Shining a Light Inside the Black Box

Part 2 of 4

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Speakers

- Fred Ducca, FHWA
- Bill Woodford, AECOM Consult
- Dave Schmitt, AECOM Consult

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Series Schedule

- Four sessions of two hours each
  - "Motivations & Data": February 12th, 2008 at 2:30 PM EST
  - "Model Testing": March 11th, 2008 at 2:30 PM EST
  - "Transportation Supply & Travel Distribution": April 8th, 2008 at 2:30 PM EDT
  - "Translating Results Into Insights for Decision Makers": May 13th, 2008 at 2:30 PM EDT
- Please submit questions to chat pod to Dave Schmitt
- Questions will be answered at the end of each session

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Speaker

- Dave Schmitt, AECOM Consult

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Model Testing

Going beyond traditional calibration and validation

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"In theory there is no difference between theory and practice. In practice there is."

- Yogi Berra

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What Should Modelers Focus On?
Insights

1. Understand the real world transportation system and how people use it…and we need detailed data to do this
2. Develop and apply meaningful testing approaches
3. Understand where the models work and where they don’t work
4. Propose and test solutions where problems are found

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Traditional Model Development
Components

- Estimation: using data to estimate values of model parameters and draw conclusions on the appropriate variables and model structure
- Calibration: implementing the model and adjusting it to reproduce current travel behaviors
- Validation: “forecasting” current travel patterns to demonstrate sufficient ability to reproduce highway counts and transit line volumes

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Traditional Model Development
Problems

- Few resources reserved for validation in model development efforts
- Limited or insufficient amount of data to verify model estimates
- Validation efforts overly focused on traffic or line volumes
- Inattention to forecasting impacts of model adjustments and properties
- Insufficient documentation of results

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Improvements to Current Practice

- Collect data to sufficiently test model estimates and results
- Perform more meaningful model tests
  - Expand model calibration/validation efforts
  - Interpret models vis-à-vis traveler behavior
  - Demonstrate reasonable predictions of change
  - Provide informative documentation of testing results and forecasting weaknesses

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Collect Data to Sufficiently Test Model Estimates and Results

- Detailed person demand/travel flow data
- Detailed freight demand/travel flow data
- Actual highway and transit speeds
- Actual point-to-point travel times
- Volumes on facilities/services

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Expanded Calibration and Validation Efforts

- Comparison of point-to-point travel times
- Inspection of person demand/travel flows
- Comparison of estimated and observed cross-tabbed trip tables
- Assignment of observed trip tables
- Comparison of volumes

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Comparing of Point-to-Point Travel Times

- Examine segment and/or end-to-end speeds and travel times by facility or corridor by mode
- Potential data sources
  - Freeway or traffic management systems (ITS)
  - Self-administered car probes
  - Public time tables or driver “run sheets”

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Comparison of Point-to-Point Travel Times: *Freeway Example*

Table 5: Comparison of Congested Travel Times along Northbound I-71 (minutes)

Interchange	*AM Peak Period*			*Midday Period*		
	Estimated	*Observed*	*Difference*	*Estimated*	*Observed*	*Difference*
17th Ave – Hudson Ave	1.22	1.06	0.16	1.22	1.08	0.14
Hudson Ave – N Broadway	1.30	1.11	0.19	1.57	1.13	0.44
N Broadway – Cooke Road	1.15	0.98	0.17	1.13	0.99	0.14
Cooke Road – Morse Road	1.16	0.95	0.20	1.15	0.96	0.19
Morse Road – SR 161	2.00	1.65	0.35	1.99	1.65	0.34
Total	**6.82**	**5.75**	**1.07**	**7.06**	**5.80**	**1.26**

Sources: Columbus FMS data (April 1-May 31, 2005 weekdays); 2000 MORPC Travel Demand Model (Run M312)

Table 6: Comparison of Congested Travel Times along Southbound I-71 (minutes)

Interchange	*AM Peak Period*			*Midday Period*		
	Estimated	*Observed*	*Difference*	*Estimated*	*Observed*	*Difference*
17th Ave – Hudson Ave	1.70	1.15	0.56	1.17	1.05	0.12
Hudson Ave – N Broadway	1.68	1.21	0.46	1.30	1.10	0.20
N Broadway – Cooke Road	1.45	1.02	0.43	1.13	0.95	0.18
Cooke Road – Morse Road	1.31	1.03	0.28	1.15	0.98	0.17
Morse Road – SR 161	2.12	1.79	0.32	1.97	1.76	0.21
Total	**8.25**	**6.21**	**2.05**	**6.73**	**5.84**	**0.88**

Sources: Columbus FMS data (April 1-May 31, 2005 weekdays); 2000 MORPC Travel Demand Model (Run M312)

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Comparison of Point-to-Point Travel Times: *Arterial Example*

	AM Peak Period					
	Northbound			Southbound		
	Obs	Before	After	Obs	Before	After
High Street	40.9	41.6	41.4	38.9	42.3	38.7
		2%	1%		9%	-1%
4th Street	8.5	11.4	10.6			
		34%	25%			
Summit/3rd				10.8	15.2	12.0
					41%	11%
Indianola Ave	9.5	7.3	9.7	7.1	7.0	7.3
		-23%	2%		-1%	3%

	Midday Off-Peak Period					
	Northbound			Southbound		
	Obs	Before	After	Obs	Before	After
High Street	39.2	34.2	38.5	46.0	34.0	46.0
		-13%	-2%		-26%	0%
4th Street	9.1	11.3	8.8			
		24%	-3%			
Summit/3rd				8.8	10.5	9.2
					19%	5%
Indianola Ave	7.1	6.8	7.2	6.1	5.3	6.3
		-4%	1%		-13%	3%

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Comparison of Point-to-Point Travel Times: *Transit Example*

Table 8: Travel Times of Major Corridor Routes (minutes)

	Peak Period			*Off-Peak Period*		
	Time Table	Model	Difference	Time Table	Model	Difference
#1 Westerville PNR-CBD	53.0	56.2	+3.2	63.0	48.6	-14.4
#1 Northern Lights-CBD	29.0	32.7	+3.7	29.0	28.6	-0.4
#2 Crosswoods-CBD	57.0	62.8	+5.8	60.0	51.3	-8.7
#2 Graceland-CBD	39.0	38.4	-0.6	40.0	29.7	-10.3
#4 Graceland-CBD	33.0	33.3	+0.3	34.0	33.8	-0.2
#29 Polaris	46.0	44.8	-1.2	--	--	--
#30 Smoky Row	49.0	54.8	+5.8	--	--	--
#31 Worthington	49.0	57.1	+8.1	--	--	--

Source: 2000 Model (Run M312)

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Methods of Inspecting Person Demand/Travel Flows

- Compare travel flows by sub-county district by purpose

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Demand/Travel Patterns
Example

Estimated Demand/Travel Patterns

	CBD	Urban	Suburbs	Tech Center	Rural	Total
CBD	1,000	1,000	-	-	-	**2,000**
Urban	40,000	1,000	-	1,000	-	**42,000**
Suburbs	7,000	1,000	10,000	35,000	2,000	**55,000**
Tech Center	1,000	3,000	3,000	1,000	-	**8,000**
Rural	1,000	19,000	7,000	3,000	-	**30,000**
Total	**50,000**	**25,000**	**20,000**	**40,000**	**2,000**	**137,000**

Observed Demand/Travel Patterns

	CBD	Urban	Suburbs	Tech Center	Rural	Total
CBD	1,000	-	-	1,000	-	**2,000**
Urban	7,000	10,000	21,000	3,000	1,000	**42,000**
Suburbs	35,000	1,000	5,000	12,000	2,000	**55,000**
Tech Center	2,000	-	1,000	4,000	1,000	**8,000**
Rural	5,000	-	-	20,000	5,000	**30,000**
Total	**50,000**	**11,000**	**27,000**	**40,000**	**9,000**	**137,000**

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Methods of Inspecting Person Demand/Travel Flows

- Compare travel flows by sub-county district by purpose
- Compare "orientation" ratio of trips to major attractions using this equation:

$$OR_i = \frac{\left(\dfrac{Trips_{i,x}}{\sum_i Trips_x} \right)}{\left(\dfrac{Trips_i}{\sum_i Trips} \right)}$$

where:
i = origin zone
x = attraction zone(s)

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The Orientation Ratio

- Computed for all zones individually
- Measures the propensity of trips from an origin zone to the attraction area
  - The numerator is the trips to the attraction area from each zone divided by the sum of all trips to the attraction area
  - The denominator is all trips from a zone divided by all trips in the region

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The Orientation Ratio (cont’d)

- Values can vary between zero and very high numbers
  - If value < 1, the region is more orientated to the attraction area than the individual zone
    - Example: low-income area next to tech center
  - If value = 1, the zone no more orientated to the attraction area than any other zone in the region
    - Example: medium-income area some distance away from employment area
  - If value > 1, the zone is more orientated to the attraction area than other zones in the region
    - Example: high-income area next to tech center

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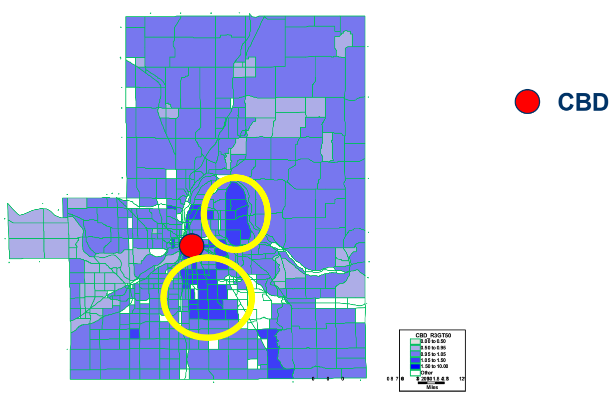
Orientation Map to CBD
Estimated



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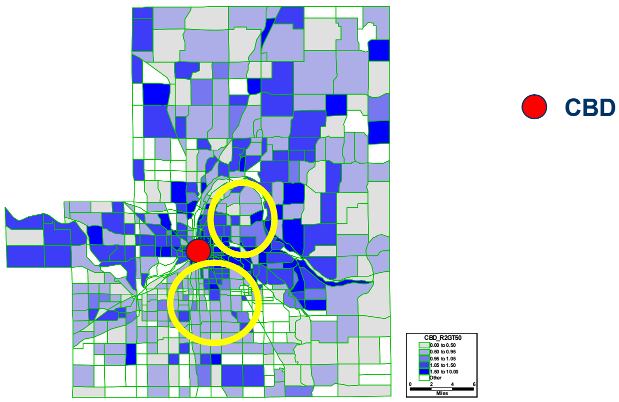
Orientation Map to CBD
Observed



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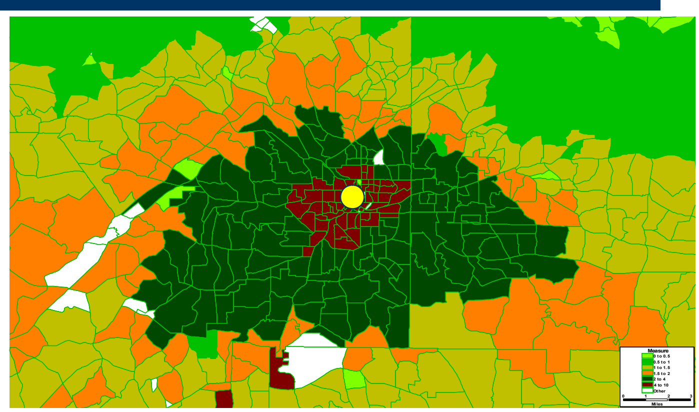
Orientation Map to CBD
Estimated



CBD

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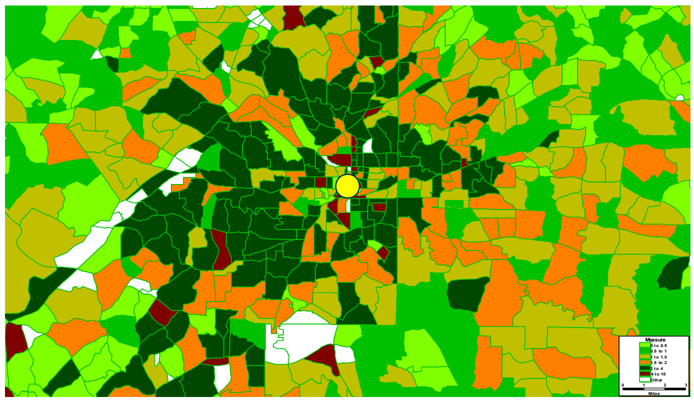
Orientation Map to CBD
Observed



CBD

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Comparing Cross-Tabbed Estimated and Observed Travel Flows

- Compare travel flows using sub-county districts across multiple dimensions including:
  - Purpose
  - Mode
  - Time of day
  - Socio-economic characteristics
  - Sub-mode/occupancy/toll road use
  - Mode of access

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Comparing Cross-Tabbed Trip Tables

Example (Observed)

Table 1a: Comparison of HBW Transit Linked Trips by Geography and Income Group (Observed)

Access Model	**Walk**
Purpose	**HBW**

Sum of Wts		Destination District						
Income grp	Origin District	CBD	Northeast	Northwest	Ottawa	Southeast	Southwest	Grand Total
1-Low	CBD	49	28	62	-	134	119	392
	Northeast	56	31	-	-	10	42	140
	Northwest	25	29	87	11	39	103	294
	Ottawa	21	5	-	-	-	-	26
	Southeast	58	18	39	-	74	111	299
	Southwest	150	17	44	-	109	290	610
1-Low Total		359	129	232	11	367	665	**1,762**
2-Medium	CBD	53	9	-	-	97	63	223
	Northeast	41	21	18	-	7	56	143
	Northwest	56	9	26	5	26	29	152
	Southeast	78	20	7	-	83	42	230
	Southwest	99	5	13	-	58	231	405
2-Medium Total		327	65	64	5	271	421	**1,153**
3-High	CBD	35	9	-	11	42	13	110
	Northwest	25	7	7	5	9	18	72
	Southeast	49	-	-	-	25	7	81
	Southwest	26	5	-	-	7	46	84
3-High Total		136	21	7	16	83	83	**346**
Grand Total		821	215	303	32	721	1,170	**3,261**

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Comparing Cross-Tabbed Trip Tables

Example (Estimated)

Table 1b: Comparison of **HBW** Transit Linked Trips by Geography and Income Group (**Estimated**)

Purpose	**HBW**

Sum of Transit Trips		Dest District						
Income grp	Origin District	CBD	Northeast	Northwest	Ottawa	Southeast	Southwest	Grand Total
1-Low	CBD	83	27	37	1	130	122	400
	Northeast	38	15	20	0	17	19	108
	Northwest	58	10	68	1	28	43	207
	Ottawa	1	-	0	0	0	0	1
	Southeast	94	8	22	0	122	82	329
	Southwest	157	14	58	0	136	351	716
1-Low Total		430	74	205	2	432	618	1,762
2-Med	CBD	44	11	20	1	54	53	184
	Northeast	33	10	15	0	14	15	88
	Northwest	45	7	51	1	16	27	147
	Ottawa	0	-	0	0	0	0	1
	Southeast	64	6	15	0	78	52	215
	Southwest	108	10	37	0	93	269	518
2-Med Total		295	44	138	2	255	418	1,152
3-High	CBD	8	2	3	0	9	8	30
	Northeast	11	3	4	0	4	5	27
	Northwest	14	2	16	0	5	7	45
	Ottawa	0	-	0	-	-	0	0
	Southeast	31	2	5	0	35	21	95
	Southwest	32	3	9	0	27	82	154
3-High Total		96	12	39	1	80	123	350
Grand Total		821	130	382	5	768	1,159	3,264

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Assignment of Observed Trip Tables

- Isolates network coding and path-building components
- Permits comparisons of the following items:
  - Individual path characteristics
  - Traffic, station and line volumes
  - Geographic locations of productions/attractions
  - Transfer frequencies

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Speaker

- Bill Woodford, AECOM Consult

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Relating Model Structure to Traveler Behavior

- A model's design can a "tell" a story about the perceived behavior of travelers
- This test helps to ensure that the various parameters, constants, coding conventions and other decision rules in the models tell a coherent story about travel behavior
- This story can be used to explain the properties of models to non-travel-forecasters

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Interpreting Model Structure *Examples*

Model Property	Interpretation
Highway assignment path cost function = time + 0.2 * distance	Travelers prefer shorter-distance trips, assuming all possible paths about equal
24-hour assignment used as impedances for HBW distribution	Travelers experience balanced congestion for all work trips; impedance does not vary by time of day for work trips
Mode choice coefficients of -0.050 OVT, -0.025 IVT	Transit riders perceive waiting and walking twice as onerous as in-vehicle time

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Demonstrating Reasonable Predictions of Change

- Models should provide reasonable predictions of change
  - Between today and a future no-build condition
  - Between a future no-build condition and a realistic alternative (i.e., a change in the transportation system)
- To be useful, tests of reaction to change must be done through applications of the model in full production mode
- Findings can highlight problems not prevalent in base year conditions

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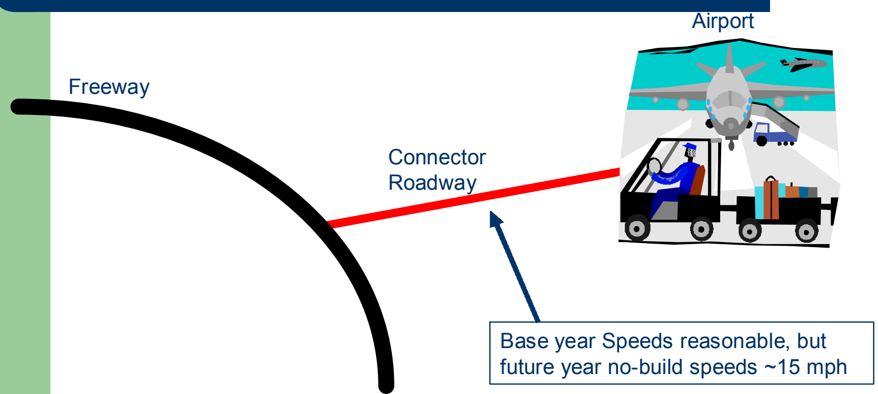
Common Tests for Reasonable Forecasts

#	Compare model results from…	…to the results from…	This compares the…	The results are different because of …
1	Previously validated year	Base year validation	Past to the present	Changes in demographics & employment and transportation supply
2	Base year validation	Future year no-build	Present to the future	Demographic & employment forecasts
3	Future year no-build	Future year TSM	The future to a modestly-changed future	Transportation supply (modest)
4	Future year TSM	Future year Build	The modestly-changed future to a future with a big project	Transportation supply (major)

Reasonableness of Predicted Changes
Example #1



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Reasonableness of Predicted Changes
Example #1 (cont'd)

- The problem is that future year no-build speeds very slow (~15 mph), although base year speeds are reasonable
- A major cause was that average time-of-day factors were applied to airport-related trips, causing an over-estimation of peak-period traffic
- The solution was to gather information on time-of-day factors more appropriate for airport-related trips and apply them accordingly

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Reasonableness of Predicted Changes *Example #2*

- Future year highway speeds slower than walking for many instances, although base year speeds are reasonable
- The cause was related to the policy of the individual MPO that excludes coding roadways in the highway network that are not explicitly funded
- Predicted strong demographic growth overwhelms transportation infrastructure

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Providing Informative Documentation

- Beyond reporting the calibration and validation results, the model documentation should describe the "readiness" of the model set for forecasting, including the presentation of:
  - The significant travel markets and facilities that exist today
  - The ability of the model set to describe the nature and magnitude of those markets
  - The reasonableness of predicted changes
  - The identification of the model set limitations that restrict the full and correct representation of current travel markets, behaviors and modes
  - Identification of future travel markets and/or facilities, their representation for forecasting
- The documentation should be devoid of technical jargon or equations

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Travel Markets and Transportation Facilities: *Description*

- It is important to identify specific markets and facilities so that model customers can be informed of model's ability to represent them
- Examples of travel markets can include:
  - Suburban workers to CBD jobs
  - Freight traffic
  - Non-work travel (from? Certain attractions?)
  - Major activity areas
- Facilities can be described in terms of mode, capacity, speeds, usage by travel markets and connection to major activity centers

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Travel Markets and Transportation Facilities: *Model Representation*

- The model's ability to represent the travel markets and transportation facilities can be shown by presenting:
  - Model structure including parameters, constants and decision rules
  - Network coding conventions
  - Results from travel flow, travel time, speed and facility/service volume comparisons

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Commonly Mentioned Limitations of Model Sets

- Inability to adequately replicate travel flows
- Inadequate speed representation
- Aggregate-level calibration and validation
- Coding conventions
- Inability of path/assignment algorithm logic to capture behaviors
- Insufficient data

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Forecasting Assessment

- Assessing the model's ability to represent future travel markets and/or facilities is important as these conditions may be insignificant or invisible in the base year
- Future travel markets can be shown by highlighting:
  - Specific areas of major population and employment growth or decline
  - New major transportation infrastructure investments
  - New travel patterns likely to emerge from these changes

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Forecasting Assessment (cont’d)

- Common forecasting weaknesses include the model set’s ability to evaluate usage:
  - Of new facility type previously not available, such as a toll road or fixed-guideway transit
  - In rapidly growing (declining) areas
  - Drastic changes in speeds and travel times

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Model Testing

Experiences

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Meaningful Model Testing

Lessons Learned

- Performing more meaningful model tests uncovers problems that would remain hidden if traditional calibration and validation practice is followed

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Real-life Examples of Hidden Problems in Model Sets

- “Scripting” errors
  - Reading node number instead of a value-of-time ratio
  - Incorrect reading of friction factors
- Data issues
  - Parking costs in wrong year dollars
  - Free-flow speeds lower than actual congested speeds
  - Vehicle counts larger than capacity
- Distribution issues
  - Employment data missing from large CBD employer
  - Observed transit trips greater than person trips on key interchange
- And many, many others

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Meaningful Model Testing
Lessons Learned

- Performing more meaningful model tests uncovers problems that would remain hidden if traditional calibration and validation practice is followed
- In an effort to avoid repeating problems, model adjustments need to better reflect travel behavior must be based on behavior and not arithmetic

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Meaningful Model Testing
Suggested Process

- Once the straightforward issues are identified and fixed, use remaining validation problems to improve behavioral aspects
- Three-step process
  - Look at patterns in the travel data
  - Understand why the model does or does not properly value the trip
  - Adjust the model

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Making Model Adjustments
Charlotte Example

Table 1c - Summary of Linked Transit Trips on all Transit Modes

	Walk Mode					Drive Mode					Drop-Off Mode					
ALL-Transit	CBD Peak	NonCBD Peak	CBD Off Peak	NONCBD Off Peak	TOTAL	CBD Peak	NonCBD Peak	CBD Off Peak	NONCBD Off Peak	TOTAL	CBD Peak	NonCBD Peak	CBD Off Peak	NONCBD Off Peak	TOTAL	GRAND TOTAL
HBW - Inc 1 (incl HBU)	402	1,652	445	1,955	4,454	41	4	-	-	44	34	67	-	50	151	4,649
HBW - Inc 2	411	1,935	468	1,604	4,418	46	-	-	-	46	6	45	25	101	177	4,642
HBW - Inc 3	702	942	656	869	3,168	310	19	3	-	331	42	7	3	60	111	3,610
HBW - Inc 4	545	360	202	262	1,368	999	35	61	0	1,095	82	36	32	2	152	2,616
HBW - All	2,060	4,889	1,771	4,690	13,409	1,396	58	64	0	1,517	164	155	59	213	592	15,518
HBO - Inc 1	516	1,538	658	2,502	5,214	9	3	-	-	12	1	30	33	121	185	5,411
HBO - Inc 2	321	893	558	1,719	3,492	4	3	-	-	8	8	99	-	26	132	3,632
HBO - Inc 3	275	525	397	983	2,180	3	5	-	0	7	-	15	25	47	86	2,273
HBO - Inc 4	123	253	124	188	689	14	11	-	-	25	-	6	-	22	28	742
HBO - All	1,235	3,210	1,737	5,392	11,574	30	22	-	0	52	9	150	58	216	432	12,058
NHB	509	1,699	733	2,520	5,462	7	2	1	-	11	45	108	47	189	389	5,862
Walk to Local	**3,804**	**9,798**	**4,241**	**12,602**	**30,445**	**1,434**	**82**	**65**	**0**	**1,580**	**218**	**413**	**163**	**618**	**1,413**	**33,438**

Begin by understanding the market:

- Express bus survey shows CBD orientation with 62% of total trips park-and-riding
- Local bus survey shows most riders being Income Groups 1-3 (under $25K) with few park-and-ride trips

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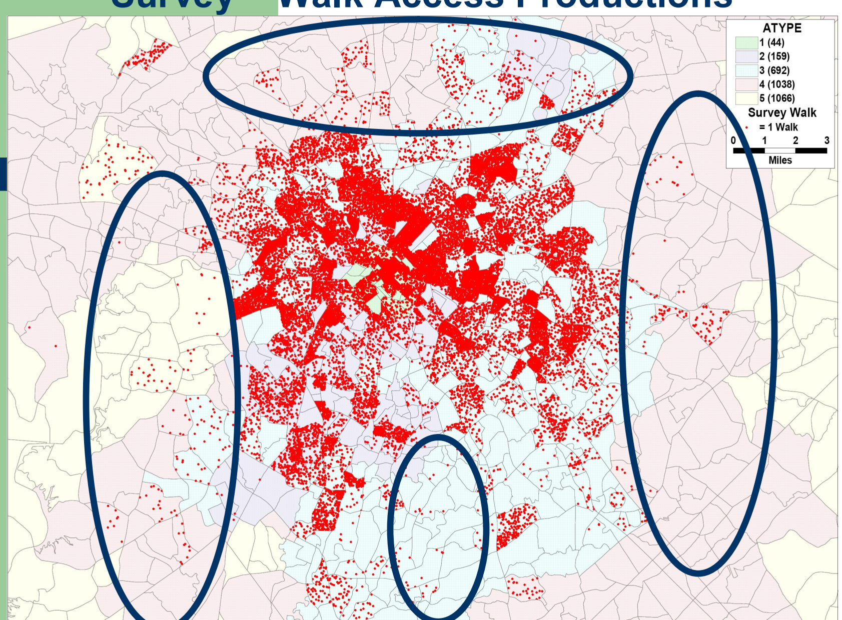
Survey – Walk Access Productions



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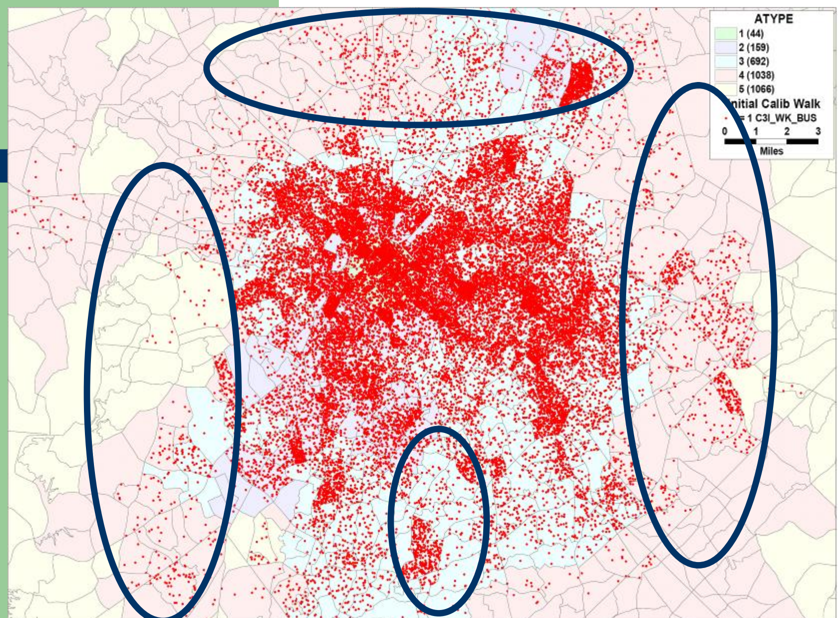
Initial Calibration – Walk Access Productions



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Addressing Walk Time Weights

- Set perceived walk time as function of pedestrian environment
  - Superior walk environment in high density areas
  - Walking more difficult in less dense environment
- Varied weights by area type
  - Lower weights for good pedestrian areas (CBD)
  - Higher weights for not-so-good pedestrian areas (Urban, Suburban, Rural)
- Pre-weighted walk times used for path-building, skims and mode choice

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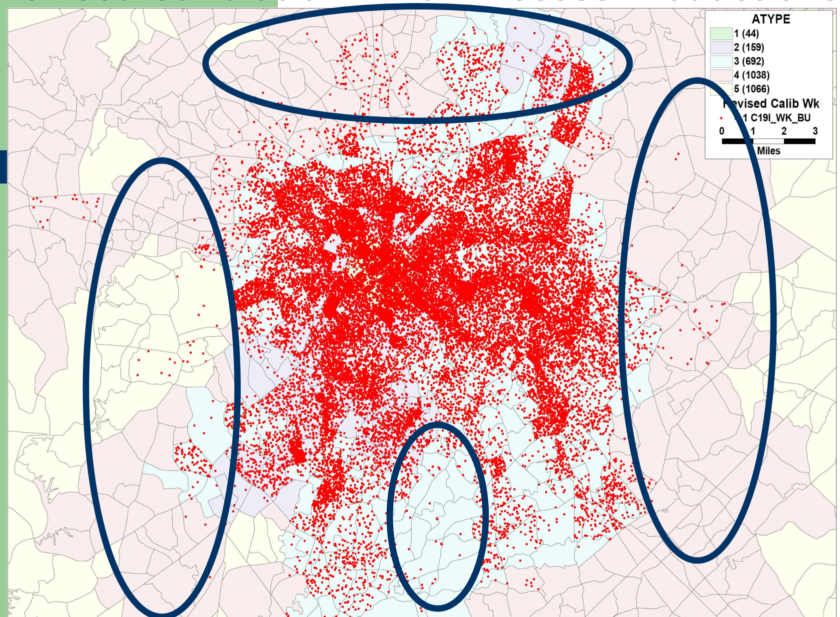
Revised Calibration – Walk Access Productions



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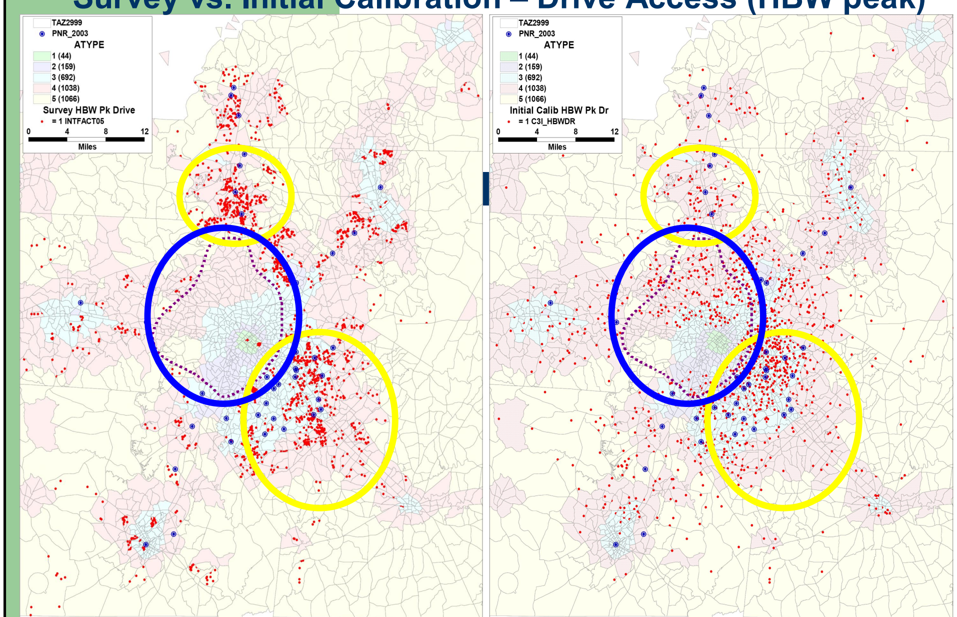
Survey vs. Initial Calibration – Drive Access (HBW peak)



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Diagnosis of Drive Access Issues

1. Too many park-and-ride trips near downtown
2. Too much backtracking (i.e., driving away from downtown to access transit which will then travel to downtown)
3. Model over-predicted park-and-ride trips on local buses versus express buses
4. Too few park-and-ride trips using formal park-ride facilities

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Impedance Adjustments
Part 1: Improved Backtracking Penalty

- In the initial calibration, the auto access impedance is weighted by drive-access distance plus transit distance:

$$\frac{\text{drive access distance + transit distance}}{\text{auto mode distance}}$$

  - This made auto access trips near downtown comparable to similar trips much further away

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Impedance Adjustments
Part 1: Improved Backtracking Penalty (cont'd)

- In the enhanced calibration, the auto access impedance is changed to reflect drive-access time plus transit travel time:

$$\frac{\text{drive access time + transit IVTT}}{\text{auto mode time}}$$

  - If this ratio > 1.0, the perceived transit IVTT is re-computed as IVT + 60*(ratio-1)
  - This formulation better differentiates backtracking from non-backtracking trips as it effectively "rewards" where you could save time by taking transit

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Impedance Adjustments
Part 2: Shadow Prices for Informal Lots

- A shadow price is an additional perceived parking cost used to reflect individual behavior at park-and-ride lots
- Set up "shadow pricing" for formal and informal lots
  - Formal park-and-ride lots – no shadow price
  - Informal park-and-ride lots
    - 70+ spaces – shadow price = 3 minutes of IVTT
    - 20-70 spaces – shadow price = 6 minutes of IVTT
    - less than 20 spaces – shadow price = 9 minutes of IVTT
- This encourages more patronage at formal lots as the expense of informal ones

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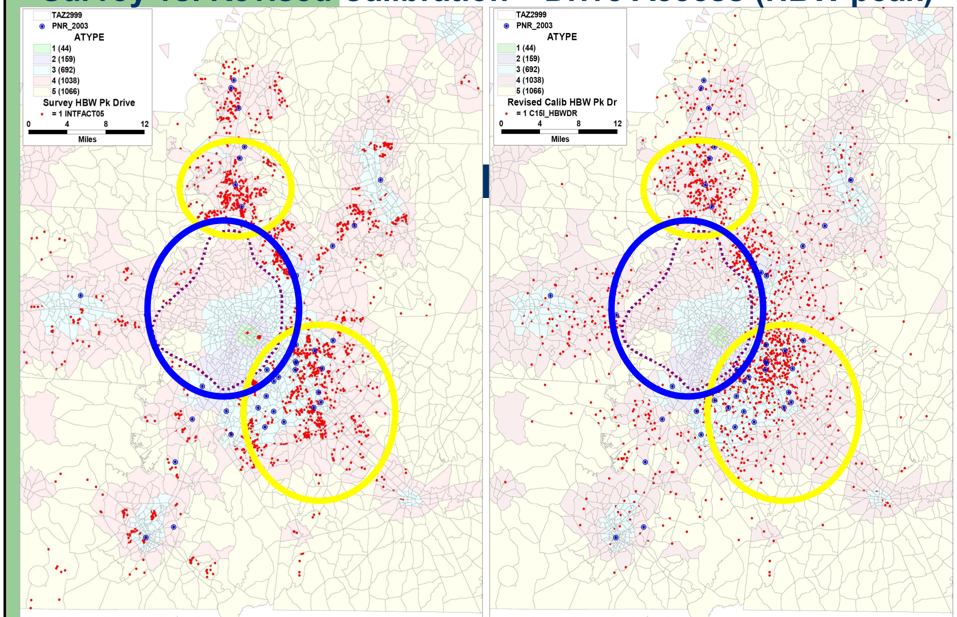
Survey vs. Revised Calibration – Drive Access (HBW peak)



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Making Model Adjustments
Example: Treating the Symptom

- Suppose a key facility is over-assigned
  - To correct the volume, free-flow speeds would be adjusted lower to compensate leading “domino effect”…
  - Speed adjustments → Altered distribution → Altered assignments → More potential speed changes → etc.
- This treatment corrects the volumes (the symptom), but distribution and estimated speeds become further from actual conditions (and reflecting the transportation system and how people use it)

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Making Model Adjustments
A Better Solution

- A better solution is to diagnose the cause by investigating:
  - Veracity of the socio-economic data
  - Reasonableness of the centroid connectors and network connectivity
  - Reasonableness of the capacities, speeds and link characteristics on nearby links
  - Distribution
  - And all other parts of the model for reasonableness

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Making Model Adjustments
Example: Eugene/Springfield, Oregon

- The assigned vehicle trips were too numerous and had much longer trip lengths than found in the survey data
- The initial solution was to raise the impedances to shorten trip lengths
- Further investigation revealed that students were represented by single-family DUs, which overstated the number of vehicle trips and the trip length
- The final solution was to represent student trip-making more accurately – as they make much shorter trips and many non-motorized ones

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What Should You Be Doing?

- Set up a separate task in your UPWP to identify a data collection plan that relates to the model development and testing
- Test your model beyond superficial aggregate measures
- Don’t underestimate the time needed to test and document the model
- Don’t underestimate the number of “hidden” problems in your model set and the time required to correct them

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Questions

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Special Thanks

- To those that contributed examples, insights and experiences:
  - Charlotte Area Transit System
  - Interurban Transit Partnership
  - Central Ohio Transit Authority
  - Atlanta Regional Commission

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References

- Central Ohio Transit Authority (AECOM Consult). July 2006. Modeling QA/QC Review Technical Memorandum.
- Federal Transit Administration (AECOM Consult). 2004-2005. Various Maps Examining Differences between Observed and Estimated Travel Patterns.
- Interurban Transit Partnership (AECOM Consult). March 2006. Grand Rapids Transit Model Methodology Report & User's Guide.
- Web site on Yogi Berra quotations. http://en.wikiquote.org/wiki/Yogi_Berra.
- Woodford. 2007. Pathbuilder Calibration with Data on Ridership Patterns. Presented at the FTA New Starts modeling workshop in September 2007.

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