A survey on the calibration and validation of integrated land use and transportation models

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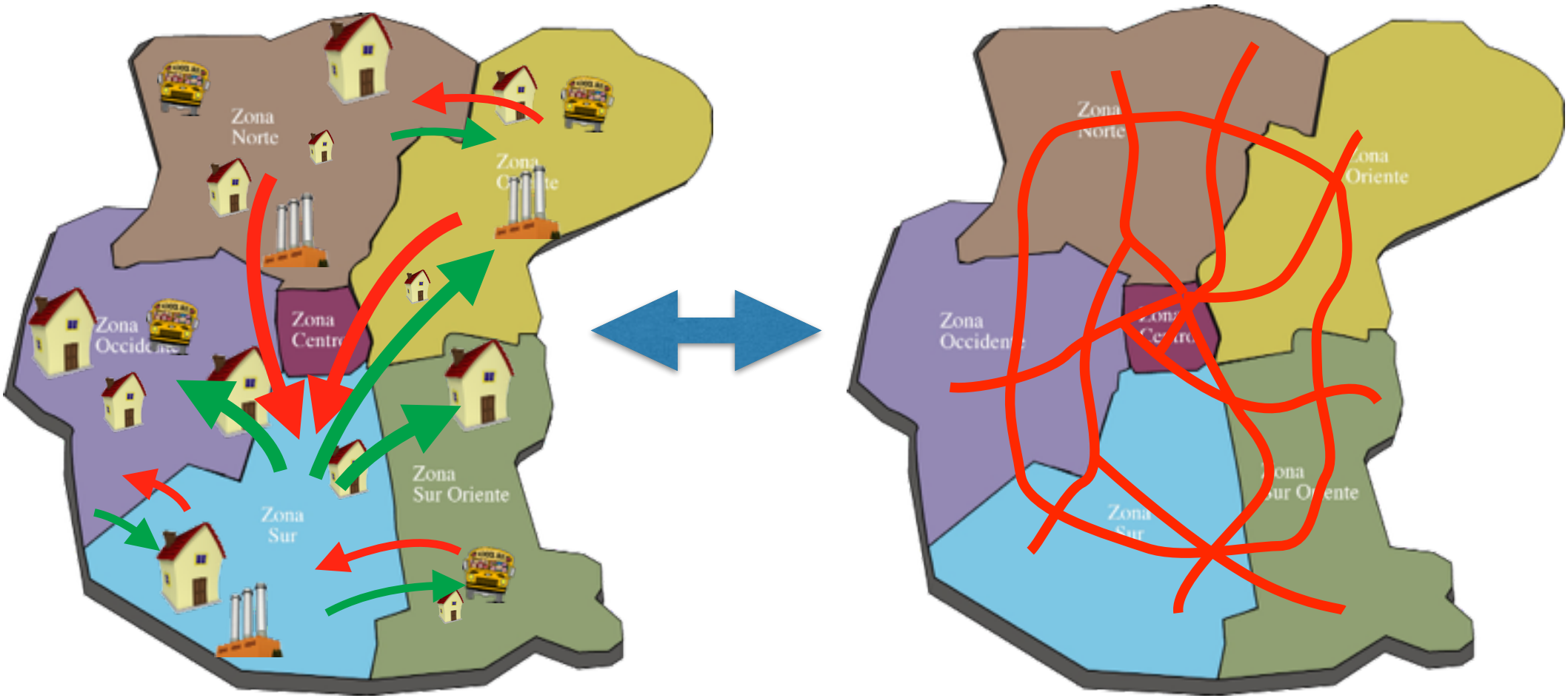
CITiES Project (Agence Nationale de la Recherche)

Introduction

Why LUTI models (Land Use and Transport Integrated models)?

- Land use (socio-economic activities) generates transportation demand
- Transportation system influences land use

→ LUTI models aim at taking feedback loops between the two into account, e.g. for urban planning



Introduction

LUTI models (Land Use and Transport Integrated models)

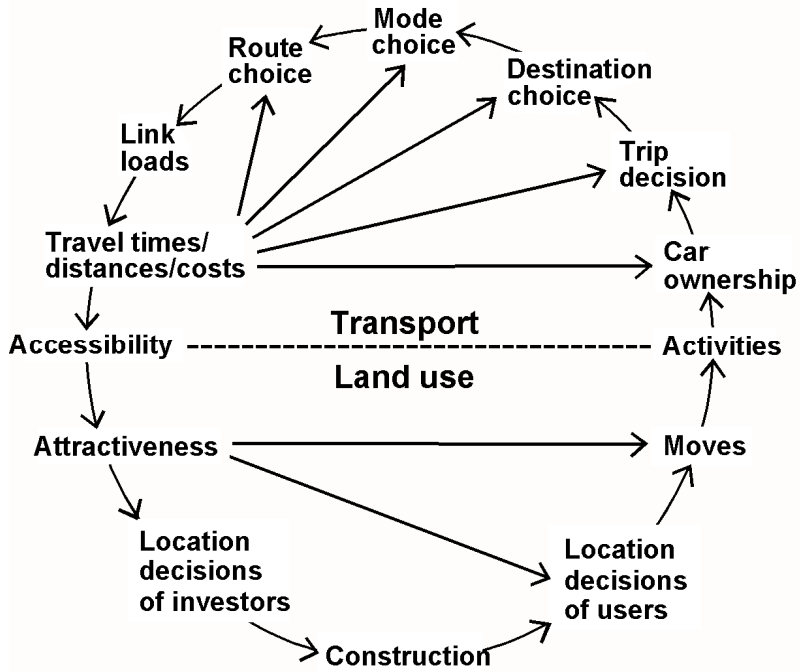


Figure 4-1: The land-use transport feedback cycle (source Wegener and Fürst, 1999, 6)[6]

Usages:

- Simulate the evolution of LU and T for planning scenarios (what if…?)

  Extract general tendencies from results rather than precise predictions

- Tools for aiding discussion, formalisation (policies, indicators, …), aiding decision-making, raising awareness

Introduction

Families of LUTI models:

- Equilibrium models (aggregate, macroeconomic spirit)
- Microsimulation (disaggregate, based on models of individual behaviour)

Requirements (like for most models), among others:

- Calibration (here, parameter estimation)
- Validation

CITiES project, funded by the French ANR (Nat. Research Agency):

- Brings together urban planners and transportation experts (academia, agencies, industry), computer scientists, applied mathematicians, economists
- Collaborate towards making LUTI models easier to use (calibration, validation, uncertainty; algorithms and methodologies)

Introduction

This work:

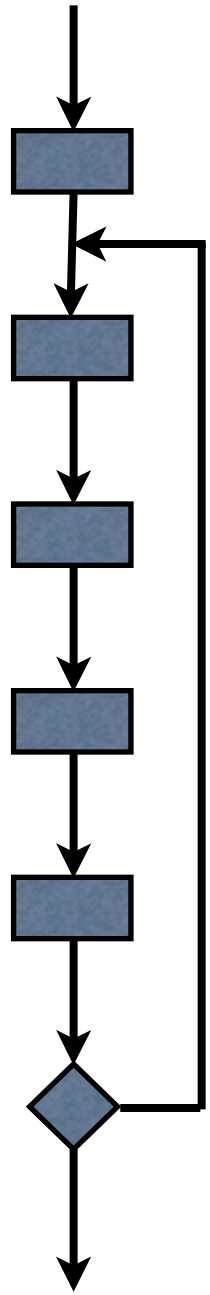
- survey on what is already used in terms of calibration and validation
- determine "best practices"

Models considered:

- CUBE LAND
- DELTA
- ILUTE
- ILUMASS
- IRPUD
- ITLUP family (DRAM/EMPAL, TELUM, G-LUM, ITGLUM)
- LEAM
- LILT
- MARS
- MEPLAN
- MUSSA
- PECAS
- PIRANDELLO
- POLIS
- RELU-TRAN
- Tigris XL
- TRANUS
- UrbanSim

Calibration

Types of approaches:



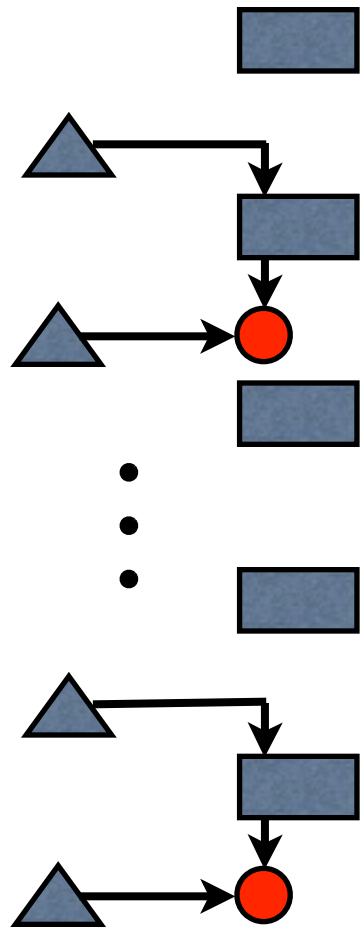
[abraham2000a] Abraham, Parameter Estimation in Urban Models: Theory and Application to a Land Use Transport Interaction Model of the Sacramento, California Region. PhD Thesis, Calgary, 2000.

Calibration

Types of approaches:

- *Piecewise (module by module)*

  Estimate parameters module by module.
  No consideration of the whole model
  (of chaining together the modules)



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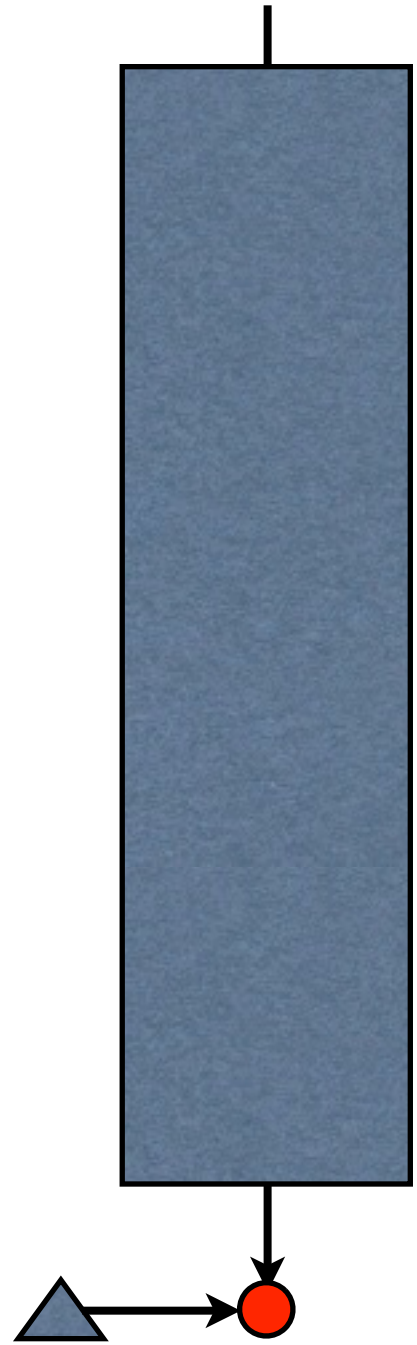
Calibration

Types of approaches:

- *Piecewise (module by module)*
- *Black box*

  Model is considered as a black box.
  Parameters estimated only based on
  observations of outputs of the
  whole model.



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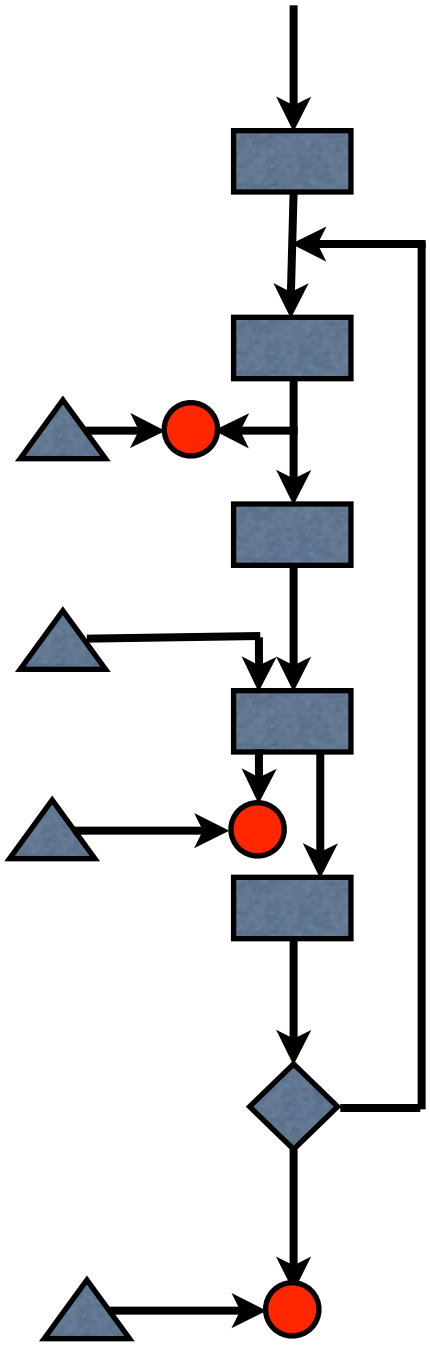
Calibration

Types of approaches:

- *Piecewise (module by module)*
- *Black box*
- *Simultaneous (all parameters)*

  Simultaneous estimation of all parameters, like in *black box*.
  In addition to model outputs, also use observations on outputs of (some) modules.
  Options:
  - Usage of additional data on module outputs, even if not required to run the entire model.
  - Run some modules twice; once using as input the outputs of other modules, once using as input observations.



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Calibration

Types of approaches:

- *Piecewise (module by module)*
- *Black box*
- *Simultaneous (all parameters)*
- *Sequential (hybrid: black box + simultaneous)*

  Start with *piecewise*, then *simultaneous*.
  In *simultaneous*: possibly only estimate subset of parameters (parameters shared by modules or linking modules, parameters found to be sensitive, …)

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Calibration

Types of approaches:

- *Piecewise (module by module)*
- *Black box*
- *Simultaneous (all parameters)*
- *Sequential (hybrid: black box + simultaneous)*
- *Bayesian sequential (sequential + confidence intervals)*

  Like *sequential*, but in addition using confidence intervals on parameters, computed when calibrating individual modules

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Calibration

Observations:

- Vast majority of models use the *piecewise* approach
  - Tradition?
  - Difficulty to inspect all parameters if estimated simultaneously
  - In practice, calibration is not a stand-alone process, but is tightly interleaved with model structuring
  - "Large computational cost of simultaneous estimation": maybe no longer entirely valid?

- A notable exception is MEPLAN
  - Experimented with *simultaneous* and *sequential* approaches

- Equilibrium models: usually calibrated using data in a base year only
- Microsimulation: calibration has to deal with stochastic nature

- Virtually no works provide uncertainty estimates on parameters
  - Hence, difficulty in attaching an uncertainty to "predictions"!

Calibration

Our goals:

- Automise parts of the calibration process
- "Translate" expert modellers' best practices:
  - Define cost functions for numerical optimisation
  - Incorporate constraints on parameters in the optimisation
  - Tools to alleviate manual calibration (e.g. automising exhaustive parameter trials)
  - Tools for inspecting results
  - Expert system embodying proven calibration methodologies

Suggestions:

- Go beyond *piecewise* calibration
- Maybe sacrifice perfect model fit for better parsimony of models (and hopefully better "predictions")
- Examine usage of robust estimation methods (robust to outliers in data)
- Automatic procedures MUST fit in modellers' workflow
- Validation…

Validation

Approaches:

- Validation by experts:
  - Check parameter values
  - Inspect fit to observations
  - Assess behaviour of model when simulating future scenarios
  - …
- Validation against observed data:
  - Often: data used for calibration
  - Additional observations, for other time instants than base year(s)
  - Additional observations, on endogenously computed variables
- Uncertainty and sensitivity analysis:
  - Of calibrated parameters
  - Of simulated model outcomes

Suggestions:

- Additional data for validation need not be complete (*all* data are helpful)
- One should aim at validating a model according to its intended uses (which questions will be posed to a model?)

Conclusions

LUTI models may become easier to use due to adopting recent tools for parameter estimation, validation, etc.

Requires multidisciplinary research

Preparation of a journal paper with detailed survey on the literature

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