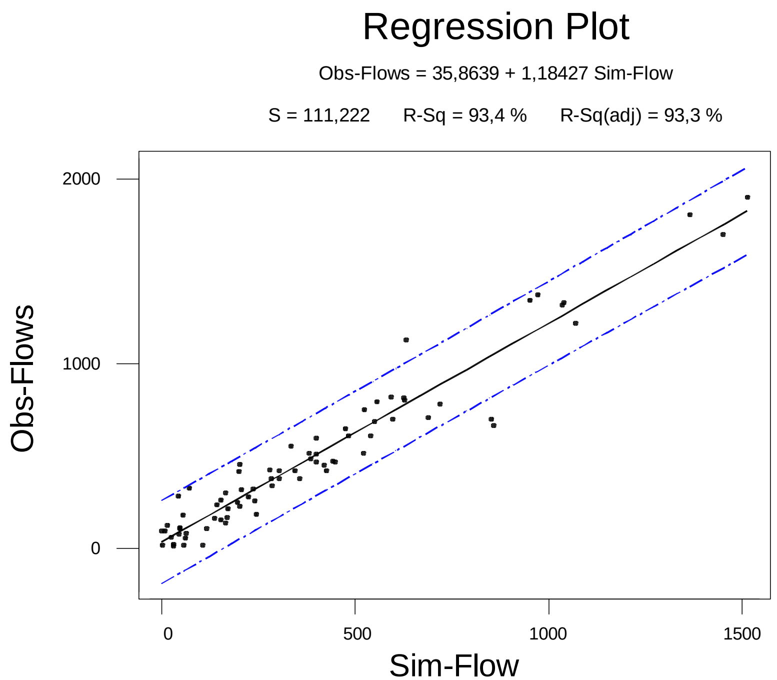
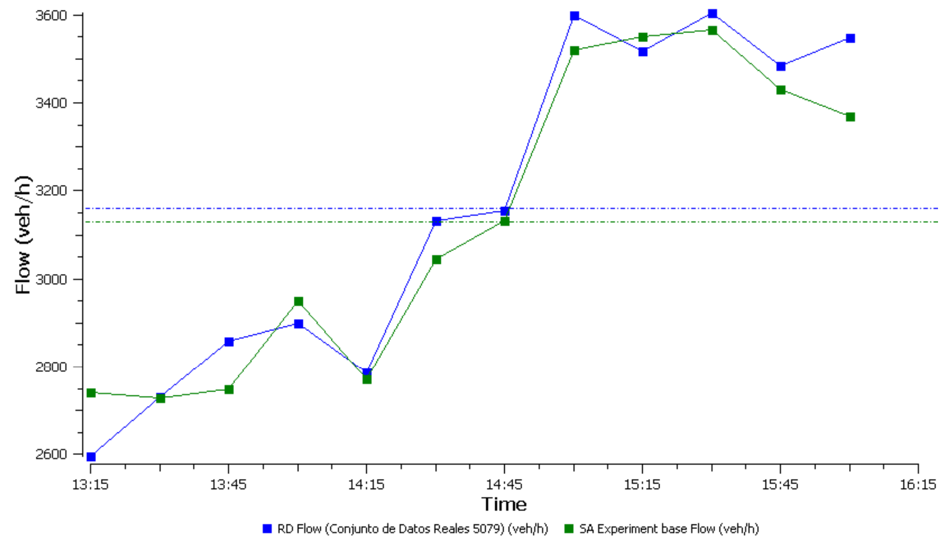
NOTES ON CALIBRATION & VALIDATION OF MICROSCOPIC TRAFFIC SIMULATION MODELS





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SOME COMMENTS ON SYSTEM MODELING

- **Methodology** for analyzing complex systems creating a simplified representation (**model**) of the system under study that describes the system structure and how it works
- The model captures the **behavioral aspects** of interest of the system (to the analyst/modeler)
- Modeling calls for **abstraction** and **simplification**
- The methodology proceeds to **experiment** with the model of the system generating system histories and **observing** system behavior **over time**
- Experiments are guided by goals and design rules
- Observation consists of **collecting statistics**

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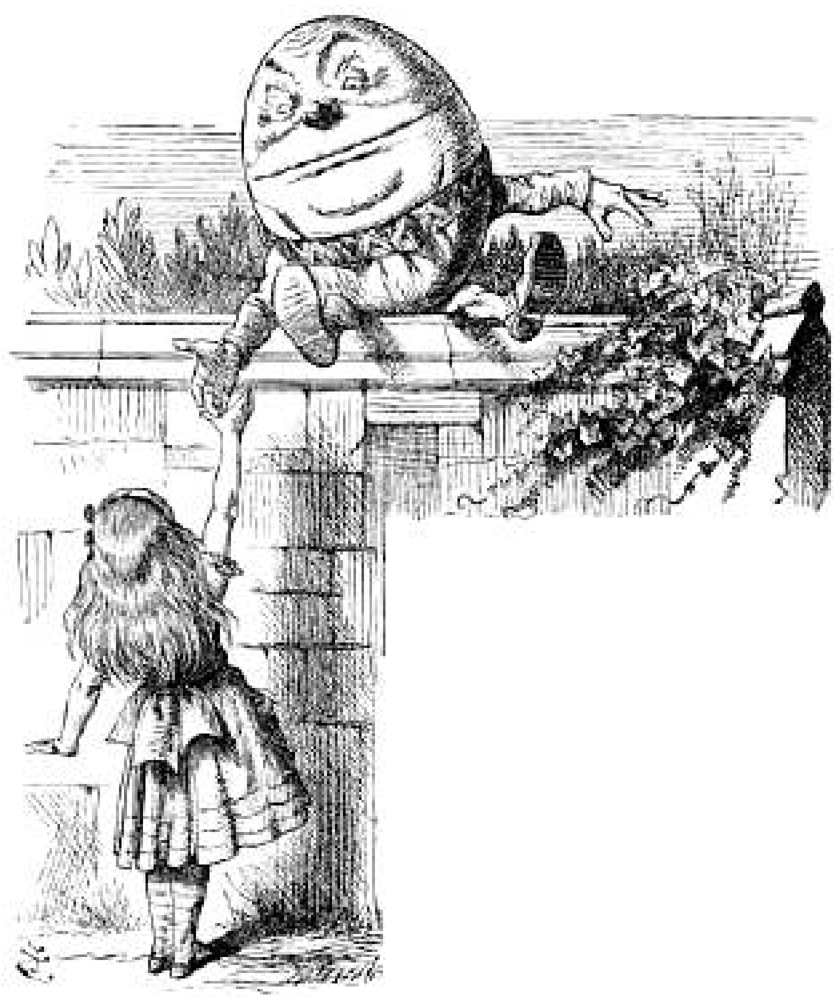
INTRODUCTORY THOUGHTS



"When I use a word", Humpty Dumpty said, in rather a scornful tone, "it means just what I choose it to mean neither more nor less".
"The question is", said Alice, "whether you can make words mean so many different things."

Lewis Carroll, Through the Looking Glass, (Chapter IV, Humpty Dumpty)

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INTRODUCTORY THOUGHTS

"What giants?" said Sancho Panza.
"Those you see there," answered his master, "with the long arms, and some have them nearly two leagues long."
"Look, your worship," said Sancho. "What we see there are not giants but windmills, and what seem to be their arms are the vanes that turned by the wind make the millstone go."

Miguel de Cervantes: Don Quixote (1605) Chapter VIII, Of the good fortune which the valiant Don Quixote had in the Terrible and Undreamed-of Adventure of the Windmills, with Other Occurrences Worthy to be Fitly Recorded

TRAFFIC SIMULATION IS FOUNDED ON THE USE OF MODELS, BUT…

All models are WRONG…

… but some are useful

G. Box

What makes a model useful?

CALIBRATION &VALIDATION:
THE KEY CONTRIBUTION TO MAKE MODELS USEFUL

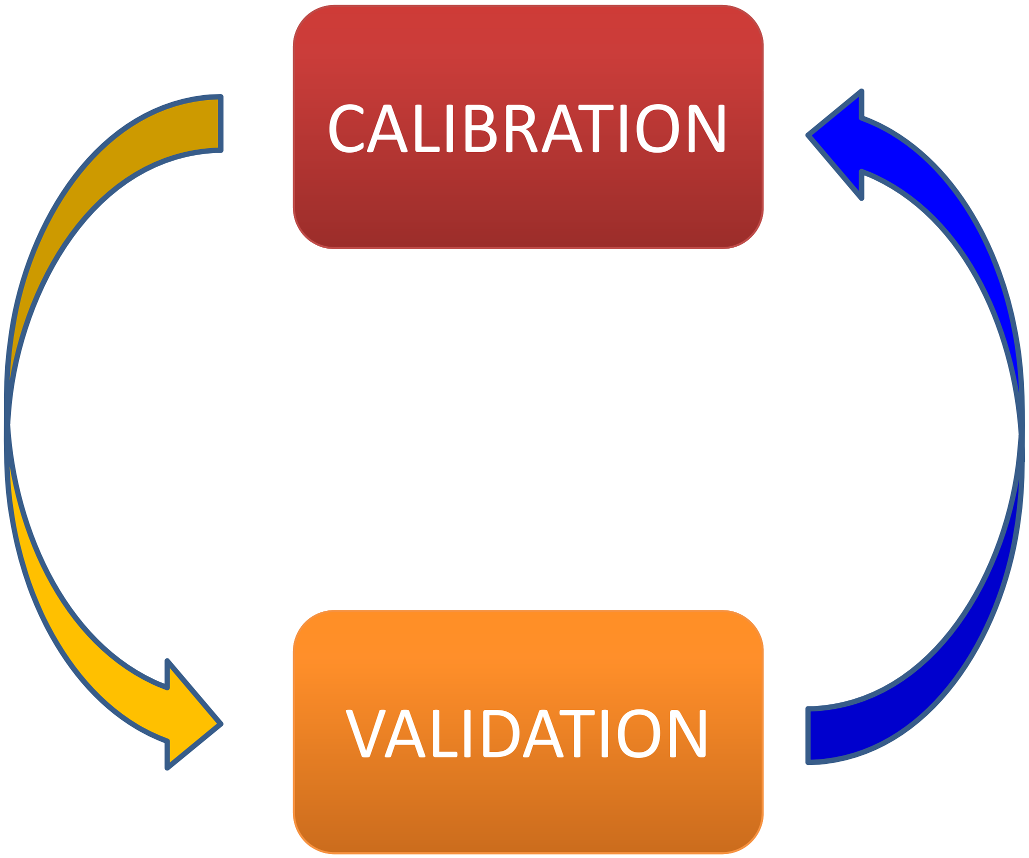
- **Calibration has the objective of finding the values of the parameters that will produce a valid model.**
- ***Calibration is the process of obtaining such values from field data in a particular setting*.**

- **Validation provides an answer to the question(*):**
- **Do model predictions faithfully represent reality?**
- **Quantification:**

P{ |"reality" – simulation prediction| < d } > a

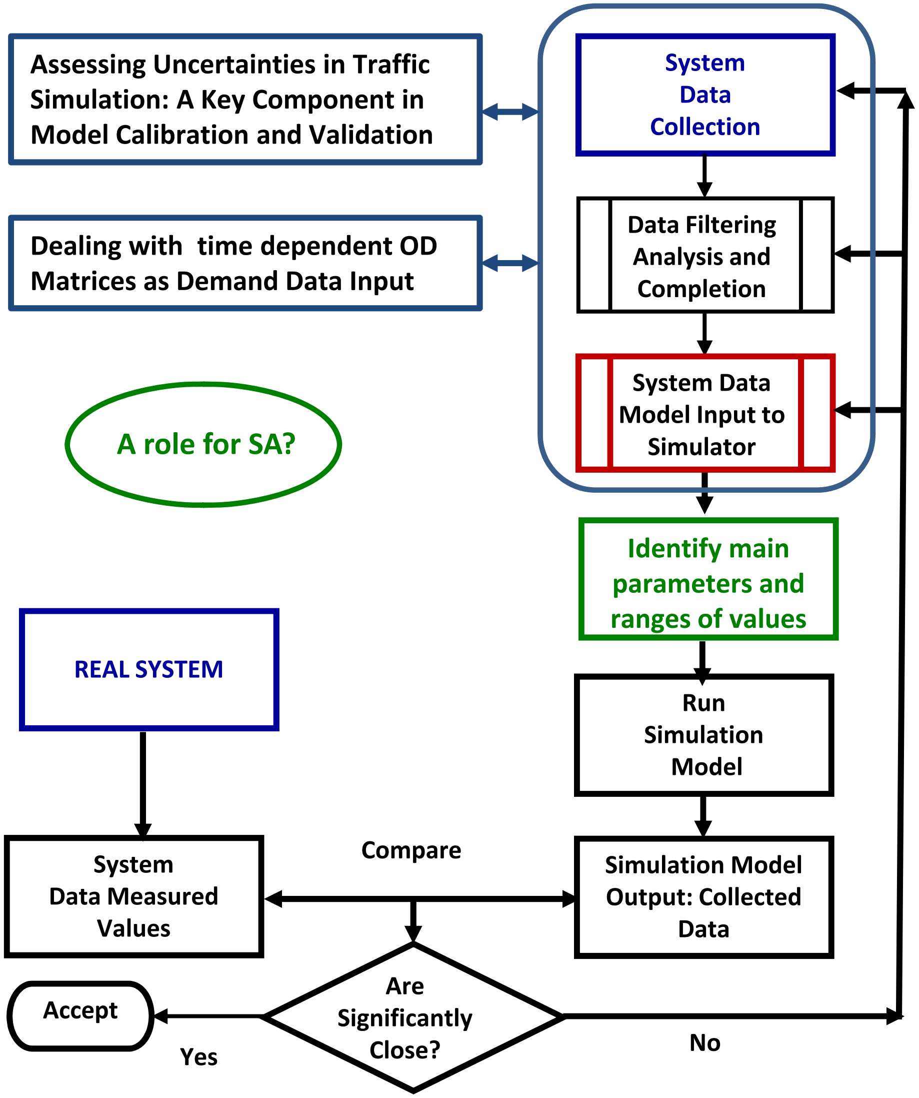
d= tolerable <u>difference</u> = how close
a= level of <u>assurance</u> = how certain

(*)Nagui M. Rouphail & Jerry Sacks, Workshop on Modeling Trends, Sitges, 2003



Calibration and Validation must be seen as an iterative process that uses inpependent samples at each level

A BASIC METHODOLOGICAL APPROACH TO CALIBRATION & VALIDATION OF SIMULATION MODELS



- **System Data Input**
  - **Observable: measurements of traffic variables (flows, speeds, occupancies…) affected by errors**
  - **Non observable: OD matrices**
- **System Data Input Model**
  - Exact or good approximations (flow data, turning percentages…)
  - **More or less appropriately modeled: Time sliced OD matrices**
- **Simulation Model**
  - **Calibration: identify main parameters and their ranges of values**
  - **determine the right parameter values**
  - **Validation:** determine how close is the model to reality
- **System Data**
  - Observable
- **Model Output Results**
- **Are they significantly close?**
  - **How d and a values are set up?**
  - **Which statistical techniques are more appropriate?**

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MICROSCOPIC TRAFFIC SIMULATION APPROACH

- **Requires a detailed representation of road network geometry**
- **Based on the movement of individual vehicles, vehicle by vehicle, with varying characteristics and multiple classes.**
- **Vehicle positions are updated using car-following logic and lane changing rules including stochastic components.**
- **Explicit representation of control strategies**
- **Vehicles travel from origins to destinations along time dependent routes selected according to stochastic route choice models that are timely updated**
- **Emulates realistically the time evolution of vehicle flows on a road network.**

CORE MODELS:
- CAR-FOLLOWING
- LANE CHANGING /GAP ACCEPTANCE
- ROUTE CHOICE (DTA/DUE)

CALIBRATION & VALIDATION GUIDELINES (FHWA Example)

- **Error Checking –**
  - Review for errors the coded transportation network and demand data.
  - Weeding out coding errors before proceeding with calibration.
  - Most of the commercial traffic simulation software provides auxiliary tools to assist the analyst to perform this function.
- **Capacity Calibration –**
  - Local calibration is performed to identify the values for the capacity adjustment parameters that cause the model to best reproduce observed traffic capacities in the field.
  - A global calibration is performed,
  - Link specific fine-tuning.
- **Route Choice Calibration –**
  - Route choice relevant in networks where alternative routes are available.
  - Global calibration with the route choice parameters
  - Link specific fine-tuning.
- **Performance Validation –** Finally, the overall model estimates of system performance (travel times and queues) are compared to field measurements of travel times and queues. Fine-tuning adjustments are made to enable the model to better match the field measurements.

METHODOLOGICAL POINTS FOR DISCUSSION (I)

- Calibration, validation and traffic data availability
  - **Detailed calibration of core models** requires access to low granularity data: i.e. trajectory data for calibration of car-following and lane changing models. This is a must for research and model development but, what about current practice?
  - From a practitioner's point of view this low granularity data are not usually available; hopefully they can have access to some acceptable aggregated data. What should they do?
  - Should we generalize Yoshii, Zhang and other similar methodological proposals for calibration with aggregated data? (Akcelik's challenge for simulation developers – 2001 Simulation Workshop)

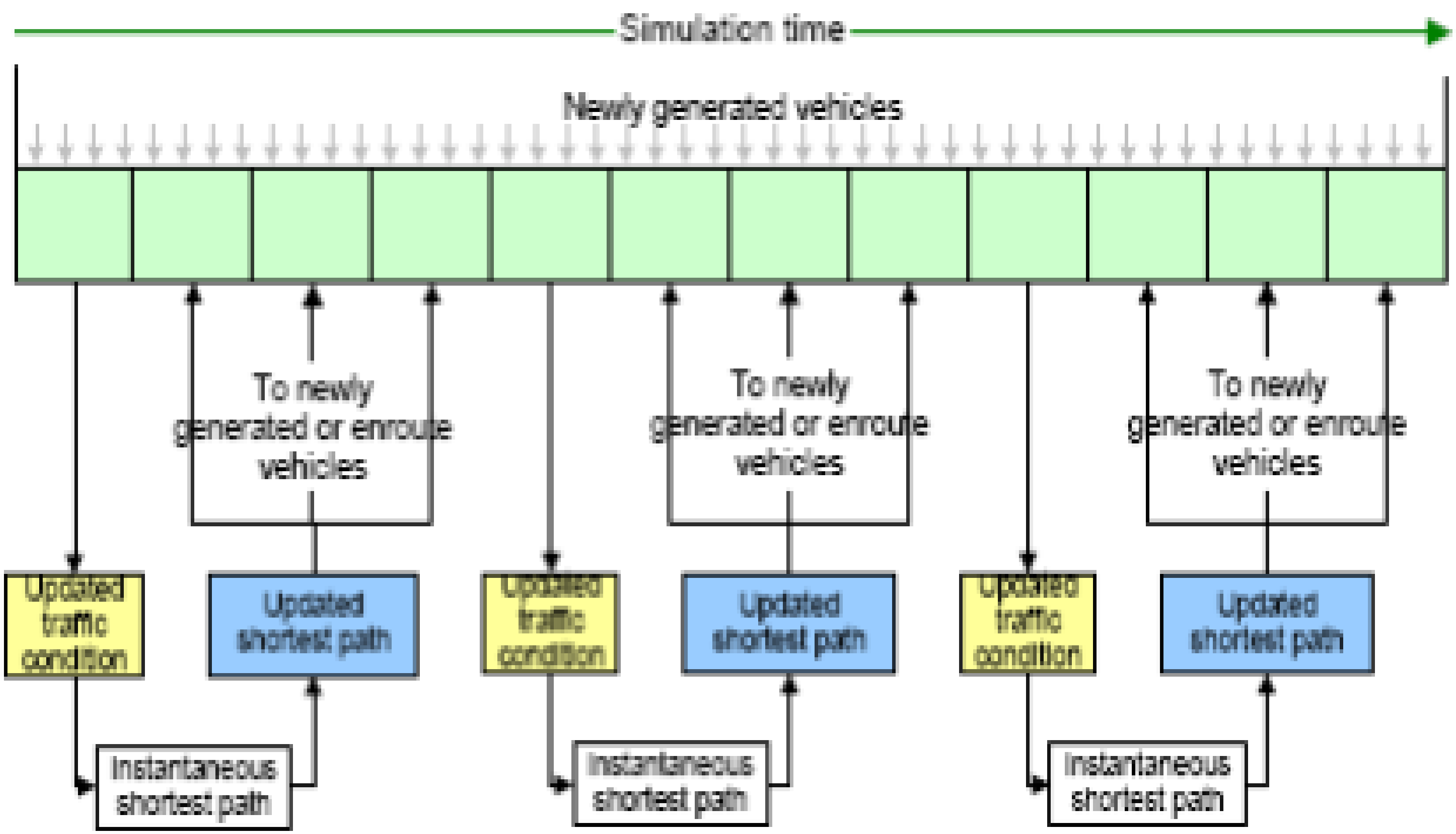
METHODOLOGICAL POINTS FOR DISCUSSION (II)

- Capacity calibration
  - Local calibration
    - Decompose the problem into simpler sub-problems prior to apply a simultaneous procedure. This can adjust the local parameters.
  - Global calibration
    - Apply a simultaneous procedure. Followed by link specific fine-tuning? Or the fine-tuning should de embed into the simultaneous procedure? A kind of bilevel process?
  - Does this overcome the potential discrepancies local/global?
  - Local calibration uses point estimators (Hollander and Liu 2008). Which are the most suitable estimators for Global calibration? Is GEH the best global estimator?

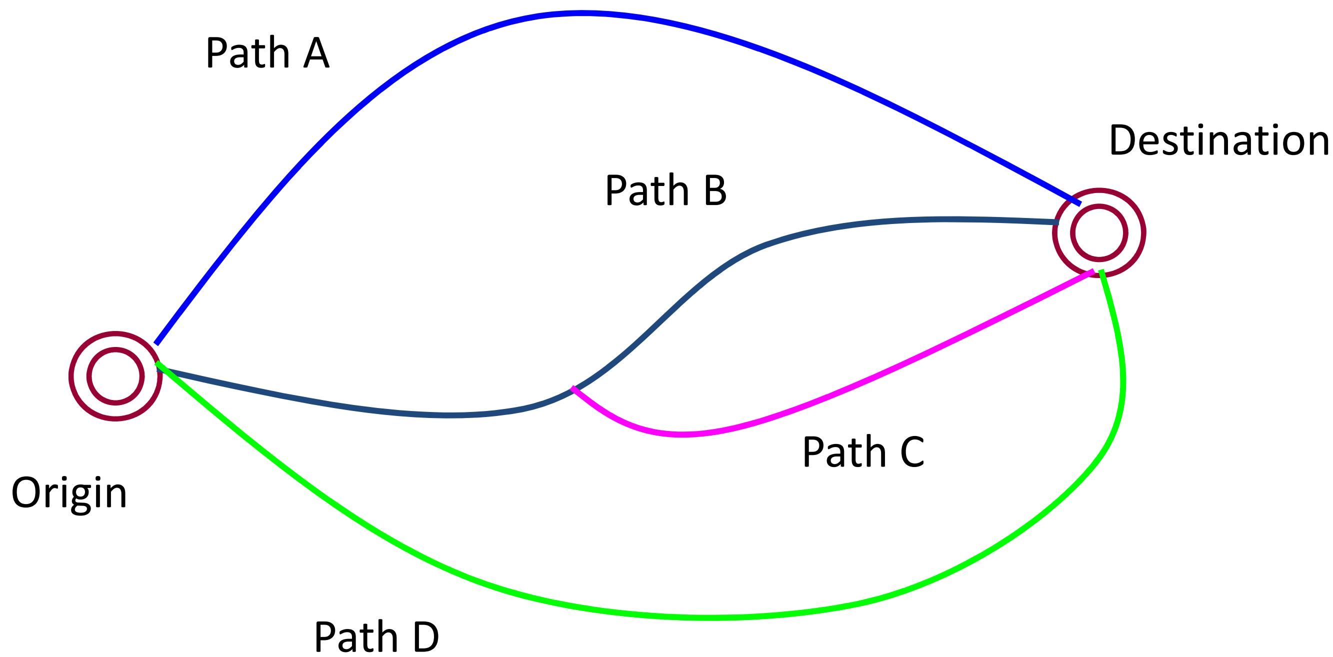
METHODOLOGICAL POINTS FOR DISCUSSION (III)

- **Route choice calibration**
  - Can it be appropriately calibrated independently of OD estimation?
  - Instantaneous or experienced travel times?
  - One shot versus iterative procedures: DTA vs DUE. (Network loading with incremental route updating that does not attempt to achieve user equilibrium and does not reach consistency between the travel time used in route generation and the experienced route travel time. Highlighted in the Figures taken or adapted from TRC 2011).

METHODOLOGICAL POINTS FOR DISCUSSION (IV) (one-shot)



ONE SHOT ROUTE CHOICE



Discrete Route Choice Model (i.e. Logit, C-Logit, Proportional.....)

$$P_k^{\tau} = \Phi\left(\text{Utility of Path k at time } \tau\right) = \frac{1}{1 + \sum_{j \neq k} e^{\left(V_j^{\tau} - V_k^{\tau}\right)\theta}}$$

MEASURING GOODNESS OF FIT

Rgap(t), relative gap function measure the progress towards equilibrium estimating at time t therelative difference between thetotal travel time actually experienced and the total travel time that would have been experienced if all vehicles had the travel time equal to the current shortest path:

$$RGap(t) = \frac{\sum_{i \in I} \sum_{k \in K_i} h_k(t)\left[s_k(t) - u_i(t)\right]}{\sum_{i \in I} g_i(t) u_i(t)}$$

flow on path k at time t

the travel time on the shortest path for the i-th OD pair at time interval t

the travel time on path k connecting the i-th OD pair at time interval t

demand for the i-th OD pair at time interval t

$$\mathbf{GEH_i} = \sqrt{\frac{2(\mathbf{ObsVal_i} - \mathbf{SimVal_i})^2}{\mathbf{ObsVal_i} + \mathbf{SimVal_i}}}$$

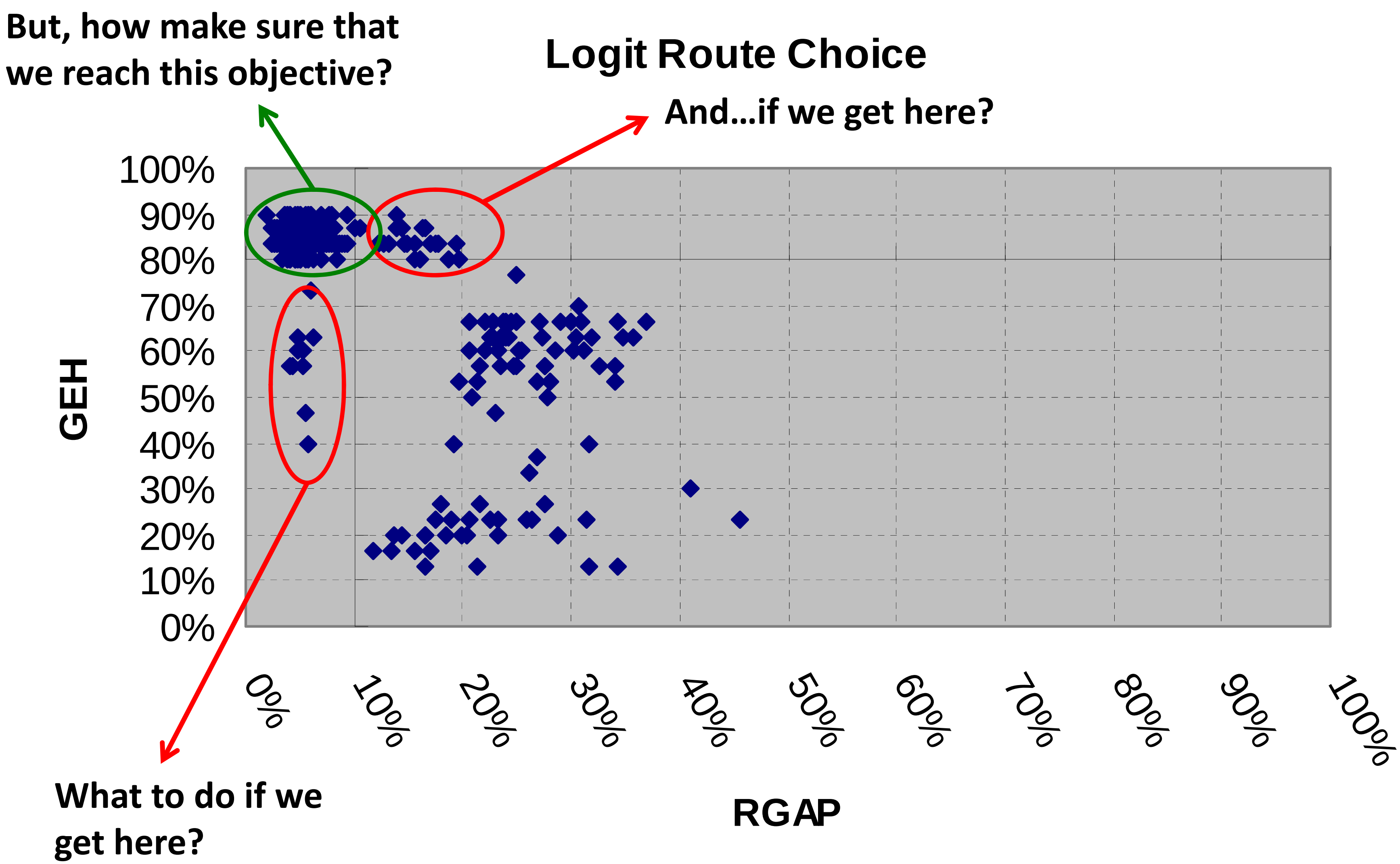
If $\mathbf{GEH_i \leq 5}$ **Then** $\mathbf{GEH_i = 1}$

Otherwise $\mathbf{GEH_i = 0}$

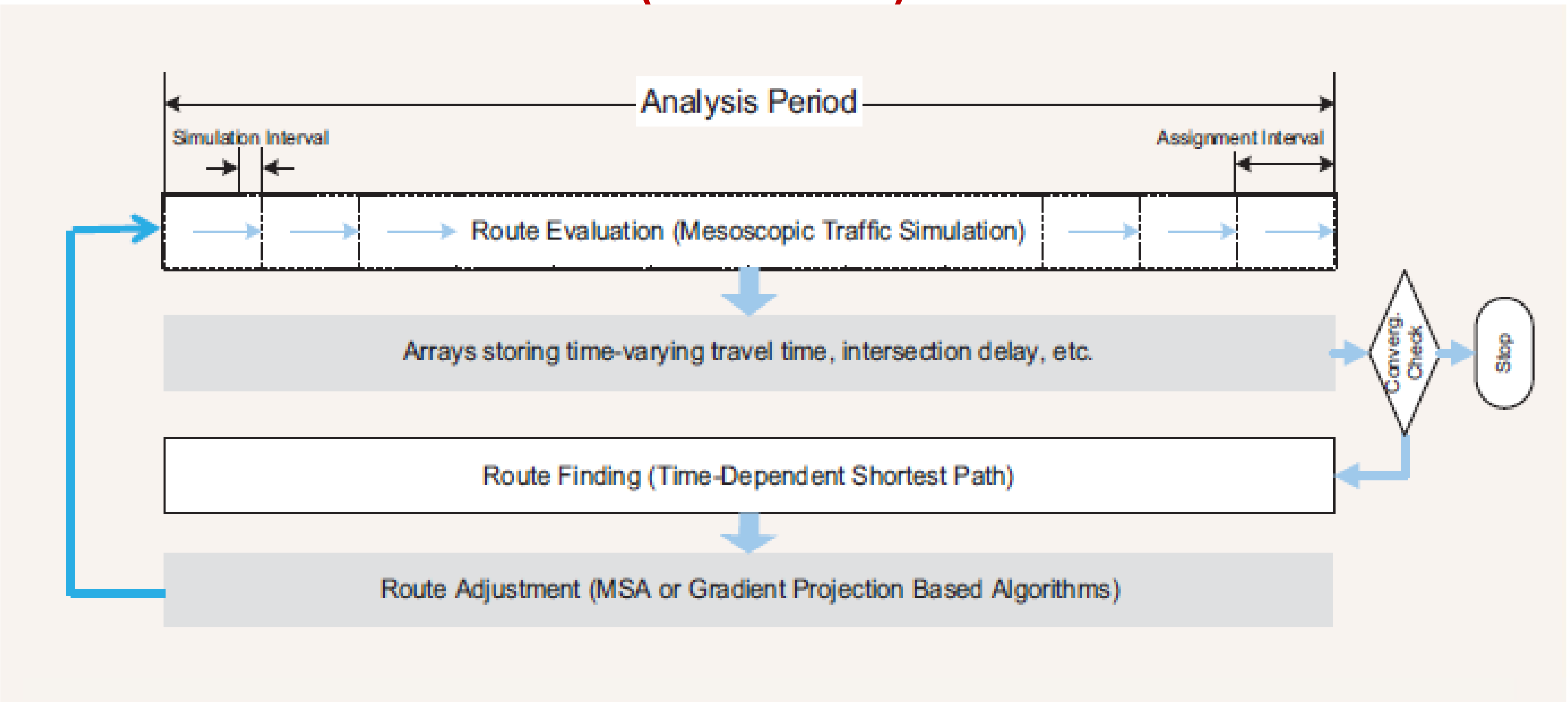
If $\mathbf{\frac{1}{N}\sum_{i=1}^{N} GEH_i \geq 85\%}$ **ACCEPT the model**

Otherwise REJECT the model

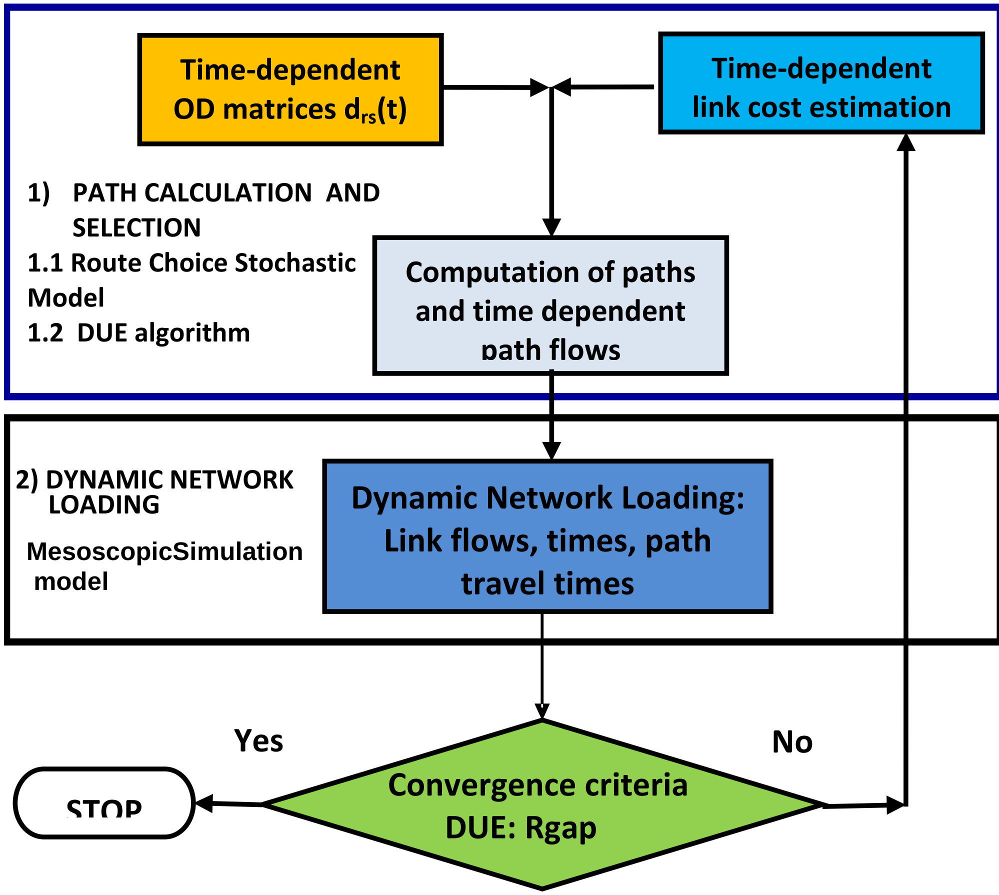
EQUILIBRIUM VERSUS OBSERVED FLOWS



METHODOLOGICAL POINTS FOR DISCUSSION (V) (Iterative)



CONCEPTUAL APPROACH TO DUE



Wardrop's Extension for DUE (Ran and Boyce, 1996)

If, for each OD pair at each instant of time, the actual travel times experienced by travelers departing at the same time are equal and minimal, the dynamic traffic flow over the network is in a travel-time-based dynamic user equilibrium (DUE) state.

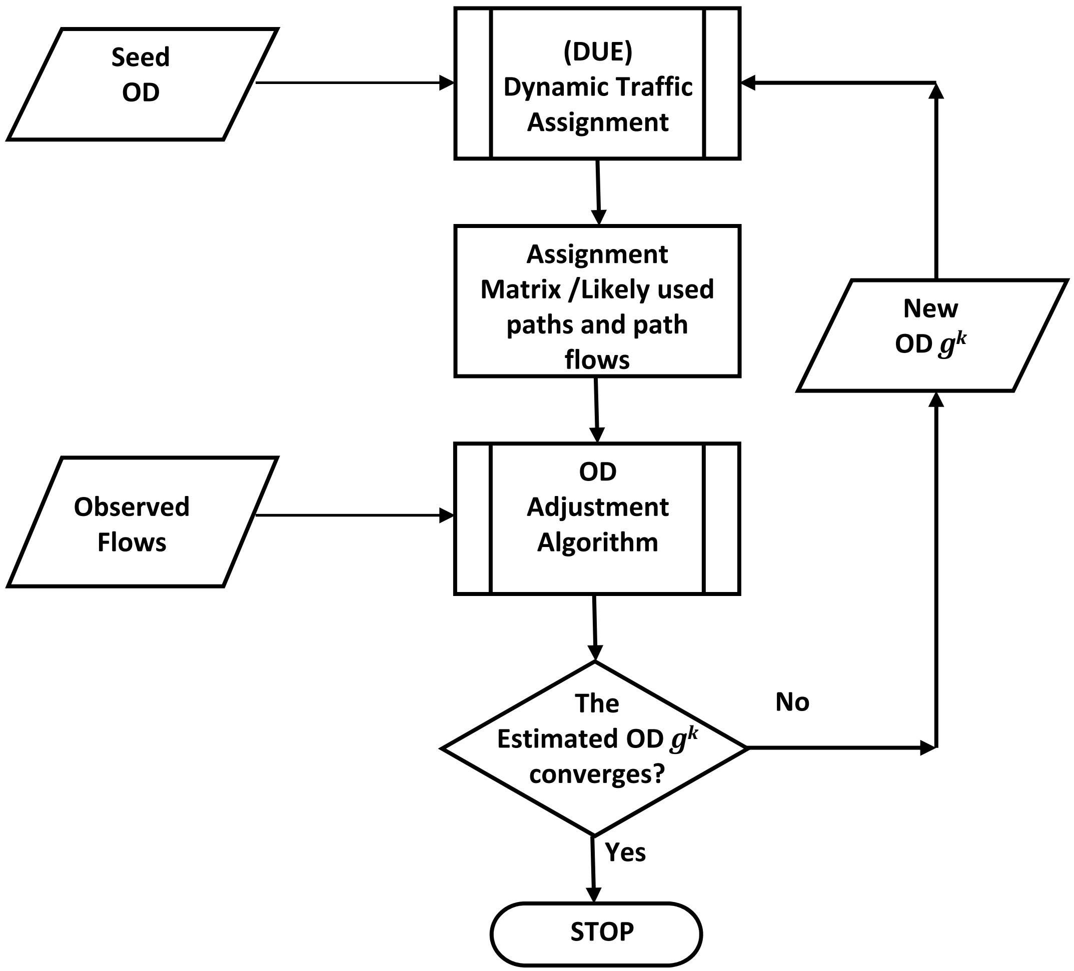
Friesz et al. (1993) formulated as the solution of a system of Variational Inequalities

Wu et al. 1998 probed that it is equivalent to solve

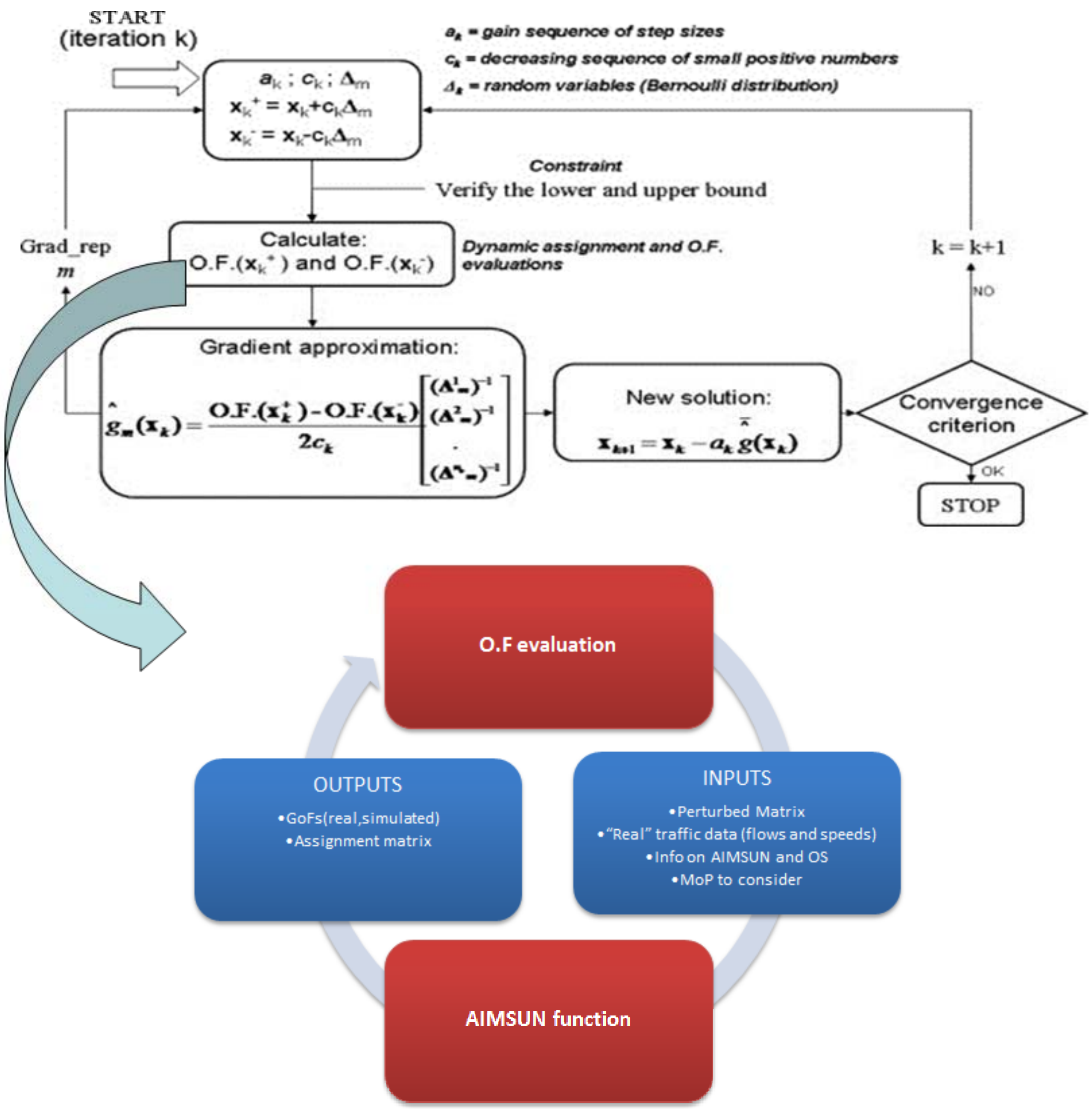
$$\sum_t \sum_{p\in\Re} \tau_{rsp}(t)\left[f_{rsp}(t) - f^*_{rsp}(t)\right] \ge 0$$

Where $\Re = \bigcup_{(r,s\in\Im)} P_{rs}$ **is the set of all available paths.**

COMPUTATIONAL DIAGRAM: COMBINATION OF OD ESTIMATION AND DYNAMIC ASSIGNMENT

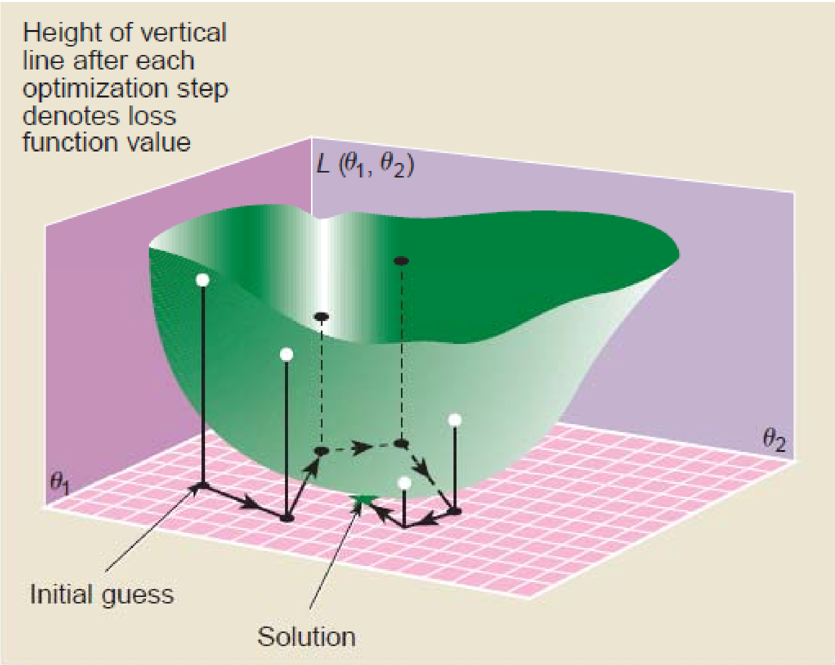


MULTITUDE EXERCISE



CALIBRATION BY SIMULTANEOUS PERTURBATION APPROXIMATION METHOD

The Simultaneous Perturbation Stochastic Approximation (SPSA) (Spall,1998) is a recursive optimization algorithm that uses an approximation to the gradient formed from generally noisy measurements (simulation) of a loss function



Example of stochastic optimization algorithm minimizing loss function $L(\theta_1, \theta_2)$ (Spall, 1998)

CALIBRATION BY SIMULTANEOUS PERTURBATION APPROXIMATION METHOD

Step 0: Initialization and coefficient selection

Step 1: Generation by Montecarlo of the simultaneous perturbation vector.

Step 2: Loss function evaluation

Obtain two measurements of the loss function based on the simultaneous perturbation around the current $\hat{\theta}_k$ (i.e. run two simulation experiments with the corresponding values of the parameters to be calibrated).

Step 3: Gradient approximation

Generate the simultaneous perturbation a approximation to the unknown gradient $g_k(\hat{\theta}_k)$ according to:

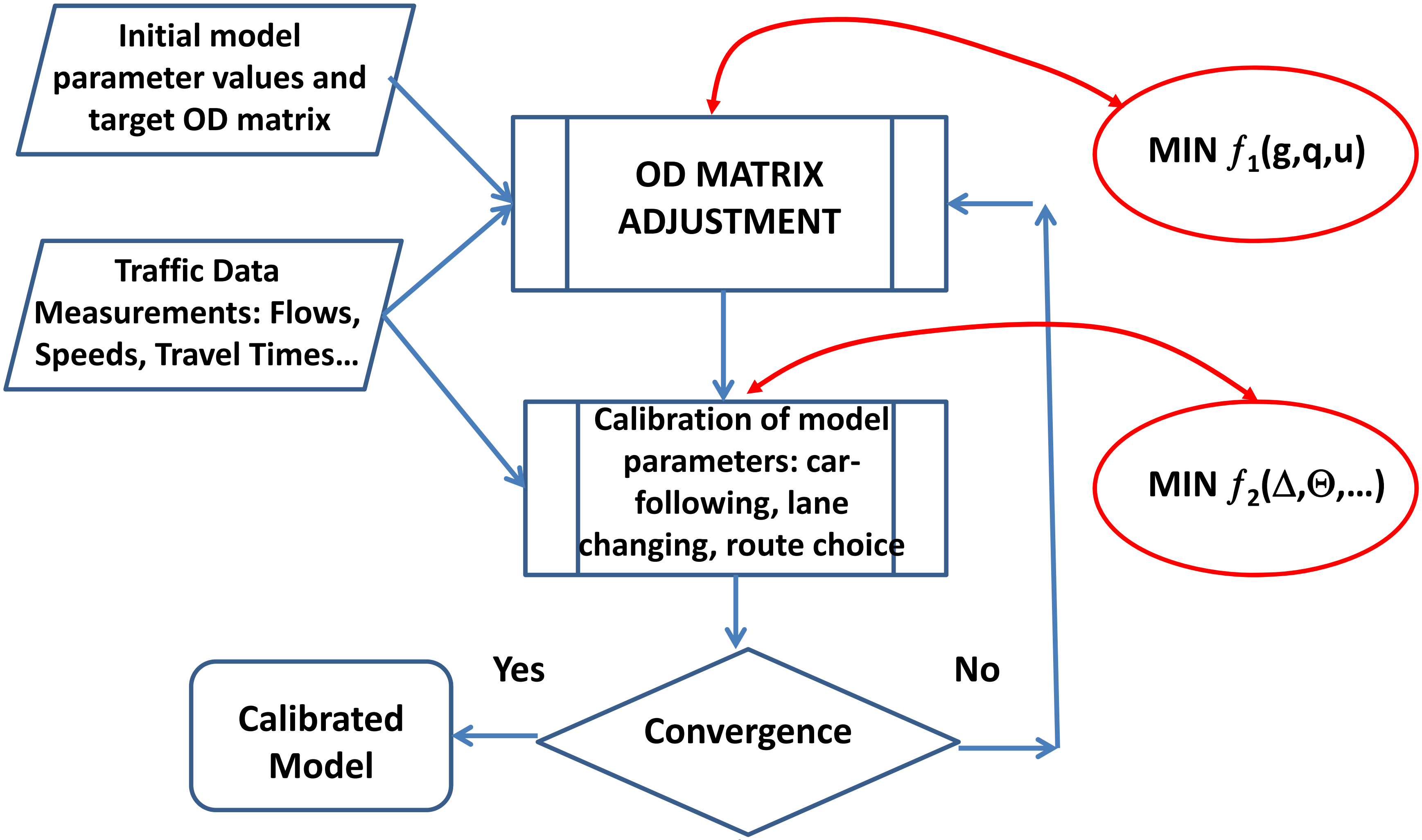
$$\hat{g}_k(\hat{\theta}_k) = \frac{y(\hat{\theta}_k + c_k\Delta_k) - y(\hat{\theta}_k - c_k\Delta_k)}{2c_k}\left[\Delta_{k1}^{-1}, \Delta_{k2}^{-1}, \ldots, \Delta_{kp}^{-1}\right]^T$$

Example of stochastic optimization algorithm minimizing loss function $L(\theta_1, \theta_2)$ (Spall, 1998)

Step 4: Update θ estimate Using: $\hat{\theta}_{k+1} = \hat{\theta}_k - a_k\hat{g}_k(\hat{\theta}_k)$

Step 5: Termination test

PROPOSAL:
COMBINED ESTIMATION-CALIBRATION PROCEDURE



CONCLUDING REMARKS

- Calibration and validation of traffic simulation models, namely microscopic models, is a critical issue for their use in the design, assessment and evaluation of traffic systems.
- A long way has been made in recent years to pave the methodological path on the problems to address for a proper calibration and validation and the statistical and analytical tools supporting them
- However, there are still some not well solved problems, especially when dealing with models of urban networks, that still require further research
- This talk has been aimed at highlighting some of them

THANK YOU VERY MUCH
FOR YOUR ATTENTION