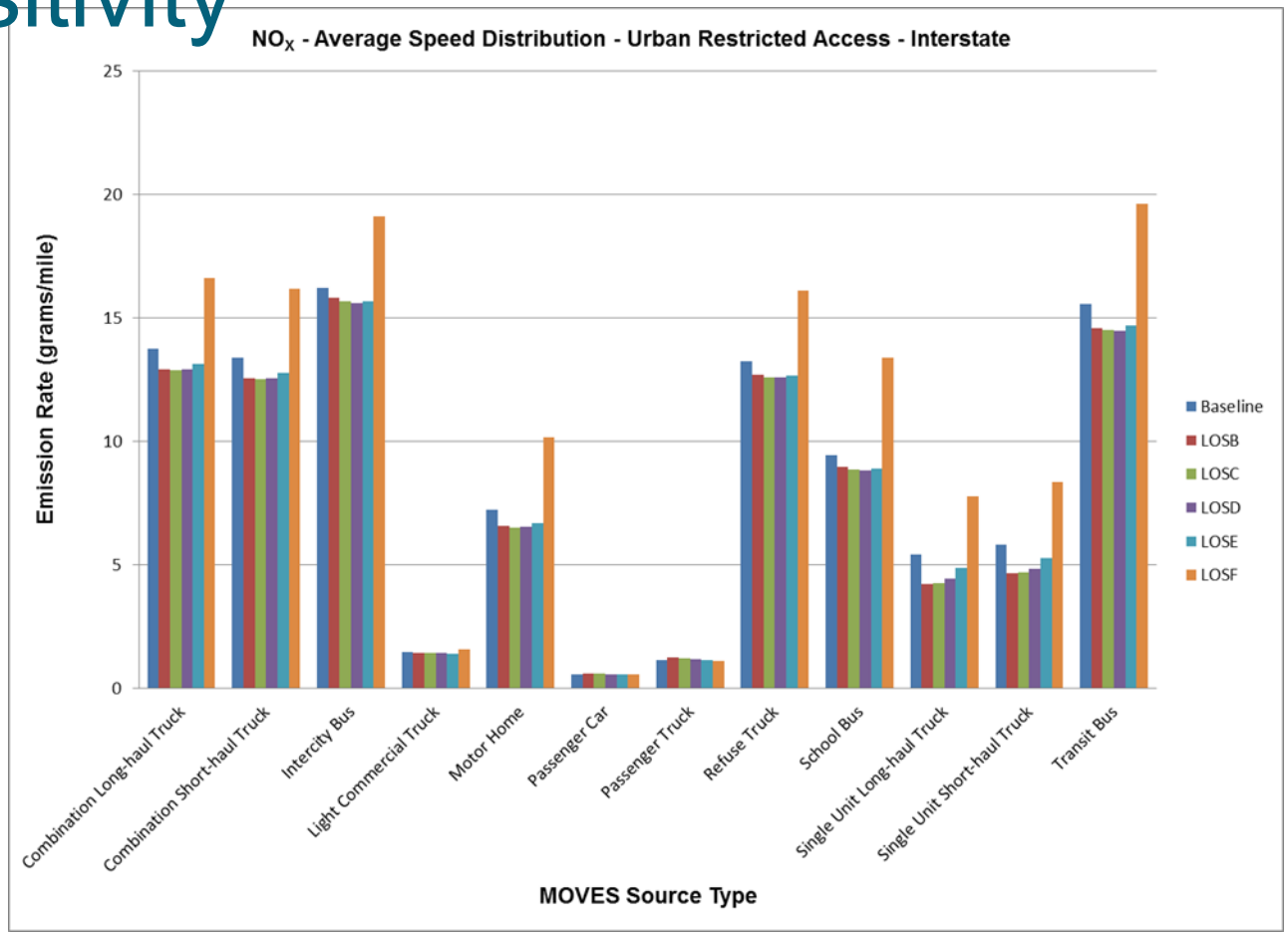
# PM2.5 – Age Distribution Sensitivity



# PM2.5 – Age Distribution Sensitivity

| Age Distribution | Passenger Car | | Passenger Truck | | Single Unit Short-haul Truck | | Combination Long-haul Truck | |
|---|---|---|---|---|---|---|---|---|
| | Emission Rate (gram/mile) | % difference | Emission Rate (gram/mile) | % difference | Emission Rate (gram/mile) | % difference | Emission Rate (gram/mile) | % difference |
| Baseline | 0.009 | 0% | 0.016 | 0% | 0.24 | 0% | 0.538 | 0% |
| Group 1 +10% (0-10 years) | 0.007 | -19.20% | 0.014 | -14.70% | 0.217 | -9.50% | 0.501 | -6.90% |
| Group 2 +10% (11-20 years) | 0.009 | 7.80% | 0.018 | 8.50% | 0.266 | 11.10% | 0.577 | 7.20% |
| Group 3 +5% (21-30 years) | 0.011 | 20.50% | 0.018 | 12.70% | 0.247 | 3.00% | 0.552 | 2.70% |

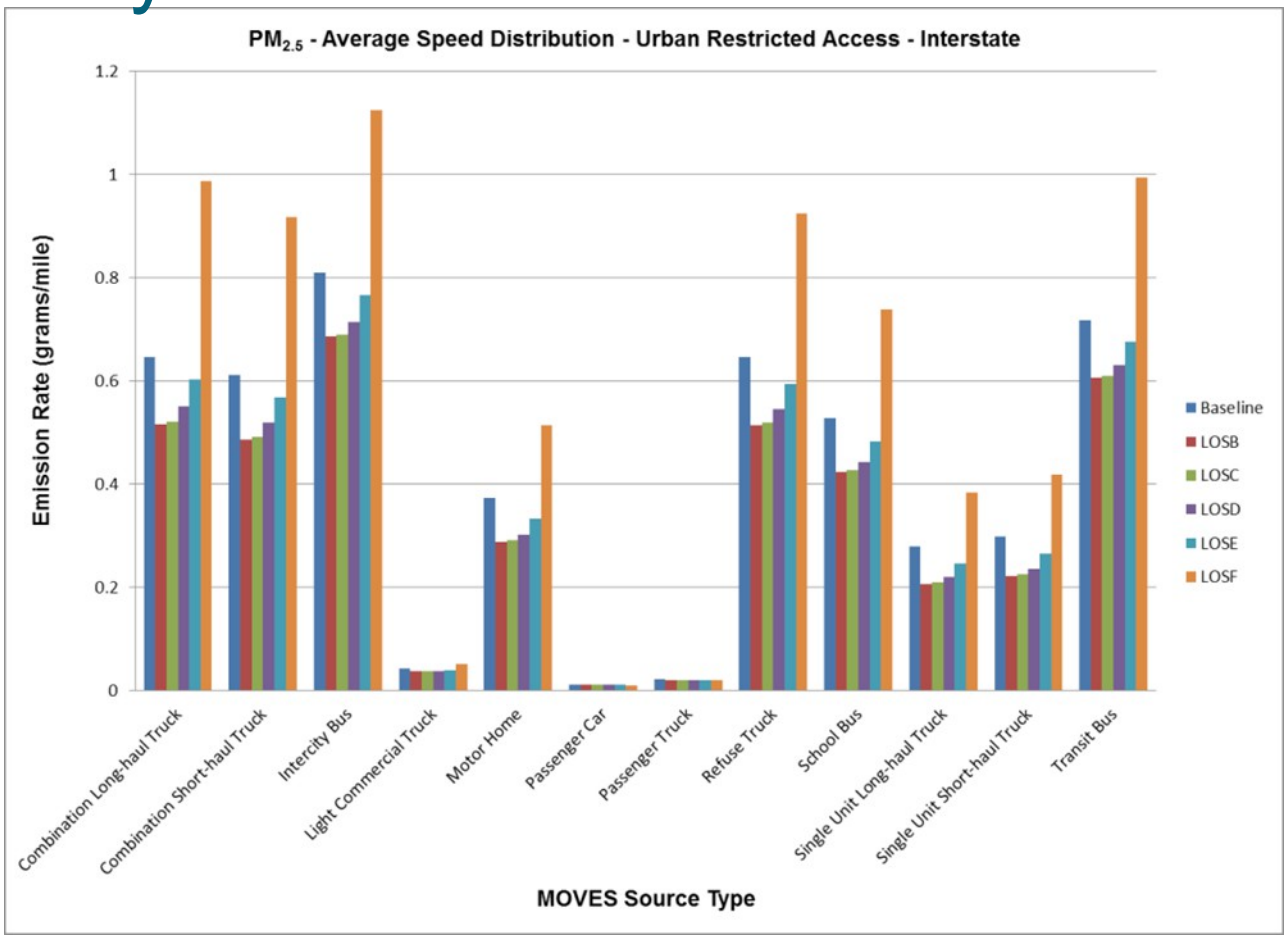
# NOX – Average Speed Distribution Sensitivity



# NOX – Average Speed Distribution

| LOS | Functional Classification | Passenger Car | | Passenger Truck | | Single Unit Short-haul Truck | | Combination Long-haul Truck | |
|---|---|---|---|---|---|---|---|---|---|
| | | Emission Rate (gram/mile) | % difference | Emission Rate (gram/mile) | % difference | Emission Rate (gram/mile) | % difference | Emission Rate (gram/mile) | % difference |
| Baseline | Urban Interstate | 0.5632 | - | 1.1536 | - | 5.81 | - | 13.743 | - |
| B | Urban Interstate | 0.597 | 6.01% | 1.2348 | 7.04% | 4.671 | -19.59% | 12.905 | -6.09% |
| C | Urban Interstate | 0.5902 | 4.80% | 1.2205 | 5.80% | 4.699 | -19.11% | 12.874 | -6.32% |
| D | Urban Interstate | 0.5761 | 2.30% | 1.1908 | 3.23% | 4.845 | -16.61% | 12.928 | -5.93% |
| E | Urban Interstate | 0.5562 | -1.25% | 1.1431 | -0.91% | 5.265 | -9.38% | 13.135 | -4.43% |
| F | Urban Interstate | 0.5578 | -0.96% | 1.1145 | -3.39% | 8.35 | 43.72% | 16.614 | 20.89% |

# PM2.5 – Average Speed Distribution Sensitivity



# PM2.5 – Average Speed Distribution Sensitivity

| LOS | Functional Classification | Passenger Car | | Passenger Truck | | Single Unit Short-haul Truck | | Combination Long-haul Truck | |
|---|---|---|---|---|---|---|---|---|---|
| | | Emission Rate (gram/mile) | % difference | Emission Rate (gram/mile) | % difference | Emission Rate (gram/mile) | % difference | Emission Rate (gram/mile) | % difference |
| Baseline | Urban Interstate | 0.0115 | - | 0.0217 | - | 0.298 | - | 0.647 | - |
| B | Urban Interstate | 0.0108 | -6.46% | 0.0203 | -6.21% | 0.221 | -25.80% | 0.516 | -20.23% |
| C | Urban Interstate | 0.0109 | -5.85% | 0.0204 | -5.68% | 0.225 | -24.46% | 0.521 | -19.40% |
| D | Urban Interstate | 0.0108 | -6.09% | 0.0204 | -6.05% | 0.236 | -20.86% | 0.55 | -14.90% |
| E | Urban Interstate | 0.0106 | -7.80% | 0.0201 | -7.39% | 0.265 | -11.08% | 0.603 | -6.77% |
| F | Urban Interstate | 0.0096 | -16.48% | 0.0191 | -11.76% | 0.418 | 40.10% | 0.987 | 52.68% |

# Next Steps

- Draft final document is complete. Posting both a detailed and summary document on the FHWA, Air Quality Website - Fall 2012.

- Webinar development and delivery to DOTs and MPOs of MOVES Model Sensitivity Analysis results – Fall 2012

- Professional Conference presentations of MOVES Sensitivity Analysis results – Ongoing

# Thank you

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# Questions?