



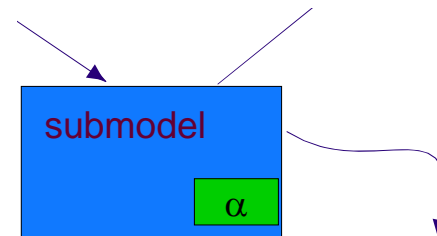
# Semi-Automated Calibration of Integrated Land Use Transport Models

---

John E. Abraham, J. Douglas Hunt  
University of Calgary

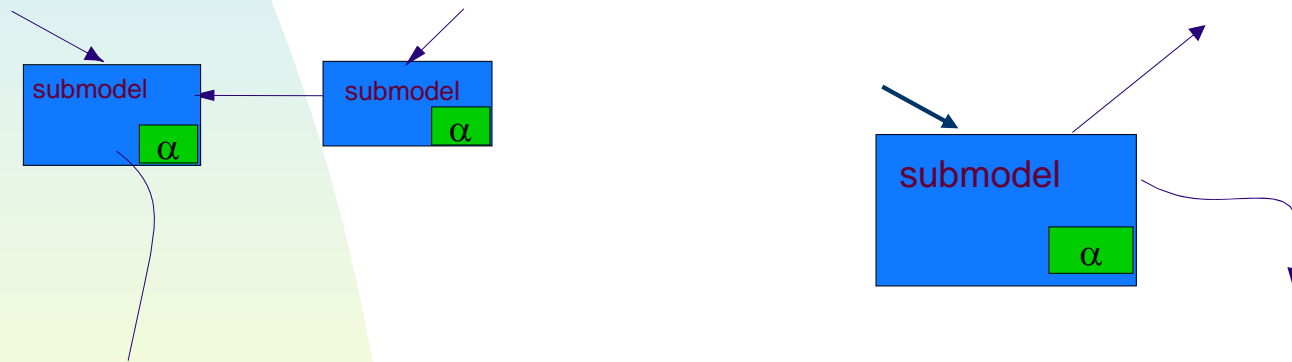
# Introduction

- Calibration of Land Use/Transport Models tends to be difficult
  - ◆ involves parameter estimation and design changes
- Everything connected to everything else



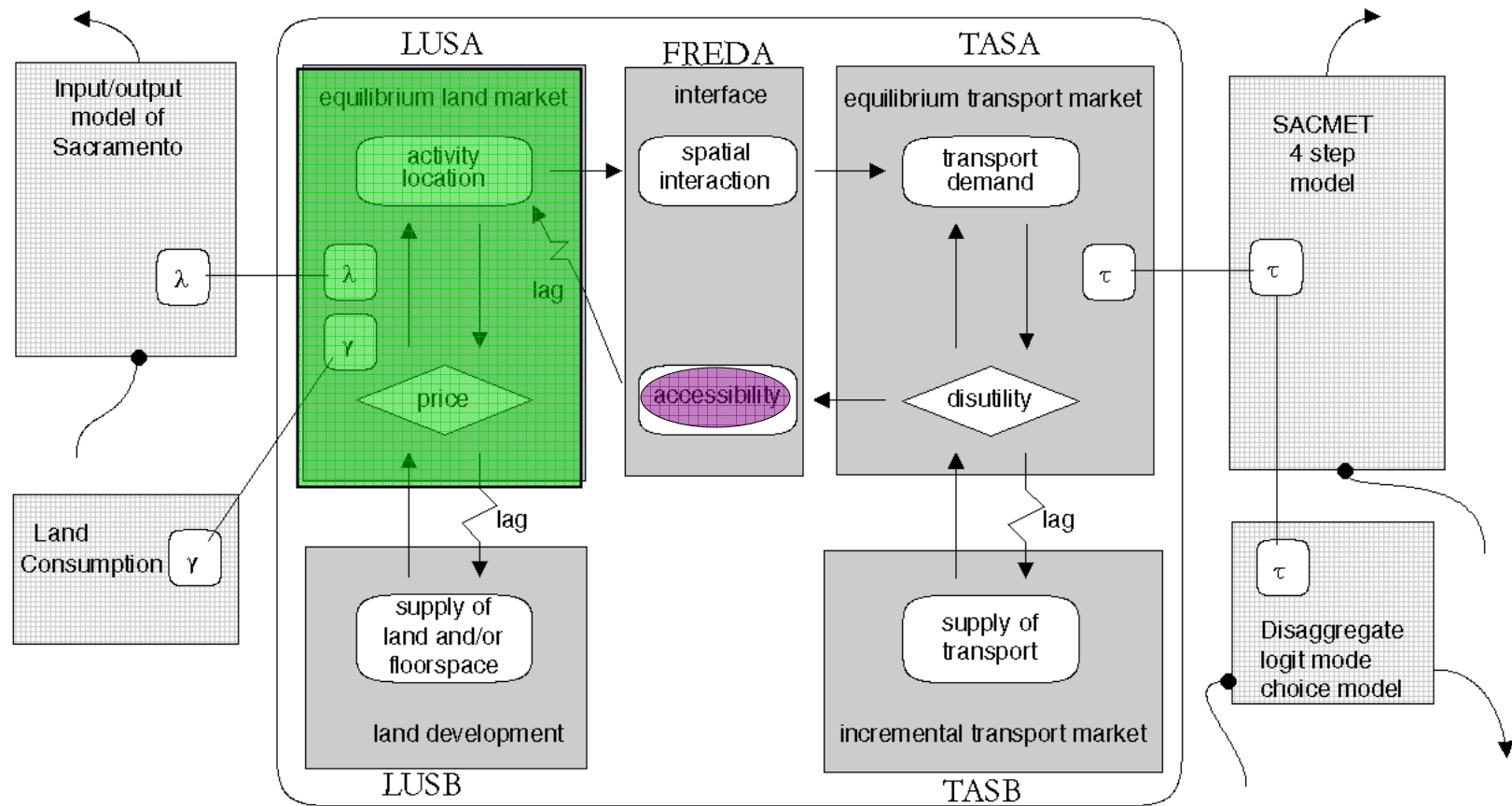
# Calibrate individual relationships

- Look at a portion of the model
  - ◆ substitute observed data to enable parameter estimation - appreciate differences!



- Explore relationships using other models
  - ◆ e.g. aggregate vs. disaggregate, conditional choice

# Models and submodels for Sacramento MEPLAN



# Overall calibration necessary

- Use relationships in the model to overcome data limitations
- Correct for biases caused by circular connections between non-linear models
- Like "validation"
  - ◆ except more formal and more thorough

# Targets and parameters for overall calibration

- Influenced by the entire model
  - ◆ e.g., trip length distributions, ground counts
- Bias correction
  - ◆ Mode shares, elasticities
- Parameters should include those that influence important targets
- Targets should include those that can confirm/adjust unsettled parameters

# Targets for Sacramento MEPLAN

Target	Number of targets	Weight
Portion of trips by private auto	5	4.1
HOV vs SOV Mode Split	5	2.2
Walk, Cycle use	2	5.77
Trip length distributions	38	0.75
Non-Auto OD Matrix	3,249	2
Auto OD Matrix	3,249	2



# Parameters for Sacramento MEPLAN

- Mode specific constants
- Mode choice dispersion parameters
- Location choice dispersion parameters

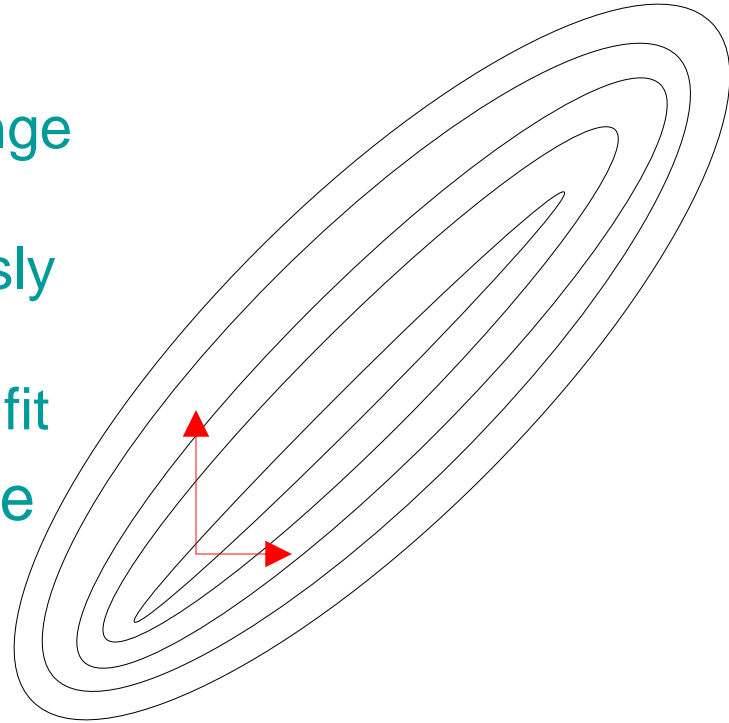


# "Hand" estimation

- Subjective
- Time consuming
  - ◆ inhibits design changes
- Not repeatable
  - ◆ difficulty in verifying calibration
- Analyst becomes intimate with the model
  - ◆ understands reasons for lack of fit
  - ◆ can identify necessary design changes

# Hand calibration difficulties

- Multiple correlations
  - ◆ need to change parameters simultaneously to improve goodness of fit
- More than three dimensions at once difficult



# Objective function

- Weighted least squares
  - ◆ LUTI models are too complex to support much else
  - ◆ can transform targets so errors distributions approach independent Normal
- Weights can be based on hypothesis
  - ◆ but subject to ad-hoc adjustment
    - ☞ influenced by model's purpose and use

# Search process

- Run the model many times
  - ◆ perturbing one parameter each time to numerically evaluate partial derivatives
  - ◆ choosing a direction
  - ◆ trying a new set of parameters
- Levenberg-Marquardt method
  - ◆ adjusts step size appropriately to blend Newton's method and Steepest Descent

# Search software

Calibration Strategy

File Parameters Targets Calibration

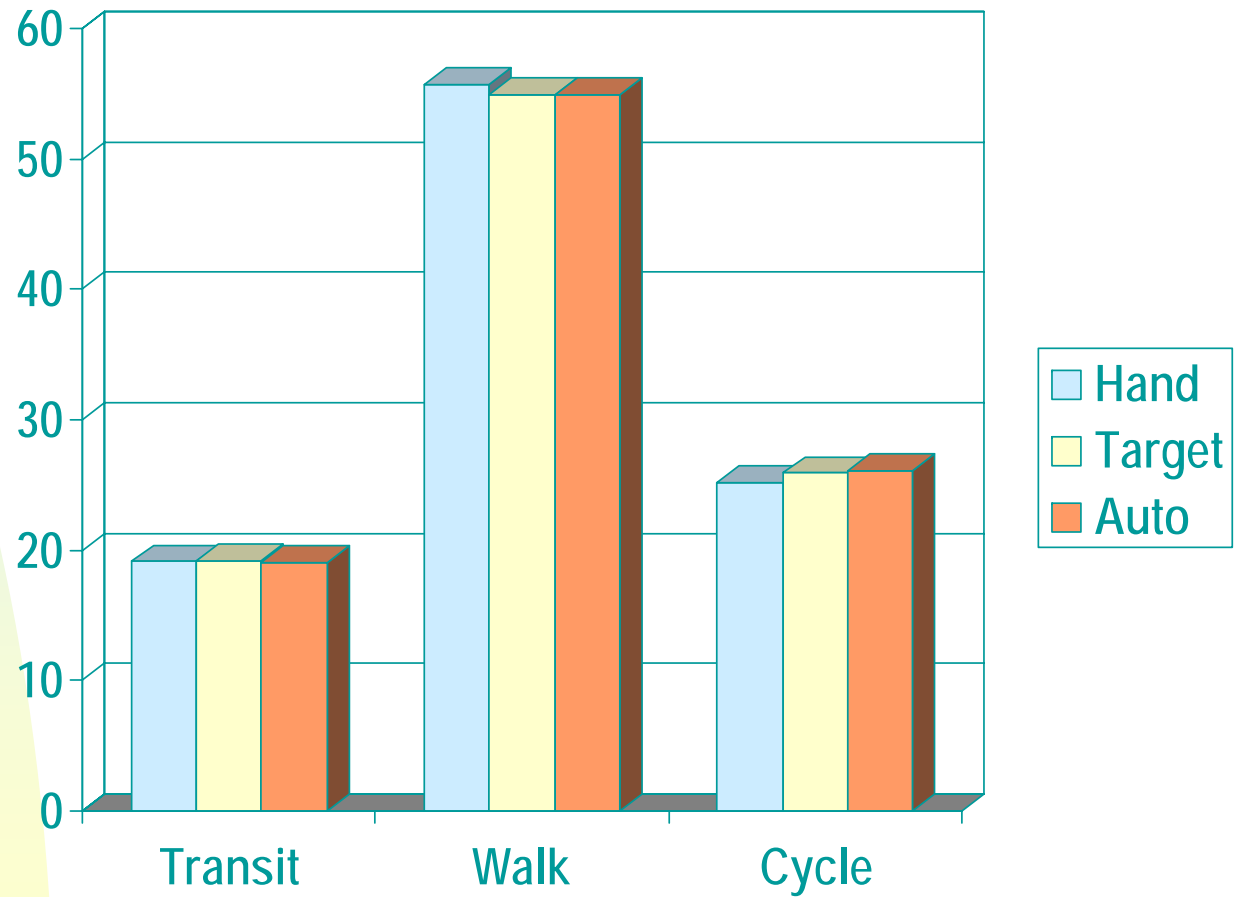
Goodness of Fit

Description	value	MinChange	MaxChange	RmsChange
MSC Diff, eg...	1.826790000...	-0.08627930...	0.076437273...	0.001855780...
ModeSC 2 1	3.087839	-0.07394210...	0.047110601...	0.001473840...
ModeSC 2 2	4.151642	-0.04930684...	0.025952518...	9.587963482...
ModeSC 2 3	4.865025999...	-0.08567856...	0.039509572...	0.001513455...
ModeSC 2 4	6.531736	-0.09173496...	0.139441345...	0.003558291...
ModeSC 2 5...	4.410809	-0.05013500...	0.031396809...	0.001117686...
ModeSC 3 4	5.029655	-0.05429577...	0.074576271...	0.001404283...
ModeSC 3 5	4.801957	-0.03744120...	0.020219041...	9.260987921...
ModeSC 3 6	4.537281	-0.05074561...	0.034014319...	0.001209535...
ModeSC 3 7	4.547745	-0.06178401...	0.039596498...	0.001278045...
ModeSC 4 1...	4.554701000...	-0.08460453...	0.101510578...	0.002186274...
ModeSC 5 1...	5.769527000...	-0.03994860...	0.058431600...	0.001474246...
MEPLAN Pa...	1.326003999...	-0.09157385...	0.056425282...	0.002050172...
MEPLAN Pa...	0.002179	-2.51363770...	1.529169933...	5.290980191...
MEPLAN Pa...	0.005466	-7.74708150...	5.716180748...	1.235209083...
MEPLAN Pa...	0.015817	-0.00562362...	0.003992239...	1.016309972...
MEPLAN Pa...	0.015399	-0.00656810...	0.017884827...	3.418290121...
MEPLAN Pa...	0.002657	-2.19365504...	6.290719896...	3.706137596...

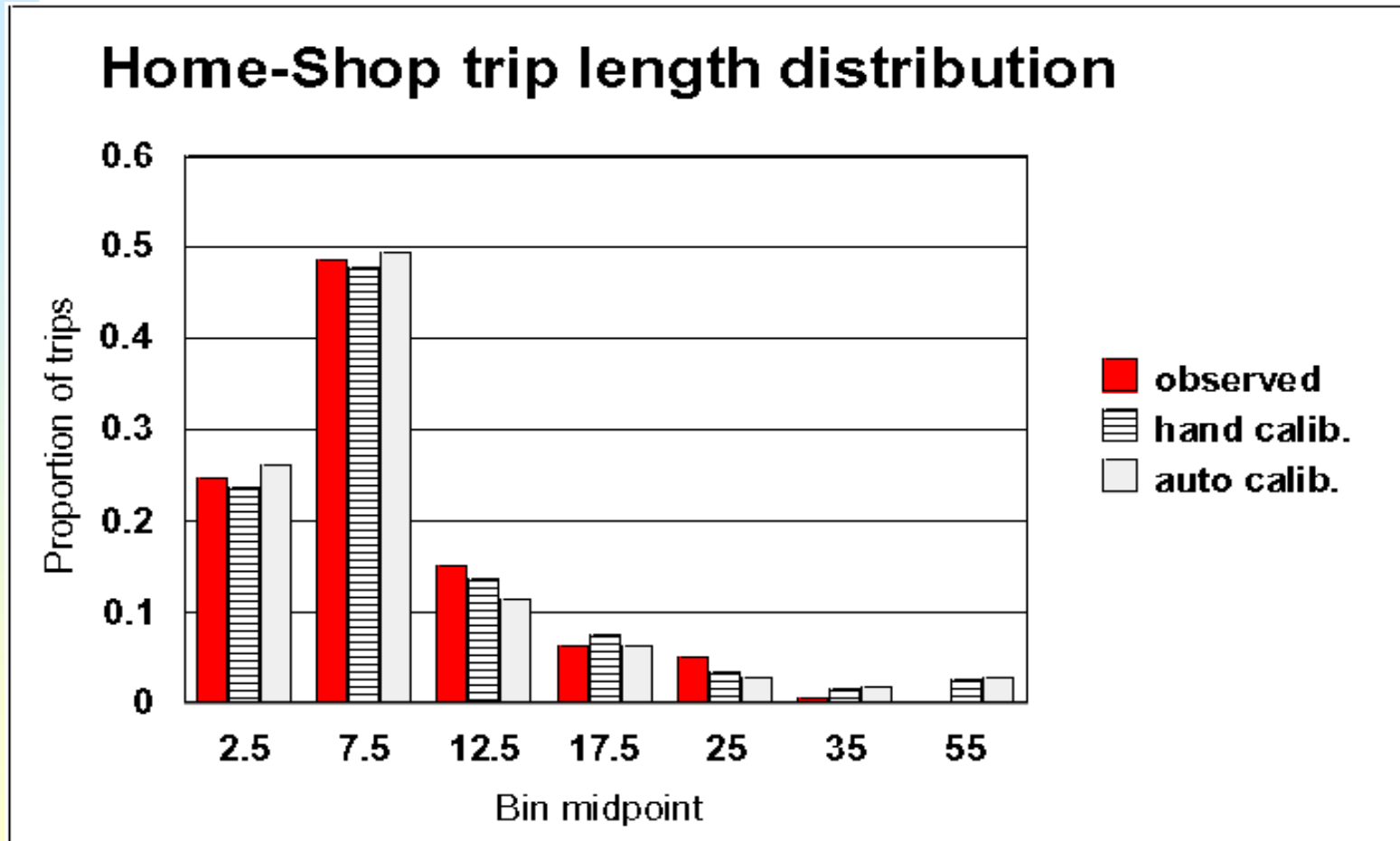
Targets

- Ratio target0.1937788986969315 val:0.18763852612648702 wt0.75(targ: 0.0 val: 5808.1184149980545 wt: 1.0f: 6 um: 2 bound
- Ratio target0.387557797393863 val:0.38154455177306157 wt0.75(targ: 0.0 val: 11810.239522993565 wt: 1.0f: 6 um: 2 bound
- Ratio target0.2100969206232364 val:0.15321787426467004 wt0.75(targ: 0.0 val: 4742.66972457245 wt: 1.0f: 6 um: 2 bound
- Ratio target0.09688944934846574 val:0.14938448196843485 wt0.75(targ: 0.0 val: 4624.011809019081 wt: 1.0f: 6 um: 2 bound
- Ratio target0.07904089008489354 val:0.07008299116896854 wt0.75(targ: 0.0 val: 2169.332279407481 wt: 1.0f: 6 um: 2 bound
- Ratio target0.032636043852609854 val:0.022772916146224002 wt0.75(targ: 0.0 val: 704.9074428506677 wt: 1.0f: 6 um: 2 bou
- Ratio target0.0 val:0.005566256494066255 wt0.75(targ: 0.0 val: 172.2965827603839 wt: 1.0f: 6 um: 2 bounds:40.0 - 50.0)/(te
- Ratio target0.0 val:0.029792402058087662 wt0.75(targ: 0.0 val: 922.1869441884244 wt: 1.0f: 6 um: 2 bounds:50.0 - Infinity)/(te

# Mode choice goodness of fit



# TLD goodness of fit



# Convergence

- Minimize

$$S(\mathbf{x}) = [\Lambda \cdot (\mathbf{y} - \mathbf{y}_m(\mathbf{x}))]^T \cdot [\Lambda \cdot (\mathbf{y} - \mathbf{y}_m(\mathbf{x}))]$$

- Assume linear

$$\mathbf{y}_m(\mathbf{x}) \approx \mathbf{y}_m(\mathbf{x}_0) + \mathbf{F} \cdot \Delta \mathbf{x}$$

- Normal conditions (at convergence)

$$0 = \mathbf{F}^T \cdot \Lambda^2 \cdot (\mathbf{y} - \mathbf{y}_m(\mathbf{x}))$$



# Weight Sensitivity

- Parameter sensitivity to weights

$$\Delta \mathbf{x} = [F^T \cdot \Lambda \cdot F]^{-1} \cdot F^T \cdot \delta \Lambda^2 \cdot (\mathbf{y} - \mathbf{y}_m(\mathbf{x}_0))$$

- Target sensitivity to weights

$$\mathbf{y}_m(\mathbf{x}) \approx \mathbf{y}_m(\mathbf{x}_0) + F \cdot [F^T \cdot \Lambda \cdot F]^{-1} \cdot F^T \cdot \delta \Lambda^2 \cdot (\mathbf{y} - \mathbf{y}_m(\mathbf{x}_0))$$



# Interactive Investigation of lack-of-fit

- Lack of fit at convergence is due to other targets "pulling" in other directions
- Software identifies those other targets

TT Dependencies for Ratio target0.356808 val:0.30648583533319124 wt0.75(targ: 0.0 val: 1713.65970301882 wt: 1.0f: 4 um: 2 bounds: 15.0 - 20.0)

A	B
Ratio target0.1003 val:0.10167581577295191 wt4.0824(Volume target0.0val:3158.0 wt1.0 m: 1 5 9 f: 1)/(Volume target0.0val:31059.5 wt1.0 m: 1 3 5 9 f: 1)	0.002867463768615201
Ratio target0.075117 val:0.056473486034330805 wt0.75(targ: 0.0 val: 315.76120704181955 wt: 1.0f: 4 um: 2 bounds:15.0 - 20.0)/(targ: 0.0 val: 5591.317788490427 wt: 1.0f: 4 um: 2 bounds:-Infinity - 5.0)	-2.3610416809056016...
Ratio target0.366197 val:0.4315594884501052 wt0.75(targ: 0.0 val: 2412.9862445629024 wt: 1.0f: 4 um: 2 bounds:5.0 - 10.0)/(targ: 0.0 val: 5591.317788490427 wt: 1.0f: 4 um: 2 bounds:-Infinity - 5.0)	1.8265261273492627...
Ratio target0.356808 val:0.30648583533319124 wt0.75(targ: 0.0 val: 1713.65970301882 wt: 1.0f: 4 um: 2 bounds:-Infinity - 5.0)/(targ: 0.0 val: 5591.317788490427 wt: 1.0f: 4 um: 2 bounds:-Infinity - 5.0)	1.6519487280862587...
Ratio target0.21925600000000003 val:0.23983801836819274 wt0.75(targ: 0.0 val: 6096.193789193407 wt: 1.0f: 7 um: 2 bounds:-Infinity - 5.0)/(targ: 0.0 val: 25417.962634408934 wt: 1.0f: 7 um: 2 bounds:-Infinity - 5.0)	1.6080729252107825...
Ratio target0.20439340878681755 val:0.2238916611423909 wt0.75(targ: 0.0 val: 24967.804871747503 wt: 1.0f: 1 2 3 um: 2 bounds:5.0 - 10.0)/(targ: 0.0 val: 111517.35059872751 wt: 1.0f: 1 2 3 um: 2 bounds:20.0 - 30.0)	-1.5611200933334494...
Ratio target0.387557797393863 val:0.38960148175478654 wt0.75(targ: 0.0 val: 12055.977822482586 wt: 1.0f: 6 um: 2 bounds:5.0 - 10.0)/(targ: 0.0 val: 30944.38390783782 wt: 1.0f: 6 um: 2 bounds:5.0 - 10.0)	1.492879657427513E-4
Ratio target0.178571 val:0.171399381057997 wt2.236(Volume target0.0val:23067.7 wt1.0 m: 8 f: 1 2 3)/(Volume target0.0val:134584.5 wt1.0 m: 3 f: 1 2 3)	-1.2407455492661373...
Ratio target0.21728743457486915 val:0.1819727883092032 wt0.75(targ: 0.0 val: 20293.123233305436 wt: 1.0f: 1 2 3 um: 2 bounds:20.0 - 30.0)/(targ: 0.0 val: 111517.35059872751 wt: 1.0f: 1 2 3 um: 2 bounds:20.0 - 30.0)	1.1531279689459847...
Ratio target0.1058 val:0.10705106061994628 wt4.0824(Volume target0.0val:15185.3 wt1.0 m: 1 5 9 f: 5 6 7)/(Volume target0.0val:141851.0 wt1.0 m: 1 3 5 9 f: 5 6 7)	-1.1527275011423608...
Ratio target0.0789 val:0.08031085440074429 wt4.0824(Volume target0.0val:3936.3 wt1.0 m: 1 5 9 f: 3)/(Volume target0.0val:49013.3 wt1.0 m: 1 3 5 9 f: 3)	9.943173470985586E-5
Ratio target0.484848 val:0.49188347391254766 wt0.75(targ: 0.0 val: 2149.544191679801 wt: 1.0f: 5 um: 2 bounds:5.0 - 10.0)/(targ: 0.0 val: 4370.02726394091 wt: 1.0f: 5 um: 2 bounds:-Infinity - 5.0)	9.846203736986249E-5
Ratio target0.38131600000000004 val:0.3762467140682558 wt0.75(targ: 0.0 val: 9563.42491950607 wt: 1.0f: 7 um: 2 bounds:5.0 - 10.0)/(targ: 0.0 val: 25417.962634408934 wt: 1.0f: 7 um: 2 bounds:5.0 - 10.0)	-9.58647415858446E-5
Ratio target0.09628200000000002 val:0.09917101028331811 wt0.75(targ: 0.0 val: 2520.725033797964 wt: 1.0f: 7 um: 2 bounds:15.0 - 20.0)/(targ: 0.0 val: 25417.962634408934 wt: 1.0f: 7 um: 2 bounds:15.0 - 20.0)	9.092455155770748E-5
Ratio target0.16347069788772206 val:0.16355894837960483 wt2.0(targ: 0.0 val: 100155.59311265656 wt: 1.0f: 1 2 3 4 5 6 7 um: 1 5 4 o: 52 d: 52)/(targ: 0.0 val: 612351.6573376646 wt: 1.0f: 1 2 3 4 5 6 7 um: 1 5 4 o: 52 d: 52)	-9.030268414254935E...

Description	value	Mi...	M...	R...
MSC Diff, eg. ModeSC 31-ModeSC 21	1.7662492...	-0...	0...	0...
ModeSC 21	3.0694498...	-0...	0...	7...
ModeSC 22	4.1685934...	-0...	0...	4...
ModeSC 23	4.9125405...	-0...	0...	0...
ModeSC 24	6.5703804...	-0...	0...	0...
ModeSC 25 6 7	4.4051196...	-0...	0...	6...
ModeSC 34	5.0020226...	-0...	0...	4...
ModeSC 35	4.8218803...	-0...	0...	5...
ModeSC 36	4.5230407...	-0...	0...	7...
ModeSC 37	4.5406674...	-0...	0...	7...
ModeSC 41 2 3 4 5 6 7	4.5325140...	-0...	0...	0...
ModeSC 5 1 2 3 4 5 6 7	5.7715145...	-0...	0...	8...
MEPLAN Parameter UTP{7}{1}{2}{3}{4}{5}{6}{7}	1.3174480...	-0...	0...	0...
MEPLAN Parameter ULP{1}{1}{2}{7}{14}	0.0025844...	-2...	1...	4...
MEPLAN Parameter ULP{1}{3}{5}	0.0064288...	-6...	3...	1...
MEPLAN Parameter ULP{1}{6}	0.0162687...	-0...	0...	8...
MEPLAN Parameter ULP{1}{4}	0.0120549...	-0...	0...	8...
MEPLAN Parameter ULP{1}{11}{12}{13}	0.0035548...	-2...	2...	6...

Targets
<input type="checkbox"/> tjmodel.meplan.calibration.Ratio
<input type="checkbox"/> TLD m 2 f 4
<input type="checkbox"/> Ratio target0.356808 val:0.30648583533319124 wt0.75(targ: 0.0 val: 1713.65970301882 wt: 1.0f: 4 um: 2 bounds:-Infinity - 5.0)/(targ: 0.0 val: 5591.317788490427 wt: 1.0f: 4 um: 2 bounds:-Infinity - 5.0)
<input type="checkbox"/> Ratio target0.366197 val:0.4315594884501052 wt0.75(targ: 0.0 val: 2412.9862445629024 wt: 1.0f: 4 um: 2 bounds:5.0 - 10.0)/(targ: 0.0 val: 5591.317788490427 wt: 1.0f: 4 um: 2 bounds:-Infinity - 5.0)
<input type="checkbox"/> Ratio target0.150235 val:0.14036124234711006 wt0.75(targ: 0.0 val: 784.8043111500124 wt: 1.0f: 4 um: 2 bounds:10.0 - 15.0)/(targ: 0.0 val: 111517.35059872751 wt: 1.0f: 1 2 3 um: 2 bounds:20.0 - 30.0)
<input type="checkbox"/> Ratio target0.075117 val:0.056473486034330805 wt0.75(targ: 0.0 val: 315.76120704181955 wt: 1.0f: 4 um: 2 bounds:15.0 - 20.0)/(targ: 0.0 val: 5591.317788490427 wt: 1.0f: 4 um: 2 bounds:-Infinity - 5.0)
<input type="checkbox"/> Ratio target0.051643 val:0.019428469468529542 wt0.75(targ: 0.0 val: 108.63074694253238 wt: 1.0f: 4 um: 2 bounds:20.0 - 30.0)/(targ: 0.0 val: 25417.962634408934 wt: 1.0f: 7 um: 2 bounds:5.0 - 10.0)
<input type="checkbox"/> Ratio target0.0 val:0.04569147836673364 wt0.75(targ: 0.0 val: 255.47557577434333 wt: 1.0f: 4 um: 2 bounds:30.0 - Infinity)/(targ: 0.0 val: 25417.962634408934 wt: 1.0f: 7 um: 2 bounds:5.0 - 10.0)
<input type="checkbox"/> TLD m 2 f 5
<input type="checkbox"/> TLD m 2 f 1 2 3
<input type="checkbox"/> TLD m 2 f 7
<input type="checkbox"/> ODMatrix m 1 5 4 f 1 2 3 4 5 6 7
<input type="checkbox"/> ODMatrix m 2 3 f 2 1 3 4 5 6 7
<input type="checkbox"/> TLD m 2 f 6

# Response to unacceptable of lack-of-fit

- Change weights
  - ◆ emphasize one target to force fit, understanding what other targets will be sacrificed
- Change design
  - ◆ Model as specified just isn't good enough
  - ◆ Add to, enhance or change the model's design
    - ☞ e.g. Davis students for mode choice
    - ☞ e.g. Splitting Office-Services

# Conclusions

- Faster calibration
  - ◆ or better calibration
- Enable design changes
- Benefits from substantial computing resources
- More complete than "validation"
- More objective & transparent
- More interactive
  - ◆ ability to explore lack-of-fit