1. PECAS Overview
   a. Background
   b. Theoretical Basis
   c. Software Implementation
   d. Data Inputs and Outputs

2. Anatomy of the Model

3. Application in Practice

4. Comparison and Assessment
PECAS Background

- PECAS (the Production, Exchange and Consumption Allocation System) is an urban and regional modeling tool to support transportation and economic planning
- Developed by Dr. Doug Hunt and Dr. John Abraham, University of Calgary
- Contains two principal models:
  - Activity Allocation (AA): an aggregate, equilibrium Spatial Input-Output Model
  - Spatial Development (SD): a disaggregate State-Transition model
- Developed initially as part of an Oregon Department of Transportation (ODOT) Statewide Modeling project as a replacement for a 1st generation statewide model using TRANUS
- Recently, CalTrans implemented a contract with UC Davis to support development of a California Statewide PECAS model, and to support MPOs within the state in the development of metropolitan level PECAS models

Tuesday, May 24, 2011
Application:
Current Applications (from model developers)

- Oregon, USA State-wide
  - part of larger modelling system with micro-simulation components
- Ohio, USA State-wide
  - Model designed and used as basis for data collection
- Sacramento Area, USA
  - Part of larger modelling system with micro-simulation components
- Calgary Region, Canada
  - Design for new urban level modelling system
- Edmonton Region, Canada
  - Design for new urban level modelling system
- Baltimore Metropolitan Area
  - Design for new urban level modelling system
The State of the Practice: Survey of MPOs in 2010

Currently Using

<table>
<thead>
<tr>
<th></th>
<th>Used in last projection series</th>
<th>Used in last RTP update</th>
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<tbody>
<tr>
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<tr>
<td>OPUS/UrbanSim</td>
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<td>4</td>
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<td>DRAM/EMPAL</td>
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<td>3</td>
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<tr>
<td>Home Grown</td>
<td>6</td>
<td>5</td>
</tr>
<tr>
<td>Other</td>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>
Evolution of Land Use Model Frameworks

1960
- Lowry: Gravity Model
- Spatial Interaction
  - DRAM/EMPAL
  - HLIM II+  
- Leontief: Input-Output Model
- Alonso/Mills/Muth: Urban Economic Bid-Rent Theory
- Orcutt: Microsimulation

1970
- Spatial Interaction
  - DRAM/EMPAL
  - HLIM II+  
- Spatial Input-Output
  - MEPLAN; TRANUS
- McFadden: Discrete-Choice Models
- Aggregate Equilibrium
  - Discrete Choice
  - METROSIM; MUSSA
- Aggregate Dynamic
  - Discrete Choice
  - HUDS

1980
1990
2000
- PECAS
- Microsimulation Dynamic
  - Discrete Choice
  - UrbanSim

2010
- Geographic Information Systems
- Spatially Detailed
  - Rule-based Planning Tools
  - Index; I-PLACE3S; WhatIf?
PECAS Overview: Activity Allocation (AA)

- Core of PECAS is a spatial input-output model
- Aggregate model representing monetary flows in the economy between Land Use Zones (LUZ) (usually aggregations of TAZs)
- Monetary flows translated to commodity flows between sectors and LUZs
- Static equilibrium; solves for exchange and consumption prices by LUZ
  - Does so annually whereas older models did so once for the entire time period
- Commodities include labor (provided by households), real estate (residential and commercial floorspace), and other goods and services
PECAS Overview: Spatial Development (SD)

- State transition style model of stochastic change of cells or parcels to alternative land use
- Followed initial version of UrbanSim (1998) parcel and gridcell developer model using this approach (later UrbanSim versions moved to other formulations)
- Unlike AA, SD is disaggregate, at gridcell or parcel level
- Uses pricing (rents) from AA and development costs
**Theoretical Basis: Input-Output Models**

- PECAS’s core (the AA) is a spatial input-output model
- This venerable approach represents an economy as a matrix
  - cells contain values representing the amount of economic activity (production or consumption) for a particular combination of sectors
  - equations represent the interlinkages between portions of the economy and allow changes in one area to be traced through to other areas
  - tracking the activities and flows by geographic location makes the table **spatial**
- Now a brief review of this approach
In order to produce a **total output of $20000**, the retail sector consumes inputs for its production process. Assume the following inputs are purchased to produce the $20000 of retail output, based on the production process for retail:

<table>
<thead>
<tr>
<th>Services</th>
<th>Retail</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basic</td>
<td>$5000</td>
</tr>
<tr>
<td>Retail</td>
<td>$2000</td>
</tr>
<tr>
<td>Services</td>
<td>$3000</td>
</tr>
</tbody>
</table>
Each other industry also requires inputs to produce the total output shown at right.

### Example I-O Expenditure Table for All Local Industries

<table>
<thead>
<tr>
<th></th>
<th>Basic</th>
<th>Retail</th>
<th>Services</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Total Output</strong></td>
<td>$10,000</td>
<td>$15,000</td>
<td>$20,000</td>
</tr>
<tr>
<td><strong>Basic</strong></td>
<td>$1,500</td>
<td>$5,000</td>
<td>$1,000</td>
</tr>
<tr>
<td><strong>Retail</strong></td>
<td>$2,500</td>
<td>$2,500</td>
<td>$5,000</td>
</tr>
<tr>
<td><strong>Services</strong></td>
<td>$3,000</td>
<td>$3,000</td>
<td>$2,000</td>
</tr>
</tbody>
</table>
# Example I-O Direct Input Requirements Matrix

This table shows the standardized inputs per dollar of output for each industry, also known as technical coefficients.

<table>
<thead>
<tr>
<th></th>
<th>Basic</th>
<th>Retail</th>
<th>Services</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basic</td>
<td>0.15</td>
<td>0.33</td>
<td>0.05</td>
</tr>
<tr>
<td>Retail</td>
<td>0.25</td>
<td>0.13</td>
<td>0.25</td>
</tr>
<tr>
<td>Services</td>
<td>0.30</td>
<td>0.20</td>
<td>0.10</td>
</tr>
</tbody>
</table>
## Multiplier Effects

<table>
<thead>
<tr>
<th>Total Output</th>
<th>Basic</th>
<th>Retail</th>
<th>Services</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Output</td>
<td>$10000</td>
<td>$15000</td>
<td>$25000</td>
</tr>
</tbody>
</table>

First Iteration
## Multiplier Effects

<table>
<thead>
<tr>
<th>Total Output</th>
<th>Basic</th>
<th>Retail</th>
<th>Services</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$10000</td>
<td>$15000</td>
<td>$25000</td>
</tr>
</tbody>
</table>

**Induced Consumption**

**First Iteration**
## Multiplier Effects

<table>
<thead>
<tr>
<th>Total Output</th>
<th>Basic</th>
<th>Retail</th>
<th>Services</th>
</tr>
</thead>
<tbody>
<tr>
<td>$10000</td>
<td>$15000</td>
<td>$25000</td>
<td></td>
</tr>
</tbody>
</table>

### Induced Consumption

#### First Iteration

<table>
<thead>
<tr>
<th></th>
<th>Basic</th>
<th>Retail</th>
<th>Services</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basic</td>
<td>$1,500</td>
<td>$5,000</td>
<td>$1,000</td>
</tr>
<tr>
<td>Retail</td>
<td>$2,500</td>
<td>$2,500</td>
<td>$5,000</td>
</tr>
<tr>
<td>Services</td>
<td>$3,000</td>
<td>$3,000</td>
<td>$2,000</td>
</tr>
</tbody>
</table>
# Multiplier Effects

<table>
<thead>
<tr>
<th></th>
<th>Basic</th>
<th>Retail</th>
<th>Services</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Total Output</strong></td>
<td>$10,500</td>
<td>$16,250</td>
<td>$25,250</td>
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</table>

## Induced Consumption

**First Iteration**

<table>
<thead>
<tr>
<th></th>
<th>Basic</th>
<th>Retail</th>
<th>Services</th>
</tr>
</thead>
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<tr>
<td>Retail</td>
<td>$2,500</td>
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<tr>
<td>Services</td>
<td>$3,000</td>
<td>$3,000</td>
<td>$2,000</td>
</tr>
</tbody>
</table>
## Multiplier Effects

<table>
<thead>
<tr>
<th></th>
<th>Basic</th>
<th>Retail</th>
<th>Services</th>
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</thead>
<tbody>
<tr>
<td>Total Output</td>
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<td>$17,344</td>
<td>$26,510</td>
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### Induced Consumption

<table>
<thead>
<tr>
<th>Basic</th>
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<th>Services</th>
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</thead>
<tbody>
<tr>
<td>Basic</td>
<td>$1,695</td>
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<tr>
<td>Retail</td>
<td>$2,826</td>
<td>$2,891</td>
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<tr>
<td>Services</td>
<td>$3,391</td>
<td>$3,469</td>
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</table>

After Convergence
# Economic Flows Can be Split by Region (Spatial I-O)

<table>
<thead>
<tr>
<th>Economic Activities</th>
<th>Region A</th>
<th>Region B</th>
<th>Final Demand and Exports</th>
<th>Total Demand</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Basic</td>
<td>Retail</td>
<td>Basic</td>
<td>Retail</td>
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<tr>
<td>Region A</td>
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<td>Region B</td>
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<tr>
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<tr>
<td>Total Inputs</td>
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</table>
Economic Flows Can be Further Split into Commodities Produced and Consumed (Make and Use Tables)

<table>
<thead>
<tr>
<th>Economic Activities</th>
<th>Region A</th>
<th></th>
<th>Region B</th>
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<th>Total Demand</th>
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</thead>
<tbody>
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<td>Retail</td>
<td>Services</td>
<td>Basic</td>
<td>Retail</td>
<td>Services</td>
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<td>Region A</td>
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<td>Retail</td>
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</table>
**Economic Flows Can be Further Split into Commodities Produced and Consumed (Make and Use Tables)**

Non-Residential Floorspace

<table>
<thead>
<tr>
<th>Economic Activities</th>
<th>Region A</th>
<th>Region B</th>
<th>Final Demand and Exports</th>
<th>Total Demand</th>
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</thead>
<tbody>
<tr>
<td></td>
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<td>Retail</td>
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<tr>
<td>Total Inputs</td>
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</tr>
</tbody>
</table>
PECAS Software Architecture

• Base PECAS system consists of two major Java modules (the AA and the SD) and supporting infrastructure
• Model runs initiated using DOS shell or Python script
• Most data stored and passed between modules in CSV format
  - Scenario inputs and parameters are set by creating CSV files
  - Most model outputs are also in many CSV files
• Parcel information is stored in a database such as SQL Server or PostGIS
• Data preparation requires GIS and statistical software
• Loose integration with travel model through squeezed skims in CSV
• Runs on a multi-processor server
  - Calibration can take days for a single run
  - Multi-decade projections can take hours
Activity Allocation (AA) Module
Inputs and Data Sources (1)

• Aggregate economic flow: IMPLAN
  - Demargined for wholesale and retail

• Synthetic households by TAZ
  - Census PUMS
  - Census SF 3 summary files
  - Automated in Python

• Synthetic employment (by industry and occupation)
  - CTPP
  - InfoUSA
  - Automated in Python

• Technology options
  - Aggregate economic flow; Census PUMS; cluster analysis

Source: Shengyi Gao (et al)
Activity Allocation (AA) Module
Inputs and Data Sources (2)

- Floorspace inventory
  - EIA Space use survey
  - Synthetic employment
  - Existing land use
- Transport costs
  - BTS commodity flow survey
  - Midday skims from the travel model
  - Logsum of mode choice by trip purpose
- Rent
  - DataQuick transactions in 2000 (residential and non-residential)
  - CoStar (non-residential)
- Vacancy rate
  - Census SF 3 summary files
  - CoStar data
- Imports and exports
  - BTS commodity flow survey
  - IMPLAN
  - TradeViewTM, zepol

Source: Shengyi Gao (et al)
Space Development (SD) Module
Inputs and Data Sources (1)

• General land use plan
  - Generalized city/county general land use plans
  - 35 land use types

• Base parcel database
  - Existing land use type
  - Zoning
  - Year built

• Rent modifier
  - Distance to freeways
  - Distance to ramps
  - Distance to highways
  - Distance to beaches
  - Distance to parks
  - Distance to schools
  - Distance to rail roads

Source: Shengyi Gao (et al)
Space Development (SD) Module
Inputs and Data Sources (2)

• Construction cost
  - RSMeans data
• Maintenance cost
• Typical FAR
• Density rent discount
• Demolition costs
• Age discount
  - Multiple sources
• Maximum/minimum intensity
  - Zoning ordinance
• Development fees
  - HCD database

Source: Shengyi Gao (et al)
1. PECAS Overview

2. Anatomy of the System
   a. Model Design
   b. Software Architecture
   c. Estimation, Calibration, and Validation

3. Application in Practice

4. Comparison and Assessment
Economic Interactions

Activity Totals

Activity Locations

Activity Interactions

Transport Demands

Consumptions

Labor and Capital Supply

Land and Floorspace Supply

Environment (externalities)

Price Signals

Occupancies

Social Impacts

Transport Supply

Flows
**PECAS Overview**

- Activity Totals
- Activity Locations
- Activity Interactions
- Transport Demands

Consumptions:

- Labor and Capital Supply

Occupancies:

- Land and Floorspace Supply

Price Signals:

- Social Impacts

Flows:

- Transport Supply

Environment (externalities)
Model Design Diagram

Model Design Diagram Details

Activity Allocation (AA) Module

- Aggregate spatial input-output model
- Represents interaction of activities through commodity flows
  - Food shipping to a processing plant to store
  - Person driving to work
- Travel model provides the yearly description of disutility of movement between locations (congestion) that underly activity interaction
  - e.g. Congestion might move two interdependent industries closer together
  - e.g. A new highway might drive development of new subdivisions
- Connection with SD
  - Activities occupy floorspace build by the SD
  - Spatial choices of activities drive prices that motivate SD developer
Activity Allocation (AA) Module
Activities and Commodities

• Activities
  - Industries: 63 (electricity utilities emphasized)
  - Households: 25, including 5 all seniors household types

• Commodities
  - Goods and services: 60 (including fuel, electricity, GHG permit, agriculture water use, etc.)
  - Labor: 19
  - Space: 38 (14 residential types; 24 non-residential types)

• Zone system
  - Land use zone: 526
  - Floorspace zone (TAZ): 5191

Counts are from California State model application

Source: Shengyi Gao (et al)
Activity Allocation (AA) Module

Decision Tree

Location Choices

Production/Consumption Choices

Exchange Location Choices
Economic Interactions

Production - Exchange – Consumption
Make and use with exchange zones

- Total Consumption
- Exchange Zone
- Buying allocation process
- Commodity flows
- Selling allocation process
- Total Production
Economic Interactions

Production - Exchange – Consumption

1: production allocation

2: technology selection

3: selling allocations
   buying allocations

allocating production activity to zones
allocating production to commodities
allocating consumed commodities to buying locations
allocating produced commodities to selling locations

3-level nested logit model
Activity Allocation (AA) Module
Joint Discrete Utility

Additional utility associated with location $l$ for activity $a$

Additional utility associated with production option $p$

Stochastic error terms

$$U^a_{lpe_1e_2...e_n} = V_l^a + \varepsilon_l^a + V_p + \varepsilon_{lp} + \sum_{n=1}^{N_p} \alpha_{pn} s_{pn} \left( V_{e_nl} + \varepsilon_{e_nlp} \right)$$

Quantity of commodity produced or consumed under production option $p$

Utility of exchanging and shipping one unit of commodity between $l$ and $e$

Source: Atlanta Regional Commission
Space Development (SD) Module

- Disaggregate process at the parcel level
  - Grid cells or parcels
- Represent developers’ actions
- Connection with AA
  - From AA: current year space price at LUZ level
  - To AA: quantity of the spaces for next year AA
- Space is a commodity consumed by the activities in the AA model
  - Unlike other commodities, space cannot be transported
  - Different activities consume different types of space
    - e.g. in Atlanta there are 8 PECAS space types (A/D/S/M/O/R/L/H)
- Rents are space prices
- Zoning rules limit the type of space the can be developed on a parcel

Source: Atlanta Regional Commission
Space Development (SD) Module

Development Events

- Year-by-year step
- Possible development events
  - E0: no change
  - En: new space type and quantity
  - Er: alter or renovate
  - Ed: derelict
- Two step process for each parcel
  - Selection of development events and update space type
  - Update space amount
- Data needs
  - Permits
  - Parcel level data
  - Rents

Source: Atlanta Regional Commission
Space Development (SD) Module

Rents

• Space prices are rents for the use of space
• Per unit of space per unit of time
• Rent equation: $Rent_h = Price_{h,z} \cdot \pi_{g\in G} \cdot LEFac_{g,h}$
  - Space price at LUZ level in AA (done by AA & SD integration)
  - Local-level effects due to:
    • Density of development around the parcel
    • Age of the structure
    • Local Effects: distance from (or proximity to) local-level influences
      • Expressway
      • Interstate exit
      • Major road
      • School
      • Marta
      • Green space

Source: Atlanta Regional Commission
Space Development (SD) Module
Simulation of Transitions

Parcel-by-parcel microsimulation

Source: Atlanta Regional Commission
Space Development (SD) Module
Decision Tree

Development Events

Building Types

Development Quantities
Space Development (SD) Module
Joint Discrete Utility

\[ RU_{hjp} = T_{hjp} j + lTr_{hjp} + l\varepsilon_s + l\varepsilon_q \]

- Rent less amortized construction cost per unit space
- Additional Rent less development costs per unit land
- Space quantity (building size)
- Land quantity (parcel size)
- Stochastic error terms

Source: Atlanta Regional Commission
Space Development (SD) Module
Parcel Level Data and Derived Floorspace

- For each parcel:
  - Area of the parcel
  - Existing space type
  - Existing space quantity (building floorspace)
  - Structure year
  - Zoning rules (allowable uses and density range)
  - Cost and fees (associated with development of each permitted space type and quantity)

- Challenges (20 Counties: every dataset is different)
  - Parcel features and ID
  - Parcel attributes (building floorspace, space type…)
  - Geocoded points for Clayton…
  - Combine parcel with tax assessors’ data
  - Updates

- 20-county parcels are cleaned and loaded
  - About 2 million parcels are cleaned

- Benefit other planning projects

Source: Atlanta Regional Commission
Space Development (SD) Module
Parcel Level Data and Derived Floorspace

20-County parcel features

<table>
<thead>
<tr>
<th>County</th>
<th>Parcels</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barrow</td>
<td>28,184</td>
</tr>
<tr>
<td>Bartow</td>
<td>42,167</td>
</tr>
<tr>
<td>Carroll</td>
<td>50,633</td>
</tr>
<tr>
<td>Cherokee</td>
<td>93,866</td>
</tr>
<tr>
<td>Clayton</td>
<td>88,723</td>
</tr>
<tr>
<td>Cobb</td>
<td>228,690</td>
</tr>
<tr>
<td>Coweta</td>
<td>55,348</td>
</tr>
<tr>
<td>DeKalb</td>
<td>230,888</td>
</tr>
<tr>
<td>Douglas</td>
<td>39,140</td>
</tr>
<tr>
<td>Fayette</td>
<td>42,808</td>
</tr>
<tr>
<td>Forsyth</td>
<td>77,639</td>
</tr>
<tr>
<td>Fulton</td>
<td>341,017</td>
</tr>
<tr>
<td>Gwinnett</td>
<td>260,371</td>
</tr>
<tr>
<td>Hall</td>
<td>77,103</td>
</tr>
<tr>
<td>Henry</td>
<td>72,839</td>
</tr>
<tr>
<td>Newton</td>
<td>44,374</td>
</tr>
<tr>
<td>Paulding</td>
<td>59,670</td>
</tr>
<tr>
<td>Rockdale</td>
<td>34,780</td>
</tr>
<tr>
<td>Spalding</td>
<td>29,616</td>
</tr>
<tr>
<td>Walton</td>
<td>36,561</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>1,934,417</strong></td>
</tr>
</tbody>
</table>

Source: Atlanta Regional Commission
Space Development (SD) Module
Parcel Level Data and Derived Floorspace

• Why do we need the derived space?
  - The quality of the parcel space data: very inconsistent
  - The (in) consistency between employment and space
  - Mixed use issues
• Derived using NAICS employment and Landpro
• New space totals at LUZ and disaggregate to TAZ
• Then, evaluation…
Space Development (SD) Module
Parcel Level Data and Derived Floorspace

- FloorSpace Synthesizer Tool
- Based on existing space type, quantity and zoning...
- Calibration

Source: Atlanta Regional Commission
Space Development (SD) Module
Parcel Level Data and Derived Floorspace

- Calibration tasks:
  - Evolution of initial synthesized results
  - Directing synthesized development to actual built-on parcels
  - Directing the correct space type to the parcel
  - Directing the synthesized built space to developed parcel in amount resembling actual quantities

Source: Atlanta Regional Commission
Space Development (SD) Module
Parcel Level Data and Derived Floorspace

Synthesized Results

Source: Atlanta Regional Commission
Full PECAS System Through Time
Integrating PECAS and Travel Model
PECAS 3-Stage Calibration Approach

• **Stage 1** - the S1 parameters
  - Consider each module separately
  - Based on specific, separate dataset
  - Often ‘disaggregate data’
  - Often statistical estimation
  - Fixed for remainder of calibration

• **Stage 2** - the S2 parameters
  - Consider each module separately
  - Based on module hitting targets
  - Often ‘aggregate data’
  - Some also S3 parameters
  - Specialized software developed

• **Stage 3** - the S3 parameters
  - Consider all modules linked together
  - Based on module hitting targets
  - ‘Aggregate data’
  - Certain S2 parameters also S3 parameters, process updates these in response to total model behaviour
  - Specialized software developed
Calibration Targets

**AA Calibration Targets**

- Buying and selling choice
  - Distance to buy or sell
  - CFS survey
- Technology choice
  - Synthetic population
  - PUMS
  - Cluster analysis
- Location choice
  - Synthetic population
  - Synthetic employment

**SD Calibration Targets**

- Transition constant
  - Building permit
  - Parcel data at two time points
- Dispersion parameter
  - Existing land use

Source: Shengyi Gao (et al)
3. Application in Practice
Sacramento Blueprint Study

DEVELOPMENT
Base Case Scenario for 2050
Sacramento Blueprint Study
FIGURE 2 Household and employment location in the PRB scenario

source: Equity Analysis of Land Use and Transport Plans Using an Integrated Spatial Model. Rodier, Abraham, Dix, and Hunt. UCD-ITS-RR09-46
SACOG Equity Analysis

FIGURE 1 Household and employment location in the BAU scenario

source: Equity Analysis of Land Use and Transport Plans Using an Integrated Spatial Model. Rodier, Abraham, Dix, and Hunt. UCD-ITS-RR09-46
SACOG Equity Analysis

FIGURE 3 Percent Change in Dwelling Units by Type Between the BAU and the PRB

SDF=single family dwelling units; MFD=multi family dwelling units

source: Equity Analysis of Land Use and Transport Plans Using an Integrated Spatial Model. Rodier, Abraham, Dix, and Hunt. UCD-ITS-RR09-46
SACOG Equity Analysis

source: Equity Analysis of Land Use and Transport Plans Using an Integrated Spatial Model. Rodier, Abraham, Dix, and Hunt. UCD-ITS-RR09-46
### TABLE 1 Average Annual Transport Cost (TC) by and across Labor Group(s) (2000 U.S. nominal dollars)

<table>
<thead>
<tr>
<th>Labor Group</th>
<th>Change in TC (dollars)</th>
<th>Percentage Change in TC</th>
<th>BAU: TC as Income Share</th>
<th>PRB: TC as Income Share</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agriculture</td>
<td>-326</td>
<td>-11.8</td>
<td>6.0</td>
<td>5.2</td>
</tr>
<tr>
<td>Construction</td>
<td>-303</td>
<td>-11.1</td>
<td>5.8</td>
<td>5.2</td>
</tr>
<tr>
<td>Educators</td>
<td>-170</td>
<td>-6.6</td>
<td>5.8</td>
<td>5.6</td>
</tr>
<tr>
<td>Entertainers</td>
<td>-372</td>
<td>-14.2</td>
<td>5.7</td>
<td>5.0</td>
</tr>
<tr>
<td>Food</td>
<td>-250</td>
<td>-9.9</td>
<td>5.5</td>
<td>5.0</td>
</tr>
<tr>
<td>Health</td>
<td>-306</td>
<td>-11.9</td>
<td>5.3</td>
<td>4.8</td>
</tr>
<tr>
<td>Maintenance &amp; repair</td>
<td>-300</td>
<td>-11.1</td>
<td>5.9</td>
<td>5.3</td>
</tr>
<tr>
<td>Managers</td>
<td>-339</td>
<td>-13.0</td>
<td>5.5</td>
<td>4.8</td>
</tr>
<tr>
<td>Non-retail sales</td>
<td>-426</td>
<td>-15.9</td>
<td>5.7</td>
<td>4.9</td>
</tr>
<tr>
<td>Office &amp; administrative</td>
<td>-323</td>
<td>-12.7</td>
<td>5.4</td>
<td>4.8</td>
</tr>
<tr>
<td>Production</td>
<td>-293</td>
<td>-10.9</td>
<td>5.9</td>
<td>5.3</td>
</tr>
<tr>
<td>Professionals</td>
<td>-351</td>
<td>-13.4</td>
<td>5.4</td>
<td>4.8</td>
</tr>
<tr>
<td>Retail sales</td>
<td>-256</td>
<td>-9.9</td>
<td>5.5</td>
<td>5.0</td>
</tr>
<tr>
<td>Service</td>
<td>-306</td>
<td>-12.0</td>
<td>5.4</td>
<td>4.9</td>
</tr>
<tr>
<td>Transport</td>
<td>-281</td>
<td>-10.6</td>
<td>5.9</td>
<td>5.4</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>-307</strong></td>
<td><strong>-11.8</strong></td>
<td><strong>5.5</strong></td>
<td><strong>5.0</strong></td>
</tr>
</tbody>
</table>
Average annual rents also decline in the region in the PRB scenario relative to the BAU (see Table 2). As described above, the total distribution of housing units by type in the PRB scenario represents a 10.9% increase in the number of multi-family units and 6.3% reduction in luxury single family dwelling units. Because of the greater supply of multi-family housing units, which are typically less expensive, average annual rents, for all but the highest income classes, are reduced in the PRB scenario. On average, rents are reduced by $1,526, which is a 6.1% reduction.

The three lowest household income classes experience reductions in annual rent ranging from $1,248 to $1,702 (percentage reductions from 6.4% to 8%). Note that according to federal government standards, the lowest household income class (less than $10,000 a year) is considered to be extremely low income (or approximately 30% of the Sacramento area median income or AMI), $10,000 to $19,000 is very low income (or approximately 50% of AMI), and $20,000 to $39,000 is low income (or approximately 80% of AMI). The middle income classes ($20,000 to $99,000) see the greatest total reduction in rent. The highest income class ($200,000 and above) experiences an increase in rent ($505), which is a 1.0% increase. The second highest income class experiences the lowest reduction in rent ($309 and 0.7%).

In sum, it appears that the preference among the highest income households for larger homes and lots, the relatively diminished supply, and higher transport costs in the outer suburban areas where such homes are typically located have driven up average rents for the highest income class and mitigated declines relative to the regional mean. It also appears that the low and middle income household categories have benefited from the significantly increased supply of multi-family housing and lower transport costs in the areas in which they are located (i.e., the inner suburbs and central business areas). Upper income households are also more likely to be owner-occupied, and thus receive less benefit from reductions in rent than do lower income households.

Note that this sort of reduction in rents will not necessarily lead to an increase in consumer surplus in AA, since AA also represents the greater preference for single family dwelling units.

The PRB scenario reduces opportunities for housing, which reduces consumer surplus, but also reduces rents for housing, which increases consumer surplus. AA represents both of these and weighs them against each other.

### TABLE 2 Change in Average Annual Rent by and across Household Class(es) (2000 U.S. nominal dollars)

<table>
<thead>
<tr>
<th>Income Class ($1,000)</th>
<th>Total Change (dollars)</th>
<th>Percentage change</th>
</tr>
</thead>
<tbody>
<tr>
<td>less than 10</td>
<td>-1,248</td>
<td>-6.4</td>
</tr>
<tr>
<td>10 to 19</td>
<td>-1,299</td>
<td>-6.0</td>
</tr>
<tr>
<td>20 to 39</td>
<td>-1,702</td>
<td>-8.0</td>
</tr>
<tr>
<td>40 to 49</td>
<td>-1,833</td>
<td>-7.9</td>
</tr>
<tr>
<td>50 to 99</td>
<td>-1,933</td>
<td>-6.7</td>
</tr>
<tr>
<td>100 to 199</td>
<td>-309</td>
<td>-0.7</td>
</tr>
<tr>
<td>200+</td>
<td>505</td>
<td>1.0</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>-1,526</strong></td>
<td><strong>-6.1</strong></td>
</tr>
</tbody>
</table>

source: Equity Analysis of Land Use and Transport Plans Using an Integrated Spatial Model. Rodier, Abraham, Dix, and Hunt. UCD-ITS-RR09-46
## SACOG Equity Analysis

**Table 3: Total Annual Value of Owned Homes (2000 U.S. nominal dollars)**

<table>
<thead>
<tr>
<th>Household Income ($1,000)</th>
<th>BAU ($100,000)</th>
<th>PRB ($100,000)</th>
<th>Percentage Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>less than 10</td>
<td>7,840</td>
<td>7,788</td>
<td>-0.7</td>
</tr>
<tr>
<td>10 to 19</td>
<td>13,384</td>
<td>13,201</td>
<td>-1.4</td>
</tr>
<tr>
<td>20 to 39</td>
<td>38,520</td>
<td>37,578</td>
<td>-2.4</td>
</tr>
<tr>
<td>40 to 49</td>
<td>20,868</td>
<td>20,258</td>
<td>-2.9</td>
</tr>
<tr>
<td>50 to 99</td>
<td>124,620</td>
<td>121,462</td>
<td>-2.5</td>
</tr>
<tr>
<td>100 to 199</td>
<td>78,739</td>
<td>78,122</td>
<td>-0.8</td>
</tr>
<tr>
<td>200 or more</td>
<td>15,298</td>
<td>15,415</td>
<td>0.8</td>
</tr>
<tr>
<td>Total</td>
<td>299,268</td>
<td>293,823</td>
<td>-1.8</td>
</tr>
</tbody>
</table>

The results suggest that lower transport and housing costs in the PRB scenario have driven down the region's cost of living, and thus average annual wages (see Table 4). Average wage income is reduced by $783 (a percentage reduction of 1.6%). By labor occupation category, average reduction ranges from a low of $50 to a high of approximately $1,000 (percentage reductions of 0.1% to 2.0%, respectively). Agricultural and construction workers, typically lower income jobs, experience some of the lowest reductions and professional, sales, and administrative labor groups, typically higher income, experience some of the highest reductions.

**Table 4: Change in Average Annual Wage Income by and across Labor Group(s) (2000 U.S. nominal dollars)**

<table>
<thead>
<tr>
<th>Labor Group</th>
<th>Total Change (dollars)</th>
<th>Percentage Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agriculture</td>
<td>-50</td>
<td>-0.1</td>
</tr>
<tr>
<td>Construction</td>
<td>-282</td>
<td>-0.6</td>
</tr>
<tr>
<td>Educators</td>
<td>-802</td>
<td>-1.8</td>
</tr>
<tr>
<td>Entertainers</td>
<td>-925</td>
<td>-1.9</td>
</tr>
<tr>
<td>Food workers</td>
<td>-752</td>
<td>-1.6</td>
</tr>
<tr>
<td>Health workers</td>
<td>-847</td>
<td>-1.7</td>
</tr>
<tr>
<td>Maintenance &amp; repair</td>
<td>-731</td>
<td>-1.6</td>
</tr>
<tr>
<td>Managers</td>
<td>-922</td>
<td>-1.9</td>
</tr>
<tr>
<td>Non-retail sales</td>
<td>-951</td>
<td>-2.0</td>
</tr>
<tr>
<td>Office &amp; administrative</td>
<td>-892</td>
<td>-1.9</td>
</tr>
<tr>
<td>Production</td>
<td>-670</td>
<td>-1.4</td>
</tr>
<tr>
<td>Professionals</td>
<td>-980</td>
<td>-2.0</td>
</tr>
<tr>
<td>Retail sales</td>
<td>-759</td>
<td>-1.6</td>
</tr>
<tr>
<td>Service</td>
<td>-749</td>
<td>-1.5</td>
</tr>
<tr>
<td>Transport</td>
<td>-719</td>
<td>-1.6</td>
</tr>
<tr>
<td>Total</td>
<td>-783</td>
<td>-1.6</td>
</tr>
</tbody>
</table>

Source: Equity Analysis of Land Use and Transport Plans Using an Integrated Spatial Model. Rodier, Abraham, Dix, and Hunt. UCD-ITS-RR09-46
### SACOG Equity Analysis

#### TABLE 5 Total and Average Consumer or Producer Surplus for PRB Scenario Relative to the BAU Scenario (2000 U.S. nominal dollars)

<table>
<thead>
<tr>
<th>Industry Activities</th>
<th>Total ($100,000)</th>
<th>Average (per million dollars of production)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agriculture</td>
<td>254</td>
<td>13,819</td>
</tr>
<tr>
<td>Construction</td>
<td>944</td>
<td>8,783</td>
</tr>
<tr>
<td>Manufacturing</td>
<td>962</td>
<td>5,588</td>
</tr>
<tr>
<td>Transport</td>
<td>249</td>
<td>12,336</td>
</tr>
<tr>
<td>Communication</td>
<td>483</td>
<td>9,630</td>
</tr>
<tr>
<td>Wholesale trade</td>
<td>996</td>
<td>8,532</td>
</tr>
<tr>
<td>Retail</td>
<td>5,354</td>
<td>20,345</td>
</tr>
<tr>
<td>Restaurants</td>
<td>2,281</td>
<td>51,192</td>
</tr>
<tr>
<td>Financial</td>
<td>1,961</td>
<td>18,934</td>
</tr>
<tr>
<td>Real estate</td>
<td>1,330</td>
<td>6,804</td>
</tr>
<tr>
<td>Business services</td>
<td>1,200</td>
<td>15,477</td>
</tr>
<tr>
<td>Automotive services</td>
<td>308</td>
<td>13,994</td>
</tr>
<tr>
<td>Amusement services</td>
<td>197</td>
<td>46,647</td>
</tr>
<tr>
<td>Education</td>
<td>717</td>
<td>36,163</td>
</tr>
<tr>
<td>Personal services</td>
<td>697</td>
<td>35,366</td>
</tr>
<tr>
<td>Non-profit organizations</td>
<td>565</td>
<td>48,809</td>
</tr>
<tr>
<td>Professional services</td>
<td>1,213</td>
<td>17,099</td>
</tr>
<tr>
<td>Government</td>
<td>2,916</td>
<td>15,501</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>22,626</strong></td>
<td><strong>15,028</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Household Income Class ($1,000)</th>
<th>Total ($100,000)</th>
<th>Average per Household</th>
</tr>
</thead>
<tbody>
<tr>
<td>less than 10</td>
<td>731</td>
<td>1,008</td>
</tr>
<tr>
<td>10 to 19</td>
<td>1,226</td>
<td>1,074</td>
</tr>
<tr>
<td>20 to 39</td>
<td>1,617</td>
<td>647</td>
</tr>
<tr>
<td>40 to 49</td>
<td>254</td>
<td>229</td>
</tr>
<tr>
<td>50 to 99</td>
<td>-1,966</td>
<td>-442</td>
</tr>
<tr>
<td>100 to 199</td>
<td>-1,384</td>
<td>-668</td>
</tr>
<tr>
<td>200+</td>
<td>-151</td>
<td>-454</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>327</strong></td>
<td><strong>27</strong></td>
</tr>
</tbody>
</table>

Source: Equity Analysis of Land Use and Transport Plans Using an Integrated Spatial Model. Rodier, Abraham, Dix, and Hunt. UCD-ITS-RR09-46
### TABLE 6 Total and Change in Annual Values of Space Categories (2000 U.S. nominal dollars)

<table>
<thead>
<tr>
<th>Industry Space</th>
<th>BAU Total ($100,000)</th>
<th>PRB Total ($100,000)</th>
<th>Total Change ($100,000)</th>
<th>Average Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agriculture &amp; Mining</td>
<td>43</td>
<td>48</td>
<td>5</td>
<td>0.3</td>
</tr>
<tr>
<td>Industrial</td>
<td>3,424</td>
<td>3,504</td>
<td>79</td>
<td>0.1</td>
</tr>
<tr>
<td>Office</td>
<td>22,561</td>
<td>22,729</td>
<td>169</td>
<td>0.1</td>
</tr>
<tr>
<td>Retail</td>
<td>24,205</td>
<td>24,240</td>
<td>35</td>
<td>0.0</td>
</tr>
<tr>
<td>Medical</td>
<td>26,152</td>
<td>26,200</td>
<td>48</td>
<td>0.1</td>
</tr>
<tr>
<td>Primary School</td>
<td>7,434</td>
<td>7,436</td>
<td>1</td>
<td>0.0</td>
</tr>
<tr>
<td>Colleges &amp; Education</td>
<td>2,653</td>
<td>2,655</td>
<td>1</td>
<td>0.0</td>
</tr>
<tr>
<td>Government Office</td>
<td>31,015</td>
<td>31,002</td>
<td>-13</td>
<td>0.0</td>
</tr>
<tr>
<td>Total</td>
<td><strong>117,488</strong></td>
<td><strong>117,813</strong></td>
<td><strong>325</strong></td>
<td>0.0</td>
</tr>
</tbody>
</table>

### Residential Space

<table>
<thead>
<tr>
<th>Residential Space</th>
<th>BAU Total ($100,000)</th>
<th>PRB Total ($100,000)</th>
<th>Total Change ($100,000)</th>
<th>Average Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Luxury SFD</td>
<td>195,707</td>
<td>185,408</td>
<td>-10,299</td>
<td>549.0</td>
</tr>
<tr>
<td>Standard SFD</td>
<td>153,245</td>
<td>152,531</td>
<td>-714</td>
<td>-243.0</td>
</tr>
<tr>
<td>Owned MFD</td>
<td>8,976</td>
<td>9,322</td>
<td>345</td>
<td>-1017.0</td>
</tr>
<tr>
<td>Rented MFD</td>
<td>26,510</td>
<td>27,069</td>
<td>559</td>
<td>-1537.0</td>
</tr>
<tr>
<td>Total</td>
<td><strong>384,438</strong></td>
<td><strong>374,330</strong></td>
<td><strong>-10,108</strong></td>
<td><strong>-820.0</strong></td>
</tr>
</tbody>
</table>

SFD=single-family development; MFD=multi-family development

source: Equity Analysis of Land Use and Transport Plans Using an Integrated Spatial Model. Rodier, Abraham, Dix, and Hunt. UCD-ITS-RR09-46
CalSIM

- California Statewide Integrated Model
- Integrated PECAS land use model and new statewide activity-based transportation model
- Spurred by California SB375: land use related reductions from autos and light trucks
- Funded by CalTrans in conjunction with metropolitan-level upgrades
- Massive data collection and imputation effort
- Timeline
  - Transportation model built and calibrated during 2010
  - Land use model calibration ongoing
  - Metropolitan models ready by 2015
- Preliminary results
Synthesized PECAS Intensity

Trip length calibration

Constrained 0 iteration model (supply/demand not matched)

Current labor flow distances

SD Calibration

- Develop Target space quantity transitions
- 10 counties selected to represent low med and high growth situations, plus San Francisco as a special county
  - Low: Sacramento, San Diego, Orange County
  - Med: Amador, Inyo, Shasta
  - High: Fresno, Imperial, Placer
  - San Francisco
CalSIM

CalSIM

Base Scenario Floorspace Change From 2000 to 2020
Commercial Low FRE

Legend
- roads
- 85,000,000
- 200,000,000
- 700,000,000

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Base Scenario Floorspace Change From 2000 to 2020
Residential Medium Separated Entrance LAX ORA SDG

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1. PECAS overview
2. Anatomy of the System
3. Application in Practice
4. Assessment
Strengths of Input-Output Models

• I-O Models provide a concise summary of the economic flows in the economy

• Multipliers from I-O models are used widely to predict the impact of changes in output of a sector on the broader economy - the multiplier effect

• With suitable data, national I-O models can be localized to states or possibly lower units of geography
  
  - Keep in mind the model represents economic flows between every geographic unit and every sector, as in an international trade model - so the data requirements to generate a highly disaggregate I-O model are immense
Limitations of Input-Output Models

• Wikipedia’s article on Input-Output models provides the following assessment:
  - “Input-output is conceptually simple. Its extension to a model of equilibrium in the national economy is also relatively simple and attractive but requires great skill and high-quality data. One who wishes to do work with input-output systems must deal skillfully with industry classification, data estimation, and inverting very large, ill-conditioned matrices. Moreover, changes in relative prices are not readily handled by this modeling approach alone.”

• I-O model theory does not account for the effects of changes in relative prices on production functions of firms, and therefore on the I-O structure

• I-O model does not allow flexible substitution among inputs and price adjustment

• I-O model deals only with monetary flows in the economy, not quantities of employment, households, population, etc.

• I-O model is an aggregate, static equilibrium model, with no capacity to represent effects of heterogeneous agents, temporal dynamics, changes in production technology
Strengths of the PECAS Model System

• Built on a half-century of Input-Output modeling of macro-economies dating to Leontief’s 1960’s model of U.S. economy, and spatial input-output models of MEPLAN and TRANUS from approximately 1970
• The spatial input-output framework has been used over several decades outside the U.S., and is beginning to see more use in the U.S., especially at a statewide scale
• Integrates interregional trade with and supports modeling of freight due to the relationship between trade and the movement of goods by mode at a time when logistics is becoming increasingly important in many cities
• The model development process can be started with IMPLAN, commercially available data that many U.S. regional planners already use
• Has been extended in PECAS to include not only origin and destination markets but also exchange markets
• Provides a static equilibrium framework, but can be run annually
• Is marketed as open source software (but not clear that it is downloadable)
Limitations of PECAS Model System

• Theory for price adjustment and its integration with I-O model needs development
• Spatial extensions to include production, consumption and exchange locations is complex and abstract
• Data is not readily available for the large number of assumptions to be made especially at the the metropolitan spatial scale, much must be synthesized.
• Creation of quantities of population, jobs, and commodity weights for freight movement are all derived by translating dollars flows to quantities
• AA module is an aggregate, static equilibrium model - not microsimulation
• SD module is a loosely coupled land transition model at a cell or parcel level, lacks demand side at comparable level of detail
• Model estimation/calibration is difficult and to our knowledge no applications have been developed without substantial consulting involvement by developers
• There is limited experience with fully operational applications. No MPOs had used PECAS for official Regional Transportation Plan updates in a 2010 survey by Maricopa Association of Governments; only one reported having used it in their projection series.
Questions and Discussion

PECAS Links:
http://www.hbaspecto.com

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