ARC Forecasting and the PECAS Spatial Economic Model: Overview

Jim Skinner
Atlanta Regional Commission
2016
What is the Atlanta Region?
What is the Atlanta Region?
Why and What?: New Directions

1. Regional Forecasting
   - IPEF was outdated (70s, FORTRAN) and limited
   - REMI was the choice

2. Small Area Forecasting
   - D/E was limited, and support had disappeared
   - PECAS was the choice, long-term
   - TAZ-D as a bridge

3. Travel Demand Model
   - 4-Step to Activity-Based
• TAZ-D developed in collaboration with PBSJ
  • Used new Regional Controls--REMI
  • Shares from E6 work used at superdistrict level
  • Spatial factors used to allocate to grid, back to TAZ
• Initial series developed late Spring 2009
• Review with local planners May-early July 2009
  • 23 meetings
Forecasts Status/ Timeline

- Plan 2040 Adopted in 2010 (REMI, TAZ-D, 4-step)
- Plan 2040 Update (for 20 counties): Spring to early summer 2013 (REMI, Hybrid, 4-Step)
- Major Plan Update (The Atlanta Region’s Plan) 2015-2016
  - New model sets ABM and PECAS (to an extent)
- Going forward
  - Further levels of implementation
  - New model areas (urbanized area change)
ARC Forecast Flow

- Modeling and analysis
- Technical Advisory Committee (TAC)
- Local government review
- Challenges and opportunities
## Forecast Process for Last Full Plan Development

<table>
<thead>
<tr>
<th>Activity</th>
<th>Regional Forecast</th>
<th>Small-Area Activity Allocation (AA) Module</th>
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<td>Geography</td>
<td>20-County area</td>
<td>Super District</td>
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<td>Number of Zones</td>
<td>21 (Up from 3)</td>
<td>78 (groups of tracts)</td>
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ARC Forecasts

Why we forecast?
- Key Component of RTP/ RDP/ WD Plans…

Regional SE forecasting
- REMI replaced IPEF
- 20 / 21 Counties
- Economic activities
- Households
- Population
- Employment

Small area SE forecasting
- PECAS/TAZD replaced DRAM/EMPAL
- 2,000 zones for TBM
- 6,000 zones for ABM

Transportation forecasting
- Migrated to Activity Based Model
REMI Models

- Comprehensive modeling estimating economic and demographic effects
- Up to 169 industry sectors across 3,089 U.S. counties including 6,000+ fully adjustable policy variables updated yearly
- In the Atlanta region, 20 counties, 70 sectors including 6,000 policy variables updated annually

More?
http://www.remi.com/products
Detailed Model Structure
New Economic Geography Linkages

Economic Geography Linkages

Diagram:

1. Output and Demand
   - Intermediate Input Productivity
   - Commodity Access Index
   - Intermediate Inputs
   - Output

2. Labor and Capital Demand
   - Labor Access Index
   - Labor Productivity
   - Employment

   - Economic Migrants

4. Compensation, Prices, and Costs
   - Composite Compensation Rate
   - Production Costs
   - Composite Prices

5. Market Shares
   - Domestic Market Share
   - International Market Share
The ARC Travel Demand Forecasting - Where Do We Start?

- ARC has maintained..
  - A 4-Step Model based on trips (= Trip-Based Model)
  - MIGRATED TO An Activity-Based Model based on tours
- ABM aims at predicting which activities are conducted where, when, for how long, with whom, the transportation mode involved and ideally also the implied route decisions
- ABM reflects the scheduling of activities in time and space
Daily “Activity” - Example

Trip-Based Model
• Home-Work: 2 trips
• Work-Eat: 2 trips
• Home-Gym: 2 trips
(no time-stamps, sequences)

Activity-Based Model
• Follows daily activity patterns
  (departure time, duration, location, frequency, mode)
ARC’s Activity-Based Model: Coordinated Travel – Regional Activity-based Modeling Platform (CT-RAMP)

Main features:

- Explicit intra-household interactions and Coordinated Daily Activity Patterns (CDAP)
- Continuous temporal dimension (hourly)
- Integration of activity generation, location, and Time-Of-Day sub-models
- JAVA-based package with TP+ Graphical User Interface
Activity-Based Models in the U.S.
The “New” LU Allocation Model (PECAS)

- PECAS (Production, Exchange and Consumption Allocation System)
  - Developed by Drs Doug Hunt and John Abraham of University of Calgary
  - Based on sound economic theory, incorporating I-O modeling approach; achieves equilibrium
  - Two Modules, run Sequentially and Annually –
    - Activity Allocation (AA) Module: equilibrium exchange and consumption prices are established by larger zone (LUZ)
    - Space Development (SD) Module: based on pricing (rents) from AA and development costs, rational “developer” makes decision or non-decision to develop space in given smaller zones (TAZ) until the market ‘clears’
  - Work Reviewed by the REMI/PECAS Technical Advisory Group (TAG)
On the Shoulders of...

- Portland and Oregon
- Baltimore
- California
  - Statewide
  - San Diego (SANDAG)
  - LA (SCAG)
- International
- Calgary
Modeling Flow
Treatment of Space (Land Areas and Locations)
Treatment of Space

parcel or grid cell site
Treatment of Space

transport analysis zone (TAZ)
Treatment of Space

land use zone (LUZ)
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System Components and Treatment of Time

- model-wide aggregate economic conditions
- economic changes;
- migration
- space development
- aggregate economic conditions
- activity allocations
- transport model
- changes in transport supply
- transport model
- year t
- year t+1
System Components and Treatment of Time

- model-wide aggregate economic conditions
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- transport model

PECAS

- changes in transport supply

year t

year t+1

- model-wide aggregate economic conditions
- activity allocations
- transport model
Just 5 Basic Choices

1: Where to locate

2: What to make and what to consume in the process (called the ‘technology’ to use)

3: Where to buy what is consumed and where to sell what is made

4: What type of space (floorspace, buildings) to build

5: How much space to build

The interactions among these
Last 2 of the 5 Choices

1: Where to locate

2: What to make and what to consume in the process (called the ‘technology’ to use)

3: Where to buy what is consumed and where to sell what is made

4: What type of space (floorspace, buildings) to build

5: How much space to build

The interactions among these
PECAS is a transport model that considers economic changes, migration, and space development. It allocates activities based on economic conditions and changes in transport supply. Year t transitions to year t+1, reflecting model-wide aggregate economic conditions.
PECAS

- Model-wide aggregate economic conditions
- Economic changes; migration
- Activity allocations
- Transport model

SD

- Changes in transport supply
- Year t

- Model-wide aggregate economic conditions
- Activity allocations
- Transport model
- Year t+1
SD: Parcel Level Data

- 20-County parcel features

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<td><strong>Total</strong></td>
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</table>
Space Development joint discrete-continuous choice

Rent less amortized construction cost per unit space

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

- **Future space type** \( h \) (development type)
- **Future space quantity** \( j \) (building space area)
- On parcel \( p \) of size \( l \) currently containing quantity \( b \) of space type \( v \)
- Zoning restricts \( j \) to range \( [Q_{hp}^{min}, Q_{hp}^{max}] \)

Additional Rent less development costs per unit land

Space quantity (building size)

Land quantity (parcel size)

Stochastic error terms

• derelict
• no change
• more the same
• different types

Quantities

\[ RU_{hjp} \]
Nested logit structure

- New space type
  - Quantity
- Add space
- Renovate
- No change
- Demolish
- Derelict

Multi-level nested discrete-continuous logit
Simulating Space Type: Sampling Distribution

\[ \Pr(h) = \frac{\exp \left( \frac{\tilde{V}_h}{l} \right)}{\sum_{h \in S} \exp \left( \frac{\tilde{V}_{h'}}{l} \right)} \]

\[ \tilde{V}_h = \frac{l}{\mu_q} \ln \left( \frac{le^{\mu_q (T_{hjp} \frac{j}{l} + Tr_{hjp})}}{\mu_q T_{hjp}} \right) \left| \begin{align*} l &= Q_{hp}^{\text{max}} \\ j &= Q_{hp}^{\text{min}} \end{align*} \right. \]
Space Development: Simulation of Transitions

parcel-by-parcel microsimulation

logit models
- industrial
- commercial
- mid density residential
- no change
- more the same
- derelict

quantity
zoning dictates set of alternatives
Space Development: Transition Quantities

aggregate results to TAZ and LUZ zones
SD Database Tables

tazs
luzs
local_effect_distances
local_effects
local_effect_parameters
parcels
current_year_table
parcelfee_xref
parcels_cost_xref
construction_commodities
space_types_group
space_to_commodity
zoning_permissions
zoning_rules_i
development_fee_schedules
development_fees
transition_cost_codes
transition_costs
transition_constants_i
space_types_i
SD GIS Layers

- Base "parcels" (grid cell, parcels)
- Cost polygons (zip codes, slopes, water table, soil) spatially joined to get cost schedule ID
- Fee polygons (cities, school board districts, other jurisdictions) spatially joined to get fee schedule ID
- Local effect feature classes, minimum distance to each affect
  - rent modifier
- Zoning polygons
TAZ Limits and Site Spec
Construction Costs

- Predominantly from GIS system for different costs by location and space type
- Modified by density shaping function which is two lines and a step increment
  - Low density cost (e.g. wood framing)
  - Higher density cost (e.g. concrete)
  - Step increment (e.g. underground parking)
Rich Density Shapes Emerge

![Graph showing the probability of development intensity (F.A.R.) at different cost per square foot. The x-axis represents development intensity ranging from 0 to 4, and the y-axis represents probability ranging from 0 to 0.07. The graph includes lines for different cost levels: $12 per sqft, $14 per sqft, $16 per sqft, $18 per sqft, and $20 per sqft. Each line shows the probability of development intensity increasing with cost.]
Floorspace Synthesis

• Complete inventory of buildings does not exist, and even where inventory data do exist it is:
  • Inconsistent with employment/population data
  • Inconsistent with simplified use rate and type in the model
• Generate synthetic built form inventory by assigning TAZ level totals to grids/parcels
  • Based on competitive scoring algorithm driven by any existing data and land suitability information
• Like a synthetic population for travel modelling
• Realistic pattern and marginal distributions with regard to age, location, zoning, etc.
FS Synthesizer: Initial Fulton Results
SD Database Tables / Columns
PECAS

- Economic changes; migration
- Space development
- Activity allocations
- Transport model
- Changes in transport supply
- Model-wide aggregate economic conditions
- Year t
- Year t+1
model-wide aggregate economic conditions

economic changes; migration

model-wide aggregate economic conditions

space development

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AA
First 3 of 5 Choices

1: Where to locate

2: What to make and what to consume in the process (called the ‘technology’ to use)

3: Where to buy what is consumed and where to sell what is made

4: What type of space (floorspace, buildings) to build

5: How much space to build

The interactions among these
Additional utility associated with location $l$ for activity $a$

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

Exchange location $e_n$ for each commodity exchanged

$$\sum_{n=1}^{N_p} s_{pn} \left( V_{e_n l} + \varepsilon_{e_n lp} \right)$$

$U^a_{lp1e2...en} = V_{lp} + \varepsilon^a_{l} + V_{lp} + \varepsilon^a_{l} + \sum_{n=1}^{N_p} s_{pn} \left( V_{e_n l} + \varepsilon_{e_n lp} \right)$
Economic Interactions:
Production - Exchange -

1: production allocation

2: technology selection

3: selling allocations
   buying allocations

3-level nested logit model

Composite utility for set of locations used for consumer surplus
Composite utility for set of technology options combines accessibilities
Composite utilities for sets of selling or buying locations are accessibilities
allocating produced commodities to selling locations
allocating consumed commodities to buying locations
Interactions Among First 3 of 5 Choices

1: Where to locate

2: What to make and what to consume in the process (called the ‘technology’ to use)

3: Where to buy what is consumed and where to sell what is made

4: What type of space (floorspace, buildings) to build

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The interactions among these
Economic Interactions: Production - Exchange - Consumption

buying allocation process

selling allocation process

commodity flows

exchange zone

exchange zone

exchange zone

total production

total production

total production
IMPLAN Data
PUMS Data: Occ by Income
PUMS Data: Occ by Industry
### Travel Demand Model Skims

**Table:**

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<th>Dest</th>
<th>AM Comp Time</th>
<th>AM Dist</th>
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<td>-30.22</td>
<td>-16.11</td>
<td>-16.01</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Note:** This table represents the travel demand model skims with various time and distance factors.
SE Forecasting

Economic value of white collar labor occupations

Source:
Interactions Among All 5 Basic Choices

1: Where to locate

2: What to make and what to consume in the process (called the ‘technology’ to use)

3: Where to buy what is consumed and where to sell what is made

4: What type of space (floorspace, buildings) to build

5: How much space to build

The interactions among these
Interactions Among System Components

- Year t
  - Model-wide aggregate economic conditions
  - Activity totals
  - Activity allocations
  - Commodity flows
  - Transport model
  - Economic changes; migration changes in transport supply
  - Economic attractions
  - Space development
  - Space rents
  - Space quantities
  - Transport generalised costs
  - Changes in transport supply

- Year t+1
  - Model-wide aggregate economic conditions
  - Activity allocations
  - Transport model
SE Forecasting

Visualization and mapping
- MapIt, WEAVE application

Building a query for CommodityZUtilities.csv

List of attributes in the file: quantity
First scenario (X): W04
Operator: Minus (X-Y)
Second scenario (Y): NB01
Start year: 2005
End year: 2040
Commodity\Commodity Group: Labour
Aggregate grouping function:
- only effective when selecting a Group
Buy(S) or Sell(S): B

Welcome to HBA Specto Map It Application! (Beta 3.1.2)
- Work with one scenario
- Compare two scenarios

View "NB01_Labour_130703_101316_with_geom" was successfully created!

Source:
Where We’re At--Overview

• A Functioning Model
  • Calibrated AA and SD
  • Reactive to Travel Model
• Results Generally Making Sense
  Ø Caveats re: Data Errors
  Ø Caveats re: Reality and Model Conflicts
• Integrated Partially with REMI
• Integrated Manually with ABM
• Scenario Testing
Values of TCU Prod 05-20
Change in TCU Prod 05-20

WO2a_AI08TCUProd_120515_085228_with_geom
Change in Prof. Svs 05-20
<table>
<thead>
<tr>
<th>Scenario name</th>
<th>Scenario Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>W04b</td>
<td>This is the base case scenario non-integrated with the transportation model</td>
</tr>
<tr>
<td>l01f</td>
<td>This is the base case scenario fully integrated with the transportation model, including the projects from the “PLAN 2040”</td>
</tr>
<tr>
<td>NB01</td>
<td>This is a scenario for policy analysis fully integrated with the transportation model and assuming no changes in transportation infrastructure</td>
</tr>
</tbody>
</table>
W04b Base: Change in Households (left); Jobs (right) between 2005 and 2022

Blue dot = 600 Households

Blue dot = 600 Jobs
Households: **Difference** between I01f and NB01 in 2040
Change in Single Family detached residential space between I01f and NB01 in 2035
Change in **Multifamily** residential space between IO1f and NB01 in 2035

Each blue dot is 38100.0, each red dot is -38100.0
Change in Households (left); Labor (right) between I01f and NB01 in 2035
Change in benefits by activities between I01f and NB01 from 2005 to 2040
Where We’re Not At--Overview

- Challenge of Model Output for Conformity
  - Nature of Output
    - HH Matrix Expansion
    - HH to Population
    - Output $ to Jobs
  - Too Much “Change” from Expectations
  - Little “Real” Ability to Adjust Output
- No Full Integration with REMI
  - Still Driven at Industry Level by IMPLAN
- No Automatic Integration with ABM
- Buy-In for Scenario Analysis
SO, Current and Future Work Program

• Model Output for Conformity
  • Achieve Calibration for Baseline TARP
  • Changed Nature of Output (Progress)
    ➢ for TDM
• Tools to Analyze & Modify Output
  • Mapit>>WEAVE/ Leaflet
  • Zoning
  • Adjustment
• LATER, full Integration with REMI
  • Still Driven at Industry Level by IMPLAN
• LATER, Automatic Integration with ABM
• Parallel Scenario Work...
Sales Tax Policy Analysis

- **Scenario 1:**
  - Forecast the expected land use impacts of improved transit
    - Propensity to redevelop around transit due to:
      - Improved accessibility
      - Higher forecast rents
    - Resulting increases in use.
Sales Tax Policy Analysis

- **Scenario 2:**
- Look for places where zoning is restricting development around transit.
- Increase zoning in the model
- Determine if developers in model use the higher density
Sales Tax Policy Analysis

- **Scenario 3:**
  - Add TOD developments to PECAS explicitly
  - Let PECAS forecast what other development does NOT occur if control total fixed
  - Look at impact on travel model ridership, congestion
Atlanta “Vision” Analysis

- City of Atlanta Design Studio
- The Goal of 1.5 Million WITH...
  - Aesthetics
  - Economic Sustainability
  - Equity
- Scenario I: Getting to It with Existing Zoning and Controls
- Scenario II: Test Desired Zoning Changes
- Others: Which Zoning and Incentive Changes “Work”
- Workshop Next Week with HBA and COA Staff
Overall Assessment/ Lessons Learned

• Terrific Theory with “Genius” Consulting
• State of the Art...
• Ability to Leverage Work for Others
• Complexity
  • Data Hungry & Synthesis Challenges
  • Elusive Understanding of Structure
  • Never Ever Done
• Staff (and Consultant) Hungry
  • Long, Long Lead Time >> Expense
• CHANGE IS HARD
  • Expectations of Staff
  • Expectations of Management
  • Appeal of the New and Shiny
Other Resources-I

- ARC (jskinner@atlantaregional.com)
- John Abraham and HBA
- Contacts for/in Other Areas
The Atlanta Regional Commission forecasts the 20-county Atlanta region will add 2.5 million people and 1.5 million jobs by 2040. Much of the population growth will take place in existing suburbs, but significant growth is also expected in the region's core.

County and regional information can be accessed in the interactive dashboard below. One-page summaries are also available for the region's 10 core counties.

One-Page Summaries

10 County Population & Employment Forecasts

<table>
<thead>
<tr>
<th>Total Employment</th>
</tr>
</thead>
<tbody>
<tr>
<td>2015</td>
</tr>
<tr>
<td>10-Co.</td>
</tr>
<tr>
<td>20-Co.</td>
</tr>
</tbody>
</table>

Select a type of change to change the graph below:

Percent Change

Employment Change

Select a County

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