Low Emissions Zones:
Simulation of Behavioral Impacts

Applications for the Environment:
Real-Time Information Synthesis (AERIS) Program

September 24, 2014
Outline

Overview of Low Emissions Zones

Scenario Development

Simulation Setup and Preliminary Results

Conclusions and Next Steps
AERIS Low Emissions Zones

Low Emissions Zones are geographically defined areas that seek to improve air quality by encouraging “eco-friendly” traveler decisions into and within the zone.

- **Incentivize “green transportation choices”** or restrict specific categories of high-polluting vehicles to improve the air quality within the area.
- **Provide incentives** for “Eco-Vehicles” based on the vehicle’s engine emissions standard or emissions data collected directly from the vehicle using Vehicle-to-Infrastructure (V2I) communications.
- Support geo-fencing the boundaries of the zone allowing these areas to be **responsive to specific traffic and environmental conditions** (e.g. Code Red Air Quality Day, Special Event, etc.)
AERIS Low Emissions Zones

Source: USDOT, August 2014
Real World Examples of Low Emissions Zones

Low Emissions Zones are gaining popularity in Europe and Asia as a means of reducing pollution and congestion in the most urban and population-dense parts of major cities

- **London**: The largest such zone in the world covering almost all of greater London, targeting emissions from older diesel-engine lorries, buses, coaches, vans, minibuses and other heavy vehicles. Increasingly tougher emissions standards are applied over time.

- **Germany**: Currently 47 low emissions zones (called Umweltzone) are in operation or being planned in cities such as Berlin, Cologne, Hanover, Mannheim, and Stuttgart.

- **Sweden**: Low emissions zones currently operating in the cities of Gothenburg, Lund, Malmö, Helsingborg, Mölndal, and Stockholm.

- Low emission zones are also currently in operation or being planned in the **Netherlands**, **Denmark**, **Italy**, and **Japan**.

Low Emissions Zones Modeling Overview

- The modeling of the AERIS Low Emissions Zones Operational Scenario was undertaken on a “regional scale” (i.e., for an entire metro area) to capture the possible impact and change in travel patterns resulting from the implementation of a Low Emissions Zone in the urban center.

- Modeling included providing travelers with information allowing them to make “green” transportation choices:
  - Destination Choice, Route Choice, Mode Choice, Time-of-Day Choice, Vehicle Type Choice
The MAG regional model covers all of Phoenix and the neighboring cities and suburbs, allowing for a thorough analysis of destination, route, and mode choice changes.

Source: -ASU, August 2014
- http://www.azpra.org/PSC
Analysis Scope

- Study the impacts of Low Emissions Zones on:
  - Energy consumption and emissions from personal travel
  - Modal shifts to transit
  - Vehicle fleet composition and choice
  - Destination and mode choice
  - Route choice
  - Activity generation and vehicle miles of travel

- Did not study the impact of Low Emissions Zones on:
  - En-route information provision for eco-drivers
  - Time-of-day based incentive policies (in progress)
  - Financial viability of Low Emissions Zones scenarios
Low Emissions Zones Scenario

- **Incentives to Eco-Travelers (modeled)**
- **Enhanced and Reduced-Fare Transit Service (modeled)**
- **Disincentives to Non-Eco Travelers (not modeled)**
- **Time-of-day Based Incentives (modeling in progress)**
What is an Eco-Vehicle?

- An **Eco-Vehicle** is any vehicle that meets the emission criteria set forth by a Low Emissions Zone policy.
- For modeling, an eco-vehicle includes vehicles in one of the following categories:
  - **Hybrid Electric**
  - **Plug-in Hybrid Electric**
  - **All Electric**

- Future implementations of Low Emissions Zones could possibly consider **other types** of vehicles, including significantly more fuel efficient gasoline vehicles.

Sources:
C. [http://www.colinappleyard.com/blog/customers_fall_for_electric_nissan_leaf](http://www.colinappleyard.com/blog/customers_fall_for_electric_nissan_leaf)
Low Emissions Zones Incentives

- For the modeling effort, **two** different incentives were considered:
  - “Monetary” incentive
    - Market penetration of eco-vehicles estimated based on models in existing literature
    - Travelers to Low Emissions Zones incentivized to use Eco-Vehicles
      - Incentive is intended to **encourage** purchase/use of eco-vehicles
  - Enhanced transit level of service to Low Emissions Zones
    - **Increased transit frequency** (i.e., transit service to the Low Emissions Zones made twice as frequent as in baseline scenario)
    - **Reduced fare** to Low Emissions Zones (i.e., fares reduced to half of baseline scenario fares)
    - Available to entire population, with expected higher impact on non-eco travelers
Assumptions for Modeling the Low Emissions Zones Policy Impacts

- All Eco-Vehicle “incentives” are converted to monetary terms for **modeling purposes**. In a real-world implementation, an incentive need not be strictly ‘monetary’

- **Infrastructure and funding costs** associated with incentive scheme were not considered as a part of Low Emissions Zone modeling framework

- “Enhanced Transit” service is **assumed to be available** in the context of Low Emissions Zone implementation

- **Costs and operational details** associated with “Enhanced Transit” are not taken into consideration
Low Emissions Zones Modeling

- To simulate the Low Emissions Zone, several vital components were included in the model:
  - Level of incentives
  - Eco-vehicle adoption rates
  - Full range of choices
    - Activity choice (activity generation)
    - Time of day choice (activity scheduling)
    - Trip chaining (activity sequencing)
    - Destination choice
    - Mode choice
    - Route choice
    - Vehicle type choice
Integrated Model System: SimTRAVEL

SimTRAVEL: Simulator of Transport, Routes, Activities, Vehicles, Emissions, and Land

Activity-based Model (ABM)
- Socio-economic Data
- Incentive Levels
- Eco-vehicle Penetration

Dynamic Traffic Assignment (DTA) Model

Next Iteration

Real-time Network Conditions (Pre-trip, En-route)

Updated O-D Travel Times

New Network Characteristics

Updated Network Characteristics

Source: ASU, August 2014
Integrated Model: Minute-by-Minute Communication

Minute ‘n’
- Send trips that depart at minute ‘n’
- Receive trips that reached their Destination at minute ‘n’

ABM

Schedule Next Activity

Update Link Travel Times (Every 15 minutes)

Minute ‘n + 1’
- Send trips that depart at minute ‘n + 1’
- Receive trips that reached their Destination at minute ‘n + 1’

ABM

DTA

Source: ASU, August 2014
MAG Regional Subarea Model for Analysis

- A sub-region of the MAG model was used to implement the policies and modeling framework.
- This allowed for faster model runs to be completed to quickly update and customize methodology.

Source: Google Maps (https://www.google.com/maps)
MAG Regional Subarea Characteristics

- Low Emission Zone (LEZ) model implemented on three-city subarea in Maricopa County (Greater Phoenix Metropolitan Area)
  - Total number of zones: 175
  - Number of LEZs: 12 (~7%)
- LEZs designated in areas with heavy retail development
- In order to simulate travel demand, a representative population of individuals and households was generated
- The model system simulates activity-travel patterns for every individual in the representative population
- Tests done on representative population of subarea:
  - Number of households: 84,030
  - Number of persons: 252,999
  - Number of trips: ~1,140,000
Smaller Test Low Emissions Zones

Source: Google Maps (https://www.google.com/maps)
MAG Regional Subarea Transit Characteristics

- Average headway for local bus services in the Greater Phoenix Metropolitan Region ~ 20-40 minutes
- Local bus single ride fare: $2
- Baseline transit ridership in the three city sub-region ~ 50,000 trips/day (4.3% mode share)
- Under the enhanced transit service scenario, transit fares to LEZs is reduced by half and frequency of service is doubled (relative to baseline)

Source: Valley Metro, Phoenix
Low Emissions Zone Modeling Considerations

- The baseline “Eco-Vehicle” penetration in the MAG Greater Phoenix Metro Area is about 2%
- Households may acquire eco-vehicles at accelerated pace in response to policies that incentivize their use
  - This will reduce the amount of overall “non-eco” vehicles in the system
  - Similar to Arizona program to allow single-occupant hybrid vehicles on high-occupancy vehicle (HOV) lanes
- Vehicle fleet composition, including mix and efficiency of vehicle fleet, changes over time
- In addition, non-eco (vehicle) travelers may be induced to shift to transit due to “enhanced service” and reduced fare
Low Emissions Zone Modeling Considerations

- Incentives provided to enhance use of eco-vehicles, especially for travel to zones of high travel demand
- Eco-Travelers can use eco-vehicles or enhanced transit service for travel to the Low Emissions Zones
- Non-eco travelers can choose between driving their non-eco vehicle or using enhanced transit service
- Changes in mode choice (especially for non-eco travelers) and changes in destination choice (for eco-travelers) can impact entire daily activity-travel pattern
### Incremental Scenario Development

<table>
<thead>
<tr>
<th>Scenario Label</th>
<th>Incentive ($)</th>
<th>Transit</th>
<th>Scenario Description</th>
<th>Eco-Vehicle Penetration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>--</td>
<td>Regular</td>
<td>[Image]</td>
<td>2%</td>
</tr>
<tr>
<td>$0.50, RT</td>
<td>0.50 for Eco</td>
<td>Regular</td>
<td>[Image]</td>
<td>3%</td>
</tr>
<tr>
<td>$1.50, RT</td>
<td>1.50 for Eco</td>
<td>Regular</td>
<td>[Image]</td>
<td>5%</td>
</tr>
<tr>
<td>$0.50, ET</td>
<td>0.50 for Eco</td>
<td>Enhanced to LEZs</td>
<td>[Image]</td>
<td>3%</td>
</tr>
<tr>
<td>$1.50, ET</td>
<td>1.50 for Eco</td>
<td>Enhanced to LEZs</td>
<td>[Image]</td>
<td>5%</td>
</tr>
</tbody>
</table>

RT – Regular Transit, ET – Enhanced Transit

Enhanced transit service to LEZs
- Frequency twice as much in the baseline scenario
- Fare reduced to half from the baseline scenario
Impacts of an Incentives-only Approach

- An incentives-only approach may increase travel in the Low Emissions Zones
- Travelers using non-eco vehicles are not affected by incentives; spatial or temporal patterns of travel do not change
- Eco-travelers now have an incentive to travel to low emission zones
  - Net result is an increase in number of trips destined to low emission zones
- Moreover, eco-travelers may travel farther distances to access the low emission zones and reap the benefits of the incentive
  - This will result in greater travel distances
- Energy and emissions reductions are realized through increased ownership and usage of eco-vehicles to access the Low Emissions Zones (i.e., higher, but cleaner, VMT)
Vehicle Mix for Low Emissions Zone Trips (Incentives Only)

**Scenario 1**
- $0.50 Incentive
- 3% Eco-vehicle Penetration

**Scenario 2**
- $1.0 Incentive
- 4% Eco-vehicle Penetration

**Scenario 3**
- $1.50 Incentive
- 5% Eco-vehicle Penetration
Emission Savings from All Trips (Incentives Only)

Change in Emissions from Baseline

- **Scenario 1**
  - $0.50 Incentive
  - 3% Eco-vehicle Penetration

- **Scenario 2**
  - $1.0 Incentive
  - 4% Eco-vehicle Penetration

- **Scenario 3**
  - $1.50 Incentive
  - 5% Eco-vehicle Penetration
Daily Activity Itinerary

Before Changing to Eco Vehicle

Activity Type
- Home Activity
- Work Activity
- Shopping Activity
- Personal Business Activity

Household ID: 49452
Person ID: 1
Household Size: 1
Number of Children: 0
Age: 56
Employment Status: Worker
Gender: Female
Daily Activity Itinerary

After Changing to Eco Vehicle

Household ID: 49452
Person ID: 1
Household Size: 1
Number of Children: 0
Age: 56 year old
Employment Status: Worker
Gender: Female

Activity Type
- Home Activity
- Work Activity
- Shopping Activity
- Personal Business Activity
Vehicle Miles Traveled (VMT) vs CO$_2$ Emissions

Vehicle Miles Traveled (VMT)

<table>
<thead>
<tr>
<th>VMT (000's)</th>
<th>BASELINE</th>
<th>$0.50, RT</th>
<th>$1.50, RT</th>
<th>$0.50, ET</th>
<th>$1.50, ET</th>
</tr>
</thead>
<tbody>
<tr>
<td>BASELINE</td>
<td>7233.6</td>
<td>7241.6</td>
<td>7250.0</td>
<td>7012.8</td>
<td>7066.4</td>
</tr>
</tbody>
</table>

Scenario 1: $0.50, RT
- $0.50 Incentive
- 3% Eco-vehicle Penetration

Scenario 2: $1.50, RT
- $1.50 Incentive
- 5% Eco-vehicle Penetration

Scenario 3: $0.50, ET
- $0.50 Incentive
- 3% Eco-vehicle Penetration
- Enhanced Transit Service to LEZs

Scenario 4: $1.50, ET
- $1.50 Incentive
- 5% Eco-vehicle Penetration
- Enhanced Transit Service to LEZs

Co2 Emissions

<table>
<thead>
<tr>
<th>Co2 Emissions</th>
<th>BASELINE</th>
<th>0.5, RT</th>
<th>1.5, RT</th>
<th>0.5, ET</th>
<th>1.5, ET</th>
</tr>
</thead>
<tbody>
<tr>
<td>BASELINE</td>
<td>2044.8</td>
<td>2014.4</td>
<td>1995.4</td>
<td>1973.1</td>
<td>1958.8</td>
</tr>
<tr>
<td>-1.5%</td>
<td>-2.4%</td>
<td>-3.5%</td>
<td>-4.2%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

U.S. Department of Transportation
ITS Joint Program Office

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Vehicle/Mode Mix for LEZ Trips

Energy and emissions benefits realized in the Low Emissions Zones through change in vehicle mix/mode share.

**Scenario 1: $0.50, RT**
- $0.50 Incentive
- 3% Eco-vehicle Penetration

**Scenario 2: $1.50, RT**
- $1.50 Incentive
- 5% Eco-vehicle Penetration

**Scenario 3: $0.50, ET**
- $0.50 Incentive
- 3% Eco-vehicle Penetration
- Enhanced Transit Service to LEZs

**Scenario 4: $1.50, ET**
- $1.50 Incentive
- 5% Eco-vehicle Penetration
- Enhanced Transit Service to LEZs
Eco-Trips to Low Emissions Zones

Baseline

$0.50, RT

$1.50, RT
Transit Trips to LEZs: No Enhanced Transit

Baseline

Low Emission Zones

Number of Transit Trips
- 0.0 - 60.0
- 60.1 - 1000.0
- 1000.1 - 2000.0
- 2000.1 - 3000.0
- 3000.1 - 4000.0
- 4000.1 - 5000.0

Low Emission Zones

Number of Transit Trips
- 0.0 - 60.0
- 60.1 - 1000.0
- 1000.1 - 2000.0
- 2000.1 - 3000.0
- 3000.1 - 4000.0
- 4000.1 - 5000.0

$0.50, RT

$1.50, RT
Transit Trips to LEZs: Enhanced Transit

- **Low Emission Zones**
- **Baseline**
  - Number of Transit Trips:
    - $0.0 - 60.0$
    - $60.1 - 1000.0$
    - $1000.1 - 2000.0$
    - $2000.1 - 3000.0$
    - $3000.1 - 4000.0$
    - $4000.1 - 5000.0$

- **$0.50, ET**
- **$1.50, ET**
# Reduction in Total Energy Consumption

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Energy (GJoule)</th>
<th>Change (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BASELINE</td>
<td>28457.5</td>
<td></td>
</tr>
<tr>
<td>0.5, RT</td>
<td>28034.8</td>
<td>-1.5%</td>
</tr>
<tr>
<td>1.5, RT</td>
<td>27772.1</td>
<td>-2.4%</td>
</tr>
<tr>
<td>0.5, ET</td>
<td>27460.9</td>
<td>-3.5%</td>
</tr>
<tr>
<td>1.5, ET</td>
<td>27261.0</td>
<td>-4.2%</td>
</tr>
</tbody>
</table>

- **Scenario 1: $0.50, RT**
  - $0.50 Incentive
  - 3% Eco-vehicle Penetration

- **Scenario 2: $1.50, RT**
  - $1.50 Incentive
  - 5% Eco-vehicle Penetration

- **Scenario 3: $0.50, ET**
  - $0.50 Incentive
  - 3% Eco-vehicle Penetration
  - Enhanced Transit Service to LEZs

- **Scenario 4: $1.50, ET**
  - $1.50 Incentive
  - 5% Eco-vehicle Penetration
  - Enhanced Transit Service to LEZs
Reduction in Energy and Emissions from Baseline Scenario

**Scenario 1: $0.50, RT**
- $0.50 Incentive
- 3% Eco-vehicle Penetration

**Scenario 2: $1.50, RT**
- $1.50 Incentive
- 5% Eco-vehicle Penetration

**Scenario 3: $0.50, ET**
- $0.50 Incentive
- 3% Eco-vehicle Penetration
  - Enhanced Transit Service to LEZs

**Scenario 4: $1.50, ET**
- $1.50 Incentive
- 5% Eco-vehicle Penetration
  - Enhanced Transit Service to LEZs
Conclusions

- There is a **3% to 5% energy and emissions savings** at modest levels of eco-vehicle penetration coupled with enhanced transit services.

- Incremental scenario development allows for the flexibility to identify the benefits of a standalone policy vs a combination of policies.

- The Low Emissions Zones modeling framework can be easily extended to any region to study the impacts of restricting/incentivizing specific vehicle types for selected zones.
Lessons Learned

Transit enhancements **amplified** the emission reductions realized through Low Emissions Zones incentives

- Non-eco travelers switch to transit at greater rate than eco-travelers

An effective Low Emissions Zone includes a **combination** of **incentives to eco-vehicles** as well as **enhanced transit services to attract non-eco travelers**

Slight increase in vehicle miles of travel due to introduction of the Low Emissions Zones incentive; more than offset by increased eco-vehicle penetration and use in the region (i.e., higher, but cleaner, VMT)
Work in Progress – Next Steps

- Model runs for the full Greater Phoenix Metropolitan Region
- Impact of offering free transit service to LEZs ($0 fare)
- Time-of-day based incentive policy
  - Impact on activity scheduling and peak period congestion
- Impact of tolls on travel to/from low emissions zones
  - Provides the potential to make Low Emissions Zones revenue-neutral
- Potential benefits could be much higher with additional improvements in future iterations
Research Team

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Booz Allen Hamilton

- Sean Fitzgerel
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For more information on the AERIS Program and access to past webinars, visit: http://www.its.dot.gov/aeris/
Questions/Comments
AERIS CV Pilots Workshop

- **Date and Location:** October 22, 2014 in Washington, D.C.

- **Purpose:** To brainstorm ideas with stakeholders on potential environmental applications that are good candidates for the upcoming Connected Vehicle Pilots Demonstration Program—helping the adopter community identify applications that have the potential to provide fuel use and emissions reductions.

- **Registration:** [www.itisa.org/aerisfall2014workshop](http://www.itisa.org/aerisfall2014workshop)