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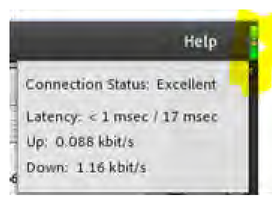

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Making a Model a Good Predictive Tool

presented to

Travel Model Improvement Program

presented by

Thomas Rossi

CAMBRIDGE SYSTEMATICS

Think Forward

December 14, 2016

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  - Andrew Rohne

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Today's Presentation

- **Study Objectives**
- **Study Approach – Backcasting and Forecasting**
- **Summary of Model Results**
- **What We Learned**
- **Lessons and Recommendations for Modelers**

STUDY OBJECTIVES AND APPROACH

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Why Do We Use Travel Demand Models

- To estimate demand for short and long term planning scenarios and alternatives
  - » Project planning
  - » Long range plans
  - » Air quality conformity analysis
  - » Policy analysis
  - » …and many other analyses

Why and How Do We Validate a Model

- Why?
  - » To assure ourselves that the model reasonably reflects travel behavior
  - » To assure others that analyses performed using the model are reasonable and defensible
- How?
  - » Check all of the input data for accuracy
  - » Compare model results to observed demand data (preferably from sources independent of those used in model development)
  - » Perform sensitivity testing for scenarios other than the "base"

Backcasting and Forecasting in Validation

- Base year validation demonstrates a model's ability to estimate travel behavior for a single point in time
- A second point would help demonstrate *sensitivity* of the model to changing conditions that affect travel demand
- Backcasting and forecasting: Compare model results to observed data for a year other than the base year
- For forecasting, choose year after base year but still in the past

Backcasting

- Backcasting can be advantageous…
  - Could look at model results for a case before a major transportation system change
  - Often, backcast year was the base year for a previous model version (so data are available)
- But it can be challenging to assemble the necessary information
  - Model region may have expanded
  - Zone structure changes may require reallocation of land use data
  - Variable definitions may have changed (e.g. income ranges)
  - Different reference period for cost and income measures (e.g. 2010 $)
  - Network changes may require effort to match count data to links/routes
    - ***(Especially for transit)***
  - No new counts can be conducted for backcast year

Short Term Forecasting in Validation

- Also has advantages…
  - Changes from base year are in “correct direction”
  - More likely to be able to look at effects of increasing congestion
  - Can collect new validation data (e.g., counts)
- But there are also challenges
  - Most data for forecast year probably need to be developed from scratch
  - May need to collect more data since this is a new scenario

Study Approach

- Use two different model versions with different base years
- Backcast or forecast the base year scenario for the “other” model version
- Use models from two different urban areas:
  - Baltimore (BMC)
  - Cincinnati (OKI)

Measures of Effectiveness

- VMT by segment
- Volume/capacity ratio
- Travel times/speeds on key corridors (OKI)
- Average trip lengths
- Mode shares (BMC)
- Transit ridership (BMC)

Questions We Hoped to Answer

- How well does the model forecast/backcast for the scenario several years removed from the base year?
- Does the model perform appreciably better for forecasting or backcasting?
- Are there particular areas where the model performs better for forecasting/ backcasting? (By geography, land use type, mode of travel, levels of congestion, time periods, or other segmentations available in the model)
- Does the model show reasonable sensitivity to the factors that changes between scenarios?

BALTIMORE MODEL RESULTS

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BMC Model Scenarios

- Model A – Base year of 2000
- Model B – Base year of 2008
- Four scenarios:
  - Scenario A00 – Model A run for base year of 2000
  - Scenario A08 – Model A run for forecast year of 2008
  - Scenario B08 – Model B run for base year of 2008
  - Scenario B00 – Model B run for backcast year of 2000
- All socioeconomic data inputs the same for each year

Highway Assignment Validation
Volume/Count Ratio

Facility Type	A00 (base)	A08 (forecast)	B00 (backcast)	B08 (base)
Freeway/ Expressway	0.96	0.87	0.99	0.90
Primary Arterial	0.87	0.94	0.95	1.01
Minor Arterial	0.83	0.80	0.93	0.89
Collector	0.80	0.80	0.90	0.90
Centroid Connector	1.01	1.05	1.00	1.00
Other	0.82	0.84	0.92	0.74
All Links	0.92	0.89	0.97	0.93

VMT by Facility Type (millions)

Facility Type	A00 (base)	A08 (forecast)	B00 (backcast)	B08 (base)
Freeway/ Expressway	49.8	50.2	50.5	51.6
Primary Arterial	25.7	29.5	27.6	31.4
Minor Arterial	22.9	23.5	25.7	26.3
Collector	2.9	6.5	5.1	6.1
Centroid Connector	12.1	12.7	11.9	12.3
Other	3.0	3.5	3.1	3.0
Total	113.5	119.3	118.8	124.6

VMT Summary Observations

- VMT growth 2000-2008
  - » From validated base year models: 10%
  - » From Model A (base year 2000): 5%
  - » From Model B (base year 2008): 5%
- Therefore, *both models underestimate VMT growth by half*

VMT by Time of Day

	A00 (base)		A08 (forecast)		B00 (backcast)		B08 (base)	
	VMT	% of daily	VMT	% of daily	VMT	% of daily	VMT	% of daily
A.M. Peak	24.8	21.9%	26.2	22.0%	27.6	23.2%	29.0	23.3%
Mid-Day	35.2	31.0%	36.8	30.8%	35.8	30.1%	37.5	30.1%
P.M. Peak	31.3	27.6%	33.0	27.7%	33.3	28.0%	35.1	28.2%
Night	22.1	19.5%	23.3	19.5%	22.0	18.5%	23.0	18.5%
Total	113.5		119.3		118.8		124.6	

Lack of change in peaking for each model due to the use of *fixed factors*

Average Speeds

Facility Type	A00 (base)	A08 (forecast)	B00 (backcast)	B08 (base)
Freeway/ Expressway	52.3	53.7	45.9	46.9
Primary Arterial	32.4	33.6	31.9	32.3
Minor Arterial	30.4	30.5	30.4	30.4
Collector	25.8	23.7	27.1	26.1
Centroid Connector	26.1	26.1	26.2	26.3
Other	25.9	28.2	27.5	28.0
Total	36.9	37.4	35.2	35.5

Main differences are due to lower free flow speeds for freeways in Model B

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Trip Generation

Trip Purpose	Scenario A00 (base)			Scenario A08 (forecast)		
	Trips	Trips/ Household	% Trips	Trips	Trips/ Household	% Trips
HBW	2,844,412	1.5	19%	3,107,253	1.6	20%
HBSc	942,617	0.5	6%	902,515	0.5	6%
HBSh	2,542,957	1.3	17%	2,605,133	1.3	17%
HBO	4,418,732	2.3	30%	4,449,273	2.3	29%
NHB	3,993,140	2.1	27%	4,174,094	2.1	27%
Total	14,741,858	7.8		15,238,268	7.7	
	Scenario B00 (backcast)			**Scenario B08 (base)**		
	Trips	Trips/ Household	% Trips	Trips	Trips/ Household	% Trips
HBW	2,551,942	1.3	18%	2,812,507	1.4	19%
HBSc	1,115,558	0.6	8%	1,070,455	0.5	7%
HBSh	2,179,029	1.2	15%	2,238,189	1.1	15%
HBO	4,544,240	2.4	31%	4,564,698	2.3	31%
NHB	4,086,304	2.2	28%	4,260,245	2.2	29%
Total	14,477,073	7.7		14,946,094	7.6	

Average Trip Lengths (minutes)

Trip Purpose	A00 (base)	A08 (forecast)	B00 (backcast)	B08 (base)
HBW	21.1	21.4	25.3	25.7
HBSc	9.3	9.8	10.1	10.4
HBSh	10.5	10.5	10.7	10.8
HBO	12.5	13.0	12.5	12.8
NHB	17.3	17.6	17.5	17.7
Total	13.5	14.0	14.5	15.1

Mode Shares

Trip Purpose	Scenario A00 (base)				Scenario A08 (forecast)			
	SOV	HOV	Tr-W	Tr-A	SOV	HOV	Tr-W	Tr-A
HBW	73.5%	14.0%	11.7%	0.8%	72.3%	13.7%	11.7%	2.3%
HBSc	3.8%	93.9%	2.2%	0.0%	3.7%	94.0%	2.2%	0.1%
HBSh	45.1%	53.7%	1.2%	0.0%	45.7%	53.3%	1.0%	0.0%
HBO	35.9%	61.5%	2.5%	0.0%	35.6%	61.6%	2.8%	0.0%
NHB	50.3%	47.8%	1.9%	0.0%	53.2%	49.1%	2.2%	0.0%
Total	46.3%	49.7%	3.9%	0.2%	46.8%	48.6%	4.1%	0.5%
Trip Purpose	Scenario B00 (backcast)				Scenario B08 (base)			
	SOV	HOV	Tr-W	Tr-A	SOV	HOV	Tr-W	Tr-A
HBW	76.0%	13.0%	9.7%	1.4%	74.6%	12.9%	11.0%	1.4%
HBSc	3.6%	94.9%	1.5%	0.0%	3.6%	95.0%	1.4%	0.1%
HBSh	44.7%	53.7%	1.5%	0.0%	45.0%	53.7%	1.3%	0.0%
HBO	39.9%	58.0%	2.0%	0.1%	39.8%	57.7%	2.4%	0.1%
NHB	54.6%	43.7%	1.6%	0.0%	57.4%	44.9%	2.0%	0.0%
Total	48.4%	48.2%	3.1%	0.3%	48.9%	47.2%	3.6%	0.3%

Transit Boardings

	A00 (base)	A08 (forecast)	B00 (backcast)	B08 (base)
Transit boardings	345,659	341,520	271,045	303,213
Transit linked trips	193,286	231,005	168,295	186,628
Transfer rate (boardings per trip)	1.79	1.48	1.61	1.62

Observed boardings: 333,000 (2000), 296,000 (2008)

OKI MODEL RESULTS

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VMT by Facility Type (millions)

Facility Type	C05 (base)	C10 (forecast)	D05 (backcast)	D10 (base)
Freeway	25.5	26.7	24.4	25.0
Expressway	4.8	5.0	3.4	3.5
Ramp	2.2	2.3	2.6	2.6
Arterial/Collector	28.8	30.1	22.1	22.0
Other	11.1	11.7	13.4	13.7
Total	72.4	75.8	65.9	66.7

Average Speeds

Facility Type	C05 (base)	C10 (forecast)	D05 (backcast)	D10 (base)
Freeway	55.3	51.1	53.9	54.5
Expressway	50.0	48.5	50.6	51.0
Ramp	11.9	9.2	39.4	42.3
Arterial/Collector	25.9	25.1	34.2	34.5
Other	18.7	15.6	29.9	29.7
Total	29.6	26.9	39.2	39.6

Main differences are due to improved speed estimates in Model B

Input Data Accuracy Checking

- When the summaries for Model C were initially created, average ramp speeds were very low
- Examination of specific network links indicated incorrectly coded capacities
- Capacities were corrected and Model C rerun
- An exhaustive check of all link capacities was not done

A.M. Peak Corridor Travel Times and Speeds

			Scenario C05 (base)		Scenario C10 (forecast)	
From	Distance (miles)	Free Flow Time (min)	Model Time (min)	Model Speed (mph)	Model Time (min)	Model Speed (mph)
CVG	13.4	18.2	33.0	24.0	53.7	14.8
Eastgate	16.2	20.0	44.9	21.0	58.6	15.9
NKU	7.8	12.3	20.9	19.3	30.9	13.0
Kings Island	23.3	27.1	50.7	27.7	63.3	22.1
Sharonville	15.1	20.0	28.0	30.5	28.7	29.8
			Scenario D05 (backcast)		Scenario D10 (base)	
From	Distance (miles)	Free Flow Time (min)	Model Time (min)	Model Speed (mph)	Model Time (min)	Model Speed (mph)
CVG	13.4	18.2	24.5	32.8	24.3	33.0
Eastgate	16.2	20.0	26.3	36.9	26.7	36.4
NKU	7.8	12.3	15.2	30.8	15.2	30.8
Kings Island	23.3	27.1	33.2	42.1	34.5	40.5
Sharonville	15.1	20.0	26.4	34.3	27.2	33.3

Trip Generation

Trip Purpose	Scenario C05 (base)			Scenario C10 (forecast)		
	Trips	Trips/ Household	% Trips	Trips	Trips/ Household	% Trips
HBW	1,782,633	1.6	19%	1,832,895	1.7	19%
HBNW	4,996,935	4.6	52%	5,110,826	4.6	52%
NHB	2,821,279	2.6	29%	2,888,266	2.6	29%
Total	**9,600,847**	8.7		**9,831,987**	8.9	
	Scenario D05 (backcast)			**Scenario D10 (base)**		
	Trips	**Trips/ Household**	**% Trips**	**Trips**	**Trips/ Household**	**% Trips**
HBW	1,323,615	1.2	15%	1,267,228	1.1	15%
HBNW	4,873,090	4.4	56%	4,989,553	4.5	57%
NHB	2,487,994	2.3	29%	2,448,128	2.2	28%
Total	**8,684,699**	7.9		**8,704,909**	7.8	

Average Trip Lengths (minutes)

Trip Purpose	C05 (base)	C10 (forecast)	D05 (backcast)	D10 (base)
HBW	20.0	20.7	13.0	13.1
HBNW	12.2	12.5	8.1	8.2
NHB	10.0	10.1	8.0	8.0
Total	**13.0**	**13.3**	**8.8**	**8.9**

Speeds are much lower in Model C, and the trip distances are similar between the two models

WHAT WE LEARNED

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Key Observations

- Changes in input data may have effects that dominate the results
  - Example: Higher network speeds in OKI Model D than Model C
  - Example: Higher trip rates in OKI Model D than Model C
- Results for base year scenarios match observed data better than forecasts/backcasts
  - No surprise here, as validation was done mainly considering the base year
- There is *more consistency* between scenarios run using the same model than between scenarios run for the same travel conditions (analysis year)

Lesson #1

Why Are There Changes in Model Parameters Between Model Versions?

- Changes in travel behavior
  - Can be reflected in new survey data
- Errors discovered since previous model update
  - Errors can be corrected (e.g., network coding)
- Model structure may be improved to take advantage of latest research
- Increased computing power can allow for model improvements
  - Example: finer level of geographic detail
- Expanded analytical capabilities
  - Example: Better representation of active transportation demand

Lesson #1 - Impacts

- The effects of these differences can be compounded
- New model may be “better,” but what to do with plans made using older model results?
- Differences in results may not mean one model is more “right”
- Models cannot anticipate everything in forecasting
  - Example – Trip making behavior may change due to variables not available in model
- Whenever a model is updated, the results will change; this does not mean that either the original or updated model results should be considered incorrect

Lesson #2

Accuracy of Data Inputs

- Garbage in, garbage out (we already knew that!)
- The impacts of incorrect input data can be substantial
- Input data need to be checked thoroughly (we already knew that, too)
- The forecasting/backcasting process can help identify “hard to find” errors

Lesson #3

Changes in Assumptions Can Have Unanticipated Effects

- Changing assumptions is usually well-intentioned
  - We want to fix problems when updating a model
- All of the effects of any changes should be examined during the validation of the updated model

Lesson #4
Calibration Changes Should Be Made Only to Improve the Model's Predictive Ability

- Calibration changes may be a necessity
- But matching the base year behavior may not be the most important objective
- Calibration changes are often made to the "weakest" components, or by adjusting those parameters that are easiest to change
- Increasing the influence of parameters that don't reflect policy variables reduces the model's sensitivity to those variables

Lesson #5

Earlier Components Show Greater Accuracy in Forecasting (Maybe)

- Upstream components seem to show more stability in the limited testing done here
  - Example - Overall trip rates appeared to decline in the BMC model region from 2000 to 2008, and both model versions showed such a decline
- We can't conclude this is always the case, though
- May reflect error propagation from earlier components downstream

Lesson #6

Use of Fixed Factors Can Make Models Insensitive to Changes over Time

- These may include many things
  - Time of day percentages
  - Mode choice constants
  - K-factors
- Sometimes fixed factors are necessary
- Implication is that the behavior being modeled is unaffected by the assumptions of the modeled scenario
  - Including that the behavior does not change over time
- When a model is updated, the fixed factors are reestimated
  - …and model results change

SOME RECOMMENDATIONS

Model Validation Should Always Include Temporal Validation and Sensitivity Testing

- We already knew this, too
- Study reinforced that insights can be provided well beyond what can be learned only from comparisons of base year model results to observed data

Temporal Model Validation Should Include a Backcast and/or a Forecast Year Application

- Can provide a valuable "second (or third) data point" for comparing model results to observed data
- A backcast can help identify the effects of changes in model assumptions and procedures from the previous model version

Recognize That Changes in Model Procedures, Assumptions, and Input Data Can Change Model Results

- Can go well beyond changes in travel behavior over time
- Effects on model results and forecasts can be examined during the model update process
- Differences should be documented
- Be prepared to deal with these differences when presenting model results

Model Inputs Need to Be Thoroughly Checked During Model Development and Validation

- Also not a new recommendation
- This study reinforces it and has helped in understanding the possible effects of such errors

Estimate Effects of Changes in Calibrated Parameters

- Whenever model parameters are changed or recalibrated during validation, the effects of these changes should be estimated if possible
- They should be recognized in any case
- Sensitivity tests can be structured to examine such effects

Recognize Effects of Error Propagation

- Recognize the effects of error propagation from model components to subsequent components
- Test for error propagation whenever possible
- Understand that downstream components may have more error associated with them than upstream components

Test Sensitivity Effects of Fixed Factors

- If it is necessary to use fixed factors or constants in models, recognize and test for the effects of model sensitivity of such factors
- When using results of models that use fixed factors, recognize the limitations associated with insensitivity to factors that are not included in the models

WHAT NEXT?

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Extending the Study to More Regions and Models

- Regions with faster growth rates
- Regions where there have been substantial changes in the transportation system
- Regions where the model update included more substantial changes in model structure
- Regions where the level of highway congestion is greater
- Regions with higher levels of non-auto travel
- Regions with a variety of managed lanes and toll roads

Deeper Dive into Model Results

- Look at results by more segments
  - Geographic subregions
  - Land use area types
  - Demographic segments (e.g., income levels)
- More detailed analysis of sensitivity to specific input variables
  - Example – if transit fares changed significantly between the two analysis years, mode choice model results could be examined in more detail to estimate the effects of the fare change on transit demand, perhaps by examining segments of the model where there were few other changes in transit service

THANK YOU AND HAPPY HOLIDAYS!

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