# The Impacts of Land Use/Land Cover Change on Future Emissions & Air Quality: A Case Study in Austin Texas

Elena McDonald-Buller, Kara Kockelman, Jihee Song, Alba Webb
Brenda Zhou, Shashank Gadda, Barbara Parmenter
& David Allen

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# Background & Motivation

- **Urbanization & land cover/land use change impacts:**
  - Biogenic & anthropogenic emissions
  - Meteorological processes: surface albedo & urban heat island
  - Dry deposition
  - Population exposure to pollutants

- Scenario planning or visioning has become common in metro areas throughout the U.S. **National & even state-level future emissions scenarios prepared for air quality regulatory requirements often do not incorporate community visions of development**.

- **Future air quality forecasts often are not considered during selection of a preferred community vision of development.**

# Objectives: Investigating Visions of Growth

- Examine the **effects of urbanization** on anthropogenic emissions from on-road mobile sources, non-road mobile sources & area sources under **four future regional visions** of development for Austin, Texas.

- Contrast the **relative** air quality **impacts** due to changes in **biogenic emissions & dry deposition**.

- Examine the impacts of alternative development patterns on **population exposure** to ozone.

- Examine the impacts of increased replacement of traditional petroleum-based fuels with **biofuels**.

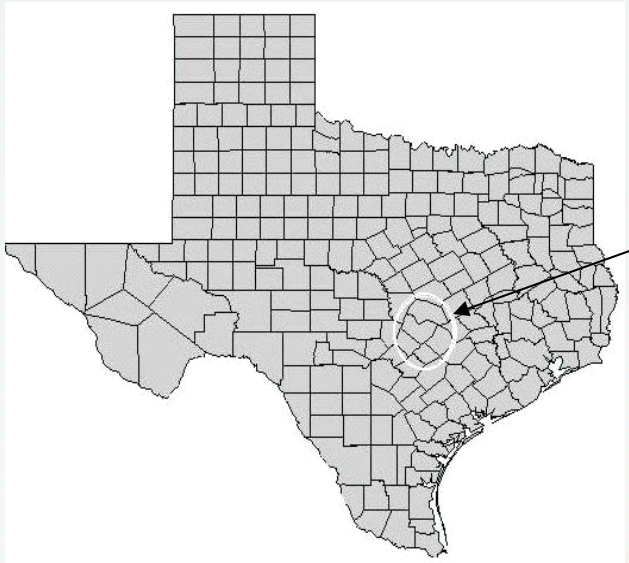
# Objectives: Visioning vs. Modeling

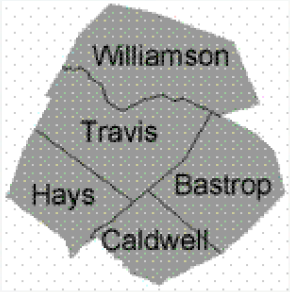
- Develop & apply integrated **transportation & land use models** to investigate predictions of future growth & implications of policies such as congestion pricing & carbon taxes, & urban growth boundaries.
- Two Models:

  (1) Gravity-based land use model + travel demand model

  (2) Model of parcel subdivision + logit for land use type + spatial SUR for land use intensity + travel demand model

# Five-County Austin-Round Rock MSA



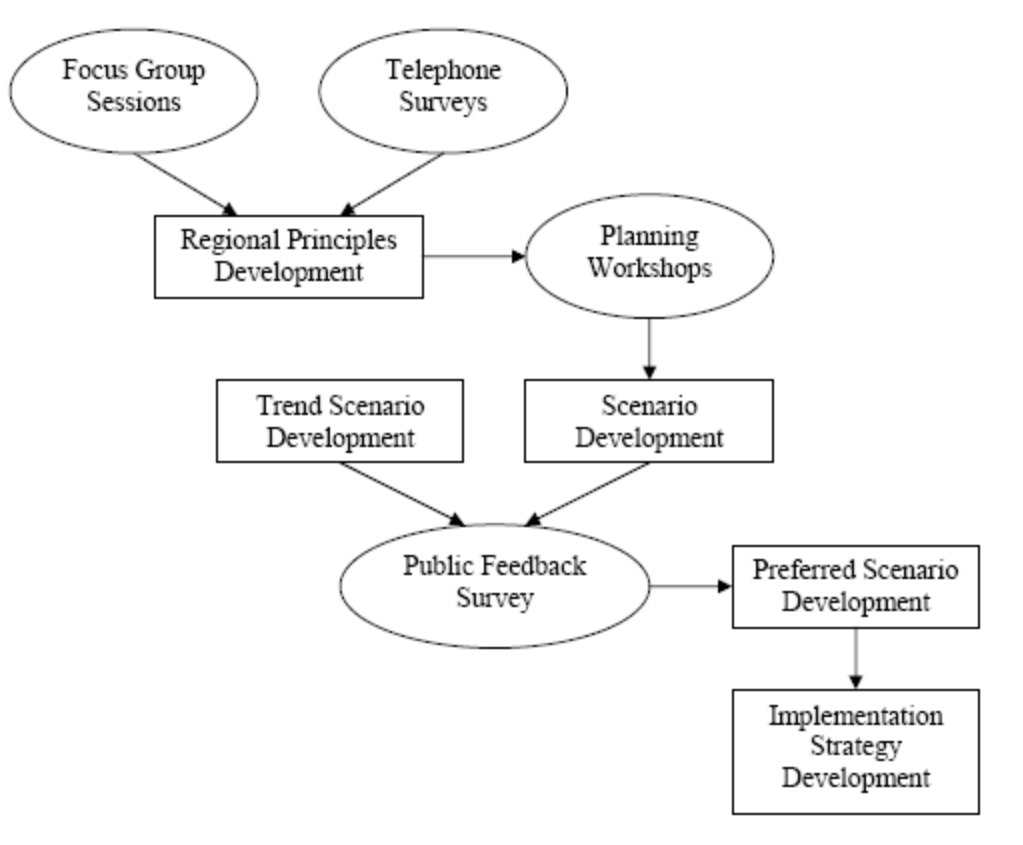



- **1.4 million population**
- **Among the fastest growing regions in the country.**
- **Among first of approximately 30 regions to enter into Early Action Compact with EPA to reduce 8-hour ozone concentrations.**

# Envision Central Texas: Land Development Scenarios

- Community-driven regional visioning initiative began in 2001. Organizers include business, environment, & community development organizations, plus elected leaders from five counties.
- Through public input process, ECT developed **four growth scenarios** (Scenarios A-D) for Austin, assuming a doubling of population for 5-county area within 20 to 40 years.

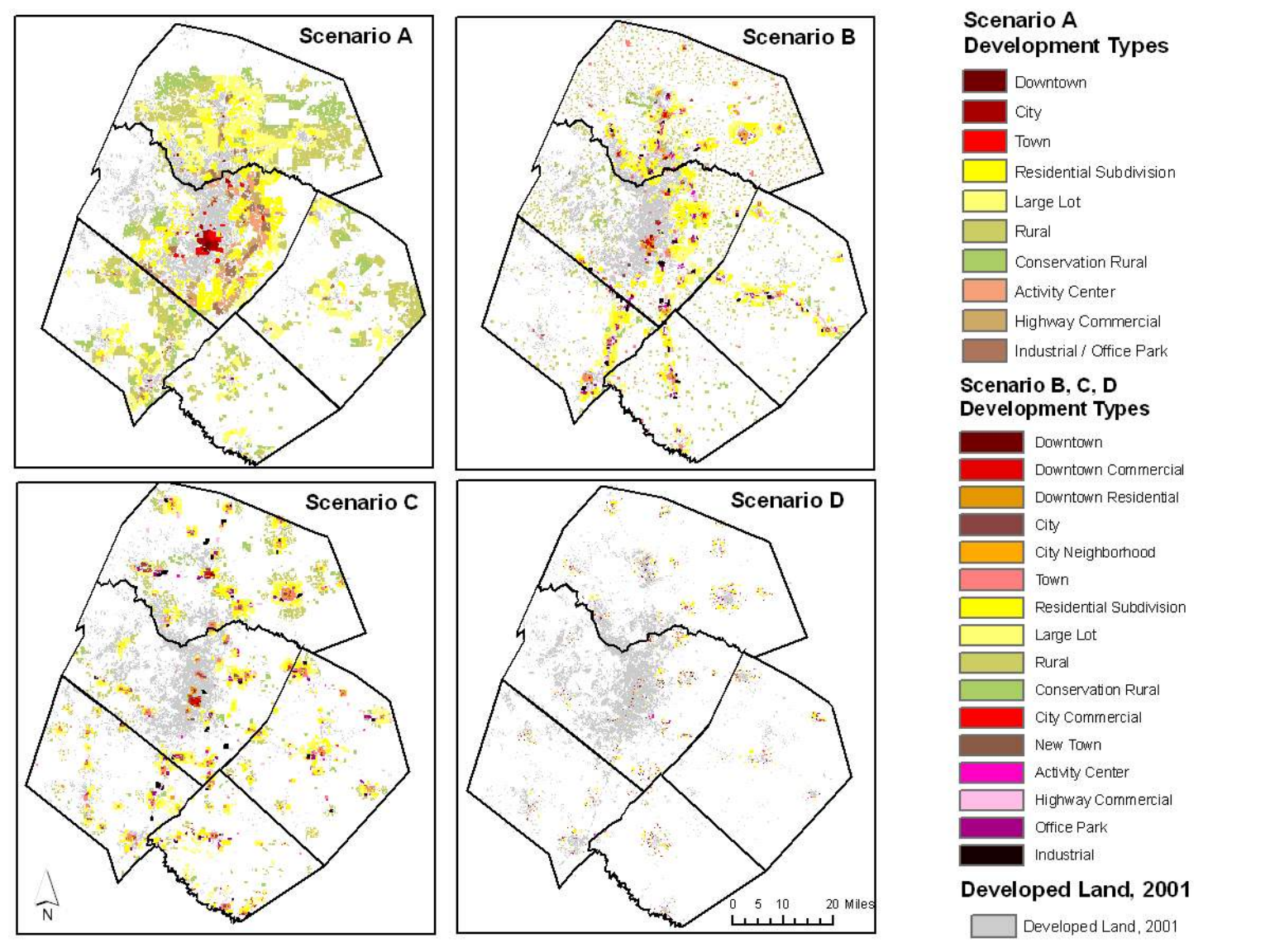
**ECT Visioning Process**




Source: Lemp et al., 2007

**ECT A: Continue current development trends**

**ECT B: Growth along major trans. corridors**

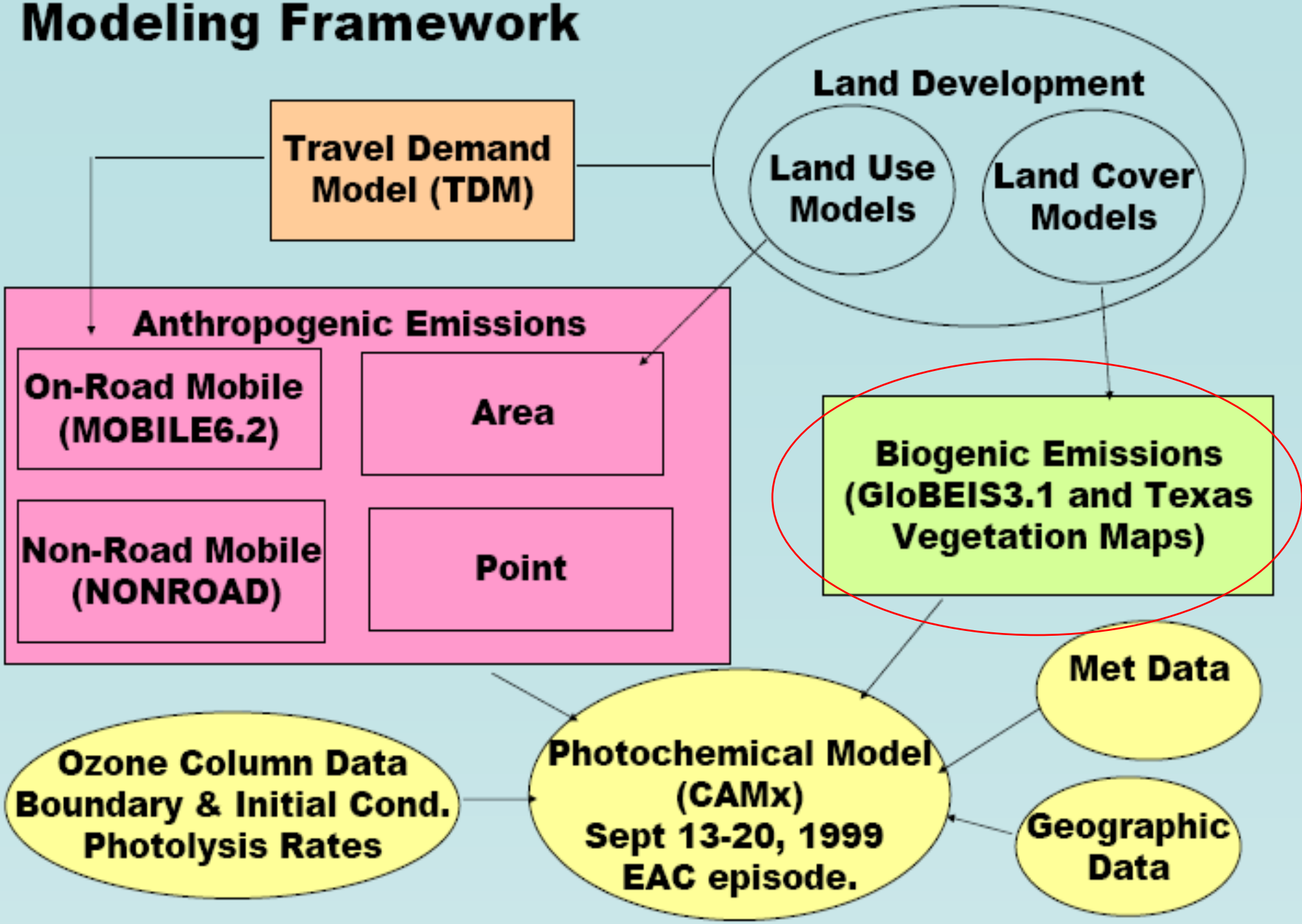



**ECT C: Clustered growth in new & existing comm.**

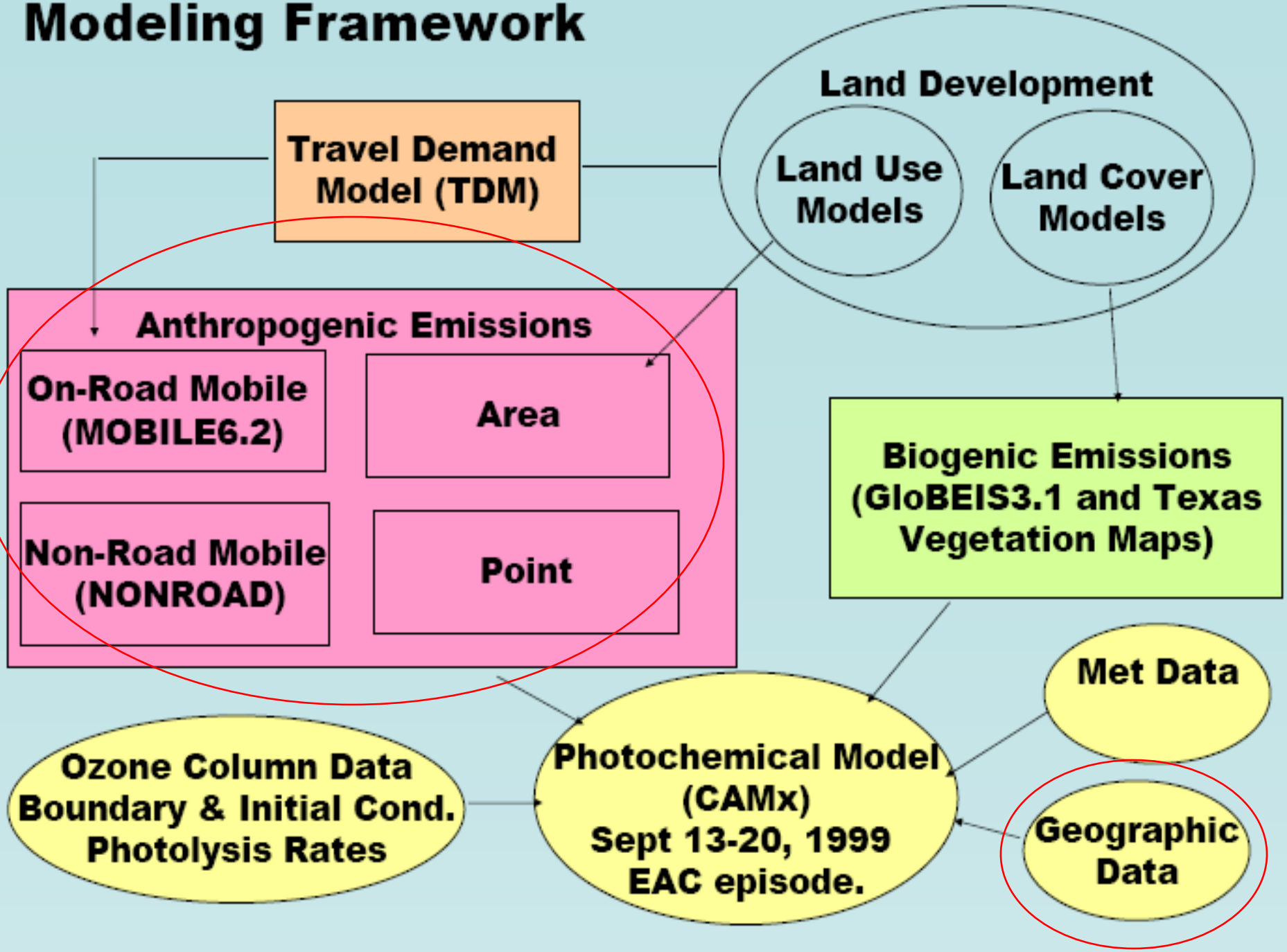
**ECT D: Infill & Redevelopment**

Source: Song et al., in press

# Modeling Framework



# Modeling Framework



# On-Road Mobile Source Emissions

- ECT Transportation Model (ECTTM) developed by Smart Mobility, Inc. with support from CAMPO.
- Link-specific analysis to obtain VMT estimates for each ECT scenario for use with MOBILE6.2:
  - Hourly, day-specific, seasonally adjusted
  - 28 vehicle types used in MOBILE6.2
  - Link functional class (Freeways, Arterials & Ramps)
- Resulting VMT by hour & vehicle type matched to MOBILE6.2 emission factors via speed to obtain emissions of HC, $NO_x$ & CO for each ECT scenario.
- Federal motor vehicle controls included.

# Non-Road & Area Source Emissions

**Non-Road Emissions**

- EPA's NONROAD Model
  - Non-road equipment population follows national growth rate regardless of ECT scenario
  - Spatial allocation factors modified
    - State-to-county level factors adjusted by ECT population & household estimates
    - Spatial surrogates for allocating county to grid cells in modeling domain modified using new, composite LULC dataset (City of Austin, USGS, Capital Area Council of Governments) & ECT development patterns
- Exceptions: aircraft, military, & locomotive operations & gas cans

**Area Emissions**

- Projected by human population

# Summary : Investigating Visions of Growth

- Differences in ozone concentrations for future visions imply that **patterns of urban development** are **not as significant as reductions in emissions per capita**, but effects of urbanization are non-negligible:

  Song et al., The Impacts of Urbanization on Emissions & Air Quality: Comparison of Four Visions of Austin, Texas, in press, *Environmental Science & Technology*, 2008.

- **Concentrated** high-density **development** in existing towns with balanced-use zoning produced **lower values of exposure** to high ozone concentrations than more typical pattern of urban sprawl.

- On-going efforts:
  - Examine increased use of biofuels.
  - Compare to U.S. EPA's post-CAAA emission scenario projections as available.

# Visioning versus Modeling

- Lemp et al., Visioning Vs. Modeling: Analyzing the Land Use-Transportation Futures of Urban Regions, *Journal of Urban Planning and Development*, 2008.

- **Visioning…**
  - Offers extensive community involvement with identification of priorities for growth
  - Contextual changes & scenario feasibility are not necessarily considered nor does scenario planning typically have an integrated approach to land use behavior & travel demand

- **Predictive modeling…**
  - Premised on data & regional trends allowing opportunities to explore policy changes & interaction of land use & transportation systems.
  - Data intensive, requires creation of explanatory variables, & does not create goal or vision.

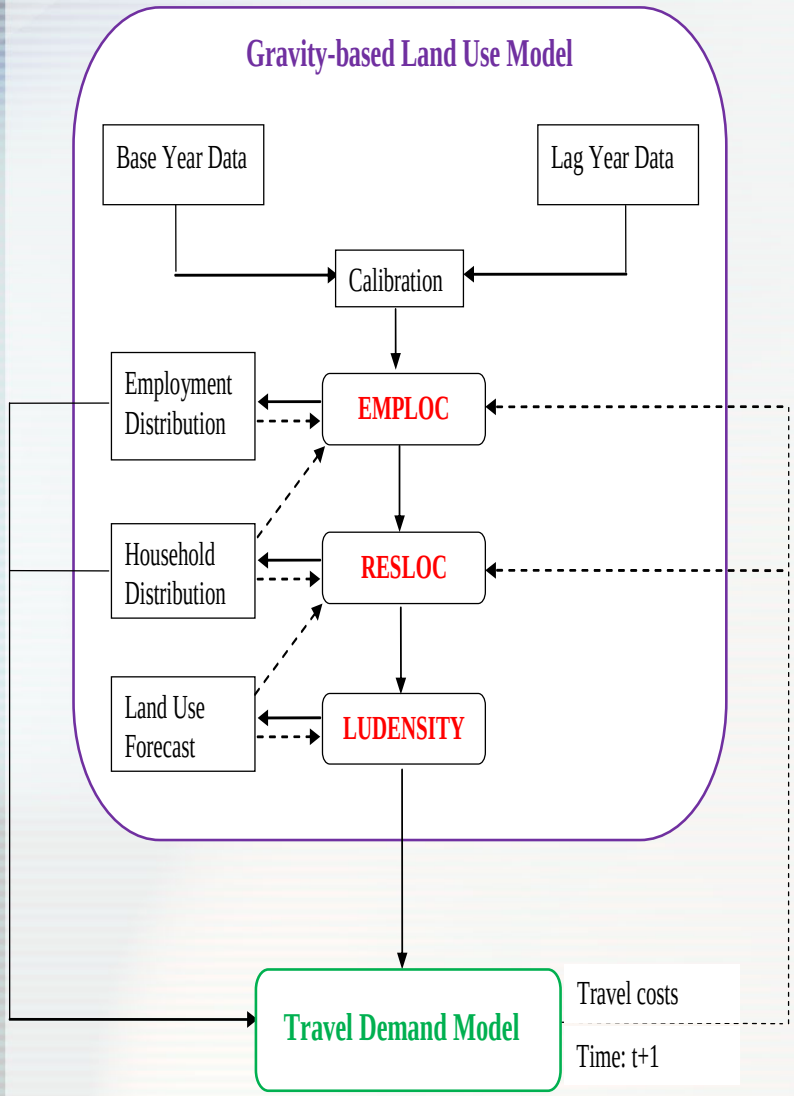
- May be most effective in tandem.

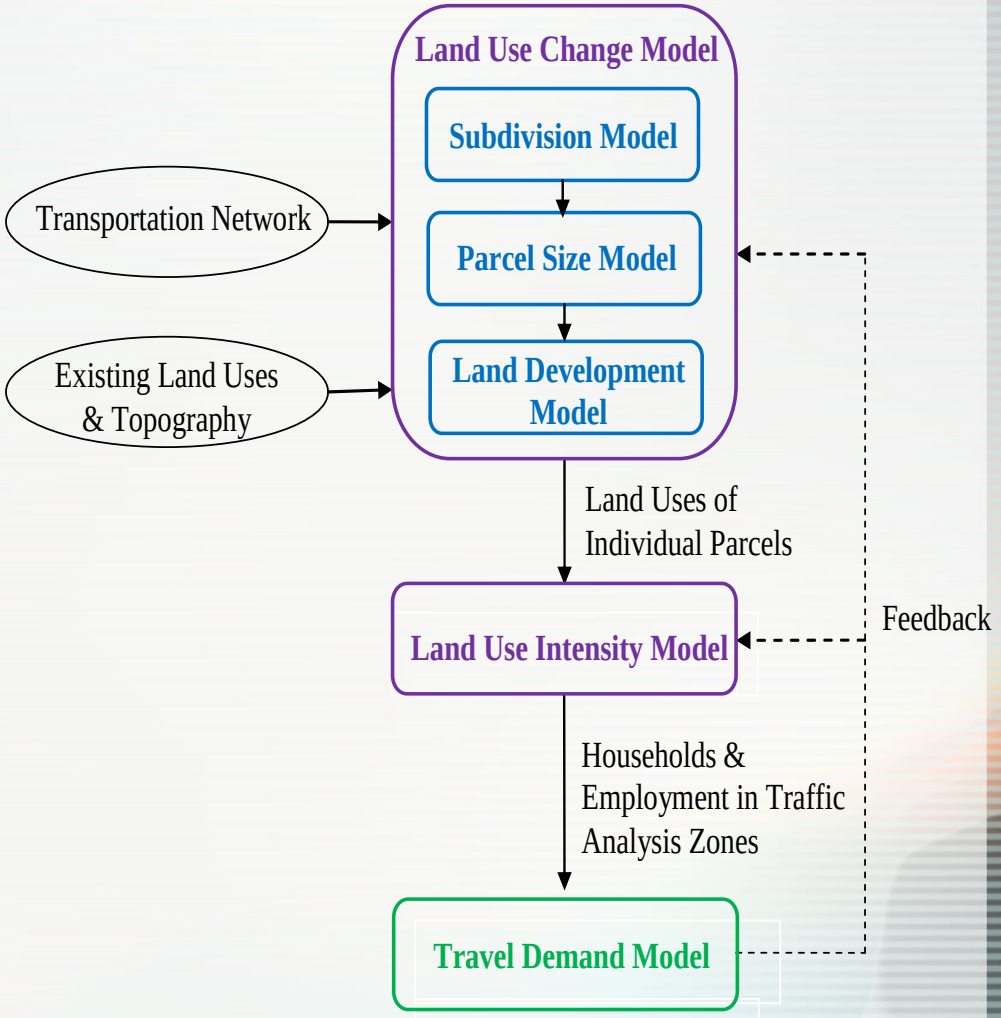
# Transportation & Land Use Analysis Using Integrated Models:

(1) Gravity-based land use model + travel demand model

(2) Model of parcel subdivision + logit for land use type + spatial SUR for land use intensity + travel demand model

# Model Logic


Gravity-based Land Use Model
Base Year Data
Lag Year Data
Calibration
Employment Distribution
EMPLOC
Household Distribution
RESLOC
Land Use Forecast
LUDENSITY
Travel Demand Model
Travel costs
Time: t+1


Land Use Change Model
Subdivision Model
Parcel Size Model
Land Development Model
Transportation Network
Existing Land Uses & Topography
Land Uses of Individual Parcels
Land Use Intensity Model
Feedback
Households & Employment in Traffic Analysis Zones
Travel Demand Model

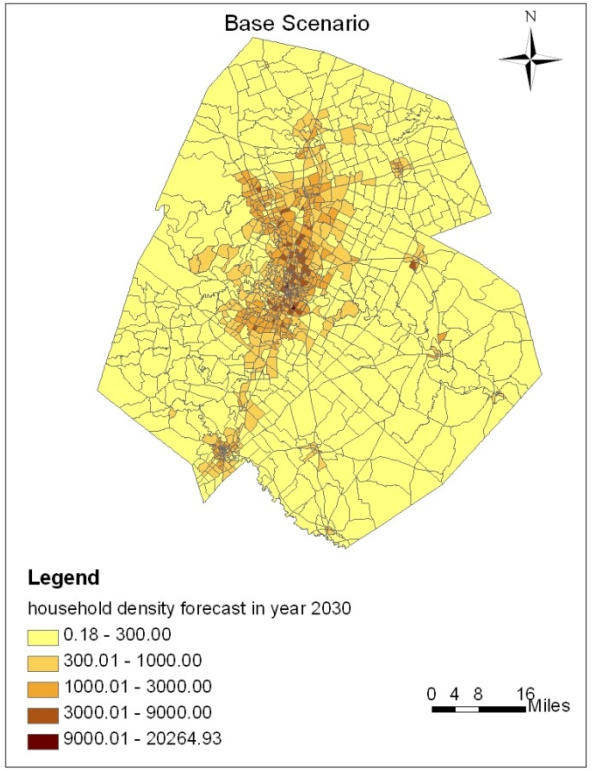
# Austin Application: Gravity-Based LU Model

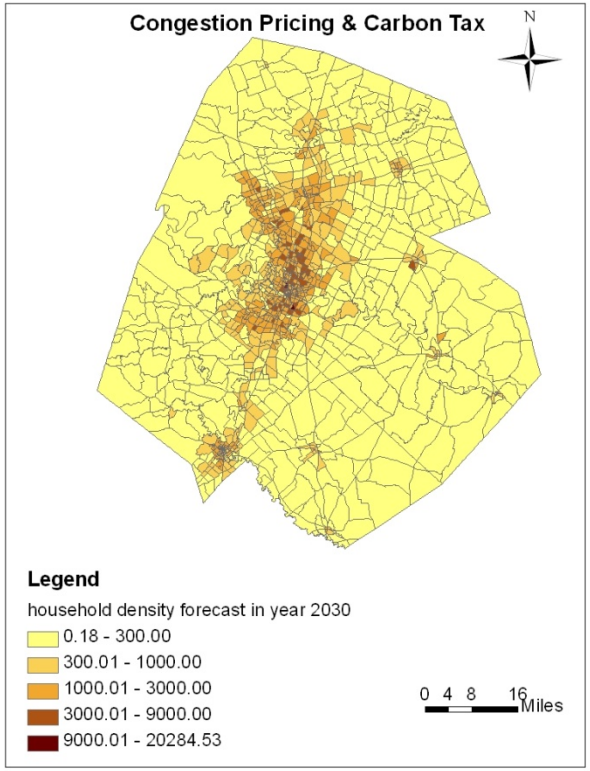
- **Model Restrictions**
  - Maximum jumps household & job counts are limited by each zone's land availability.
  - In any five-year interval, model will not allow > 5% decrease or > 5% increase of household & job counts in fully developed zones.
- Three **Policy Scenarios**
  - Business-as-usual (BAU)
  - Road pricing (congestion toll + per-mile carbon tax)
  - Urban growth boundary
- Coded in MATLAB & freely available on line.
- **See poster** on model implementation.

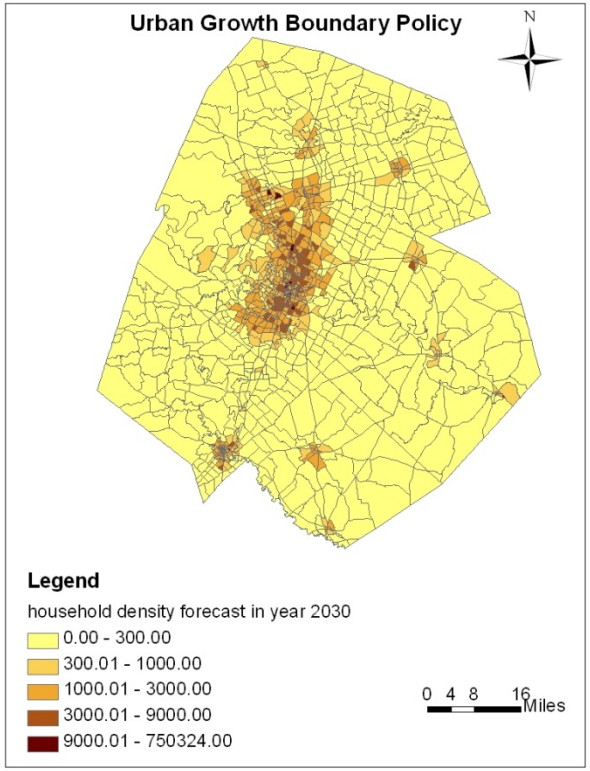
# Austin Application: LUCLUI Model

- **Model Restrictions**
  - Land development model's alternative-specific constants were iteratively adjusted.
  - "Targets" do not naturally embed into the model system. (Forecasted household & job counts were adjusted to match control totals.)
- Two **Policy Scenarios**
  - Business-as-usual (BAU)
  - Road pricing (congestion toll + per-mile carbon tax)
- **See poster** on model implementation.

# Gravity-Based LU Model: 2030 Households Forecasts




BAU: Households remain concentrated in urban areas & along regional freeways

Congestion pricing/carbon tax Similar location choices as BAU but reduced travel

UGB: new development within pre-defined zones

Results for LUCLUI were consistent with gravity-based model's.

# Comparisons Across Policy Scenarios

- **Travel demand model outputs**

| | Model | Business as Usual | Congestion Pricing & Carbon Tax | Urban Growth Boundary |
|---|---|---|---|---|
| Vehicle Miles Traveled ($x10^6$ weekday) | Gravity-Based | 85 | 71 | 70 |
| | LUCLUI | 84 | 71 | - |
| VMT-Weighted Average Speed (miles/hour) | Gravity-Based | 50 | 54 | 51 |
| | LUCLUI | 51 | 54 | - |

- **Spatial distribution of households & jobs**

| | Model | Business as Usual | Congestion Pricing & Carbon Tax | Urban Growth Boundary |
|---|---|---|---|---|
| Household Accessibility Index ($x10^6$) | Gravity-Based | 1.81 | 1.53 | 3.74 |
| | LUCLUI | 2.58 | 2.42 | - |
| Employment Accessibility Index ($x10^7$) | Gravity-Based | 6.29 | 6.32 | 6.93 |
| | LUCLUI | 6.37 | 6.37 | - |

$$\text{Note: Accessibility Index} = \sum_i \frac{Count_i}{DistToCBD_i}$$

# Comparisons Across Policy Scenarios

- **NOx Emissions (tpd)**

| | Model | Business as Usual | Congestion Pricing & Carbon Tax | Urban Growth Boundary |
|---|---|---|---|---|
| On-road mobile | 2007 | 62 | NA | NA |
| | Gravity-Based | 24 | 20 | 20 |
| | LUCLUI | 24 | 20 | - |
| Non-road mobile | 2007 | 22 | NA | NA |
| | Gravity-Based | 9 | 9 | 9 |
| | LUCLUI | 9 | 9 | - |
| Area | 2007 | 10 | NA | NA |
| | Gravity-Based | 22 | 22 | 20 |
| | LUCLUI | 23 | 23 | - |

Magnitude & directionality of emission changes between 2007 Base Case & gravity-based & LUCLUI models were very similar to differences between Base Case & ECT scenarios. Large decreases in mobile sources driven by phase-in of new federal standards. Both road pricing & UGB produce 20% decrease in on-road NOx emissions relative to BAU scenarios.

# Comparisons Across Policy Scenarios

- **VOC Emissions (tpd)**

| | Model | Business as Usual | Congestion Pricing & Carbon Tax | Urban Growth Boundary |
|---|---|---|---|---|
| On-road mobile | 2007 | 34 | NA | NA |
| | Gravity-Based | 23 | 19 | 19 |
| | LUCLUI | 22 | 19 | - |
| Non-road mobile | 2007 | 22 | NA | NA |
| | Gravity-Based | 23 | 23 | 23 |
| | LUCLUI | 23 | 23 | - |
| Area | 2007 | 111 | NA | NA |
| | Gravity-Based | 224 | 226 | 215 |
| | LUCLUI | 254 | 254 | - |
| Biogenic | 2007 | 211 | NA | NA |
| | Gravity-Based | 150 | 151 | 206 |
| | LUCLUI | 201 | 202 | - |

# Summary: Integrated Modeling

Two integrated land use & transportation models…

- **Gravity-based** allocation methods enjoy a simple model structure, moderate data demands, & relatively **straightforward** estimation, but reasonable forecasts emerged only after imposing a variety of rules.

- New & distinctive **land use change/land use intensity model** exploits emerging **parcel-level data &** innovations in **spatial econometric techniques**. But complexity in specification & application, along with data availability across the wider region present challenges. In addition, population & job targets did not naturally embed into the model system, necessitating reliance on external control totals.

# Summary: Integrated Modeling

- **Urban growth boundaries** can have **significant land use & transportation effects**, while road pricing is estimated to have negligible land use impacts. Both offer benefits for on-road mobile emission reductions.

- Magnitude & directionality of future emission changes predicted by integrated modeling are generally very similar to those from the ECT visioning scenarios.

- Air quality modeling & analysis of population exposure metrics are on-going.

# *Thank you!*

## *Questions &/or Suggestions?*

Note: Please see **three posters** on Austin visioning scenario results, implementation of gravity-based & parcel-based models.