# Semi-Automated Calibration of Integrated Land Use Transport Models

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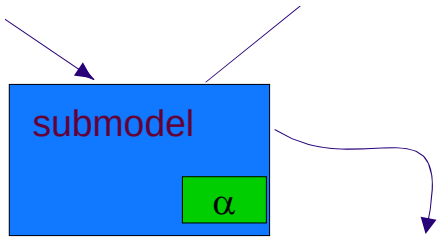
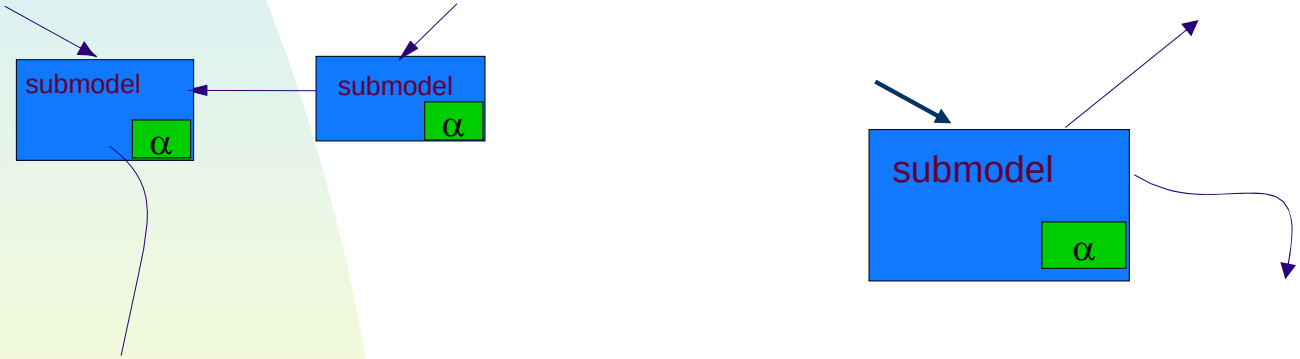
# Introduction

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



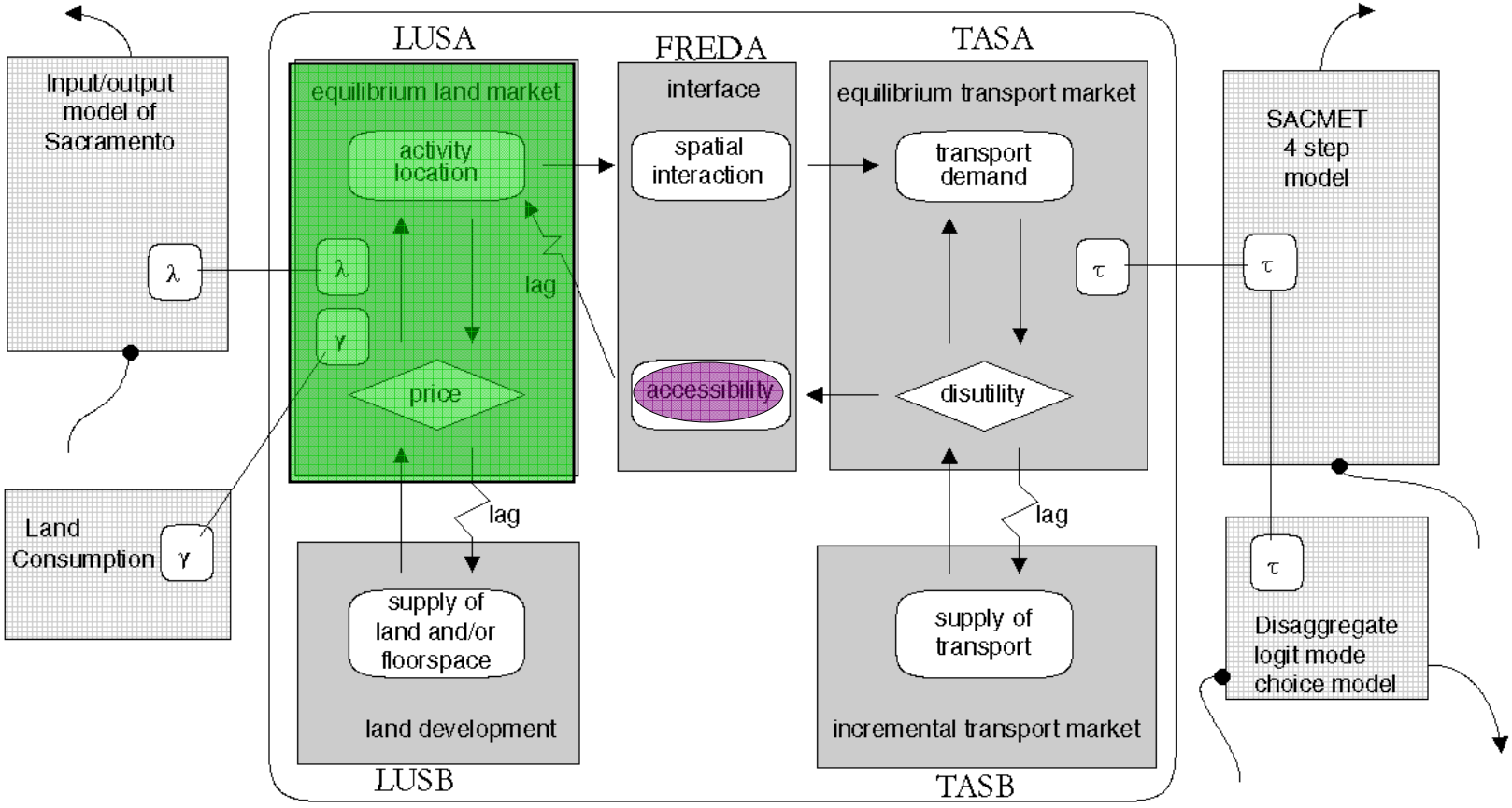
# Calibrate individual relationships

- 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

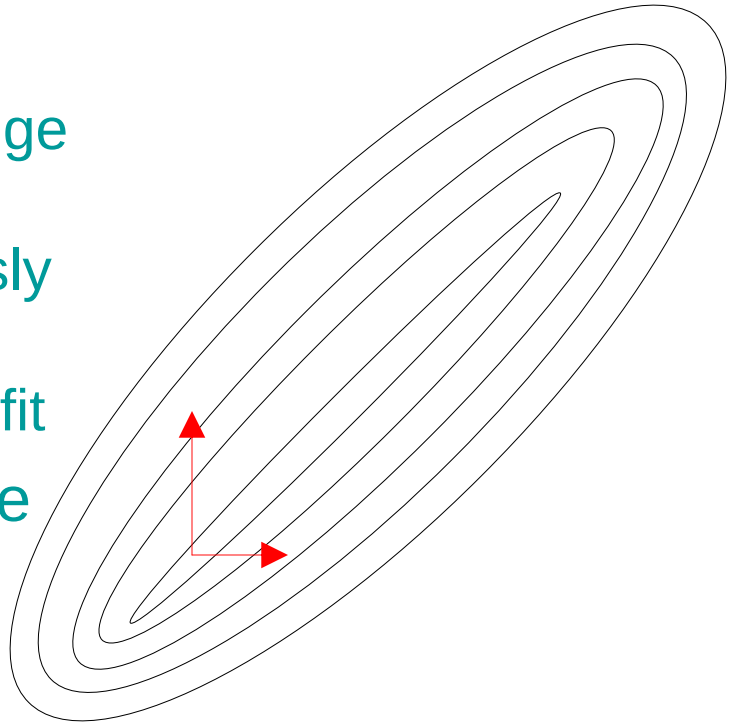
- Mode specific constants
- Mode choice dispersion parameters
- Location choice dispersion parameters

# "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



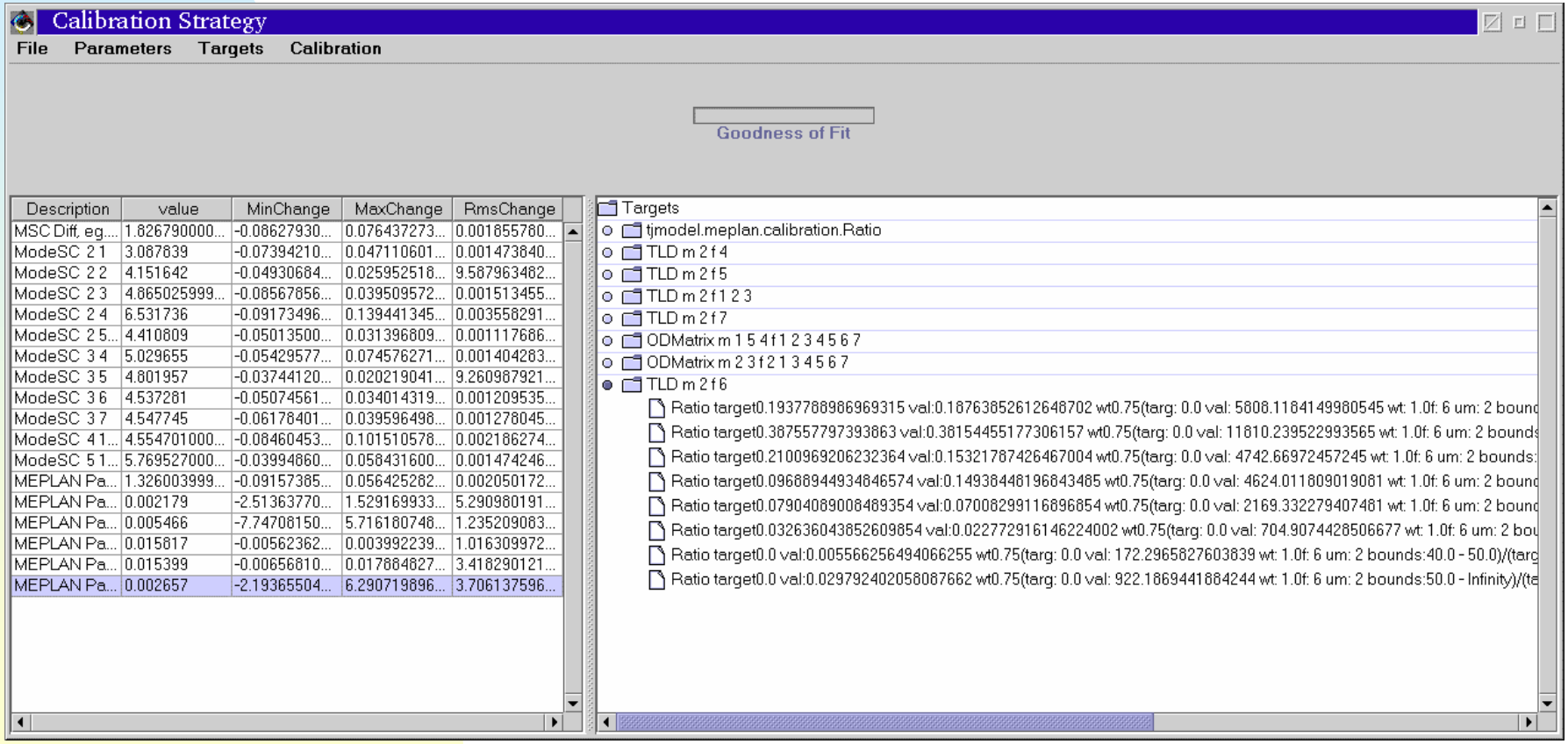
# Objective function

- 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

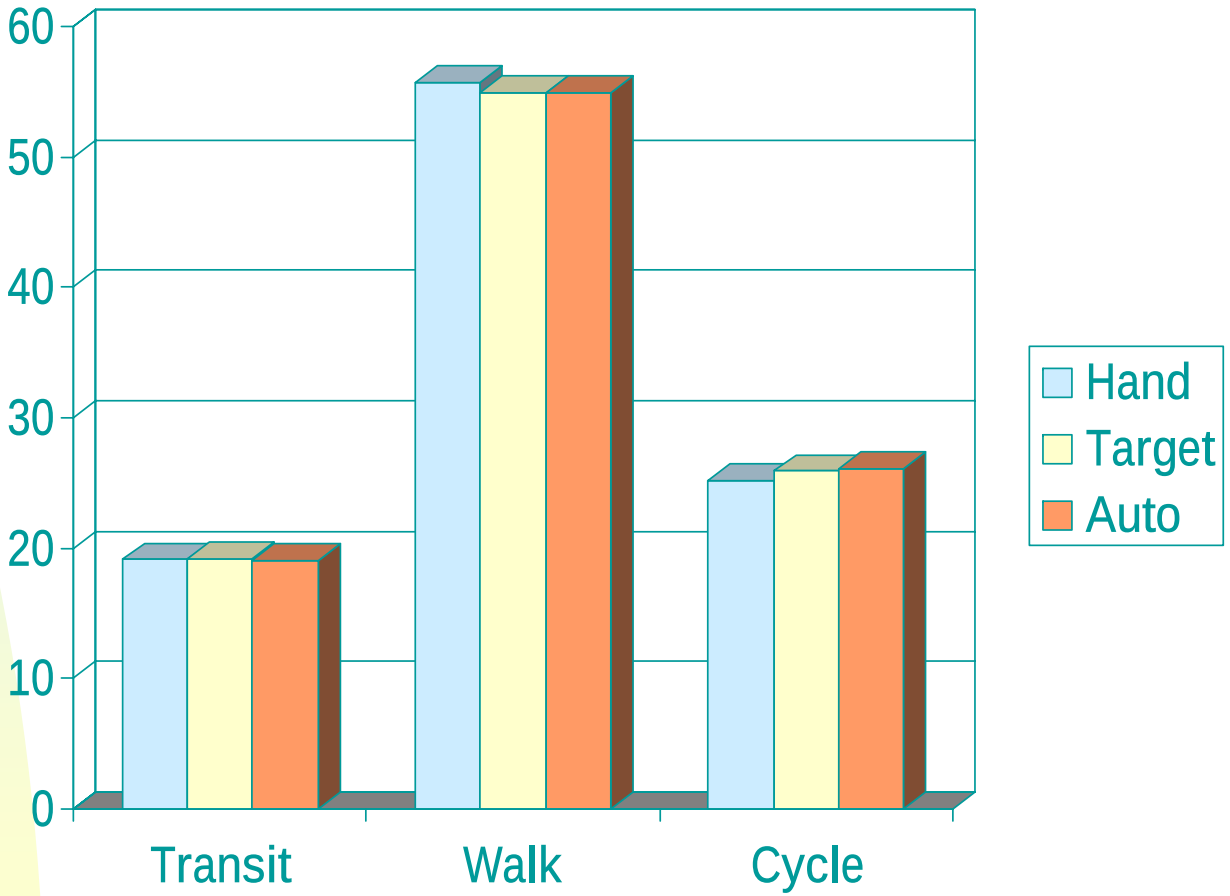
# Search process

- 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

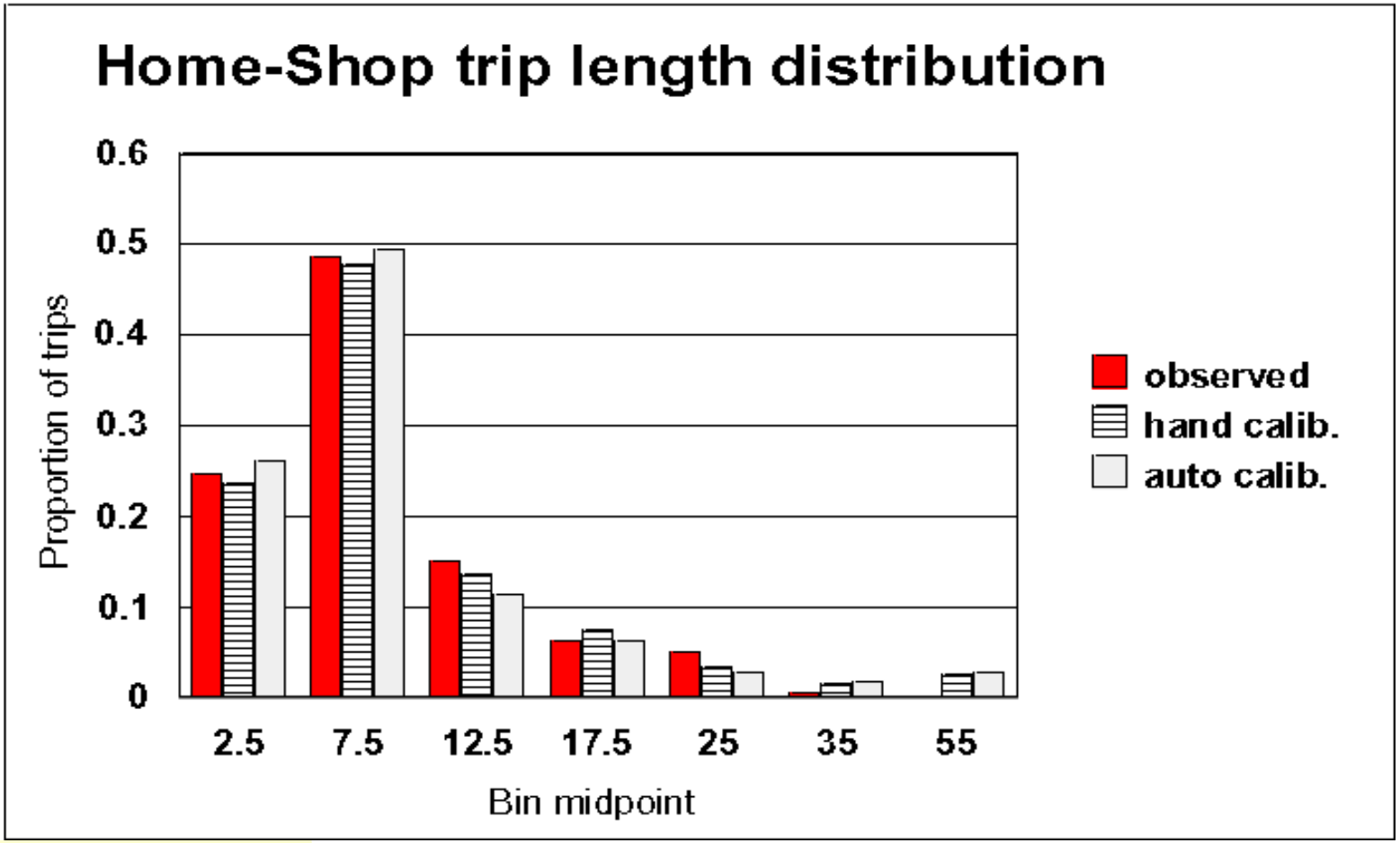
# Search software



# Mode choice goodness of fit



# TLD goodness of fit



# Convergence

- Minimize

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

- Assume linear

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

- Normal conditions (at convergence)

$$0 = F^T \cdot \Lambda^2 \cdot (y - y_m(x))$$

# Weight Sensitivity

- Parameter sensitivity to weights

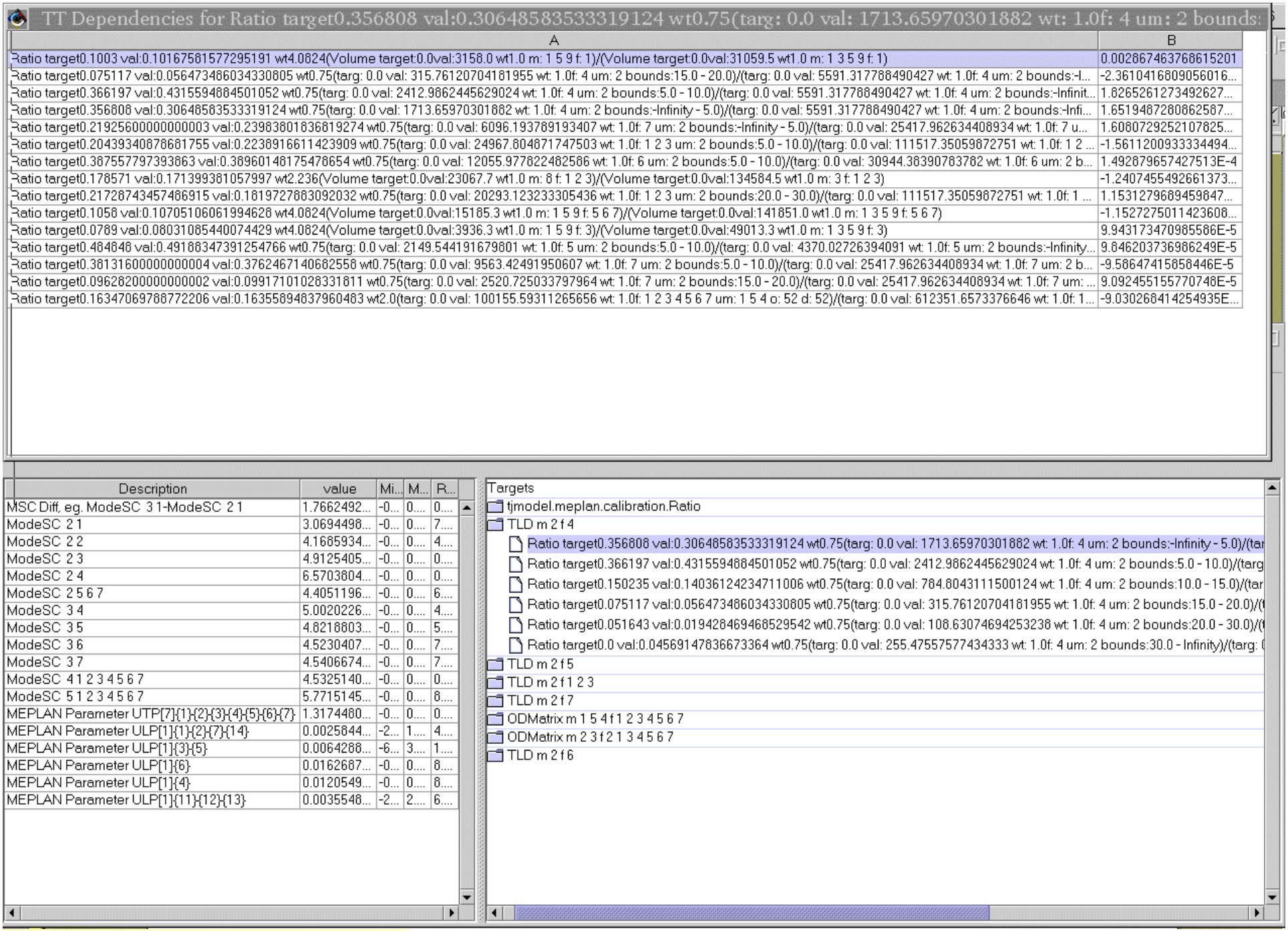
$$\Delta x = [F^T \cdot \Lambda \cdot F]^{-1} \cdot F^T \cdot \delta\Lambda^2 \cdot (y - y_m(x_0))$$

- Target sensitivity to weights

$$y_m(x) \approx y_m(x_0) + \boldsymbol{F} \cdot [F^T \cdot \Lambda \cdot F]^{-1} \cdot F^T \cdot \delta\Lambda^2 \cdot (y - y_m(x_0))$$

# 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:
A
B
Ratio target0.1003 val:0.10167581577295191 wt4.0824(Volume target:0.0val:3158.0 wt1.0 m: 1 5 9 f: 1)/(Volume target:0.0val:31059.5 wt1.0 m: 1 3 5 9 f: 1) 0.002867463766815201
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:-I... -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:-Infinit... 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:-Infi... 1.6519487280862587...
Ratio target0.21925600000000003 val:0.23983601836819274 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 u... 1.6080729252107825...
Ratio target0.20439340878681755 val:0.22389166111423909 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 ... -1.5611200933334494...
Ratio target0.387557797393863 val:0.38960146175478654 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 b... 1.492879657427513E-4
Ratio target0.178571 val:0.1713993810579 97 wt2.236(Volume target:0.0val:23067.7 wt1.0 m: 8 f: 1 2 3)/(Volume target:0.0val:134584.5 wt1.0 m: 3 f: 1 2 3) -1.2407455492661373...
Ratio target0.21728743457486915 val:0.18197278830920 32 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 ... 1.1531279689459847...
Ratio target0.1058 val:0.10705106061994628 wt4.0824(Volume target:0.0val:15185.3 wt1.0 m: 1 5 9 f: 5 6 7)/(Volume target:0.0val:141851.0 wt1.0 m: 1 3 5 9 f: 5 6 7) -1.1527275011423608...
Ratio target0.0789 val:0.08031085440074429 wt4.0824(Volume target:0.0val:3936.3 wt1.0 m: 1 5 9 f: 3)/(Volume target:0.0val: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... 9.846203736986249E-5
Ratio target0.381316000000000004 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 b... -9.58647415858446E-5
Ratio target0.09628200000000002 val:0.09917101028331811 wt0.75(targ: 0.0 val: 2520.7250337979 64 wt: 1.0f: 7 um: 2 bounds:15.0 - 20.0)/(targ: 0.0 val: 25417.962634408934 wt: 1.0f: 7 um: ... 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... -9.030268414254935E...
Description
value
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MSC Diff, eg. ModeSC 3 1-ModeSC 2 1 1.7662492... -0... 0.... 0....
ModeSC 2 1 3.0694498... -0... 0.... 7....
ModeSC 2 2 4.1685934... -0... 0.... 4....
ModeSC 2 3 4.9125405... -0... 0.... 0....
ModeSC 2 4 6.5703804... -0... 0.... 0....
ModeSC 2 5 6 7 4.4051196... -0... 0.... 6....
ModeSC 3 4 5.0020226... -0... 0.... 4....
ModeSC 3 5 4.8218803... -0... 0.... 5....
ModeSC 3 6 4.5230407... -0... 0.... 7....
ModeSC 3 7 4.5406674... -0... 0.... 7....
ModeSC 4 1 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
tjmodel.meplan.calibration.Ratio
TLD m 2 f 4
Ratio target0.356808 val:0.30648583533319124 wt0.75(targ: 0.0 val: 1713.65970301882 wt: 1.0f: 4 um: 2 bounds:-Infinity - 5.0)/(tar
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
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)/(tar
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)/(t
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)/(t
Ratio target0.0 val:0.045691478366733 64 wt0.75(targ: 0.0 val: 255.47557577434333 wt: 1.0f: 4 um: 2 bounds:30.0 - Infinity)/(targ: (
TLD m 2 f 5
TLD m 2 f 1 2 3
TLD m 2 f 7
ODMatrix m 1 5 4 f 1 2 3 4 5 6 7
ODMatrix m 2 3 f 2 1 3 4 5 6 7
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 sacraficed
- 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