Improved estimation of travel demand from traffic counts based on a new linearization of the network loading map

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Outline

Introduction

Proportional network loading

Local regression

Global regression

Outlook and summary
Outline

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Global regression

Outlook and summary
Problem statement

• microsimulation-based dynamic traffic assignment (DTA)
  – disaggregate demand simulator (one traveler at a time)
  – disaggregate supply simulator (all travelers jointly)

• calibration of DTA microsimulators
  – use, e.g., traffic counts to improve microscopic demand
  – must identify how demand affects link flows

• linearization of network loading map answers “what if” questions
Some notation

- Disaggregate demand consists of travelers $n = 1 \ldots N$
  \[ u_{ni}(k) = \begin{cases} 
  1 & \text{if } n \text{ plans to enter link } i \text{ in time step } k \\
  0 & \text{otherwise}
\end{cases} \]  
  (1)

- Link demand
  \[ d_i(k) = \sum_{n=1}^{N} u_{ni}(k). \]  
  (2)

- Network loading maps link demands $\{d_i(k)\}$ on link flows $\{q_i(k)\}$
- Linearize this mapping for arbitrary microsimulations
Test case
Test case

- microsimulation: 1800 potential travelers on either path
- simple choice model: prob. of making a trip is 2/3
- avg. demand $D_A$, $D_B$ for path A, B is 1200 veh
Test case

- demand $d_{45}$ for link 45 is 2120 veh
- capacity of all links is 1800 veh
- realized flow $q_{34}$ on link 34 is 600 veh
Test case

• spillback on link 34, mathematically:

\[
\frac{\partial q_{34}}{\partial D_A} = \frac{\partial q_{34}}{\partial d_{23}} + \frac{\partial q_{34}}{\partial d_{34}} + \frac{\partial q_{34}}{\partial d_{45}} = 0 \\
\frac{\partial q_{34}}{\partial D_B} = \frac{\partial q_{34}}{\partial d_{14}} + \frac{\partial q_{34}}{\partial d_{45}} = -1
\]  

(3)
Test case

- calibration scenario: flow of 900 veh is measured on link 34
- $\partial q_{34}/\partial D_A = 0$ and $\partial q_{34}/\partial D_B = -1$ explain this
- cause is demand for path B, which is not 1200 but 900 veh
Calibration

- use Cadyts ("Calibration of dynamic traffic assignment") tool
- free software, http://transp-or2.epfl.ch/cadyts/
- calibrates arbitrary demand dimensions from traffic counts
- relies on a linearized network loading map
Outline

Introduction

Proportional network loading

Local regression

Global regression

Outlook and summary
Proportional network loading: specification

• assume that all link demand is served by the network

\[ q_i(k) = d_i(k) \quad \forall i, k. \]  \hspace{1cm} (4)

• does not account for spillback
• good approximation only for uncongested conditions
• local scope
Proportional network loading: calibration results

\[ \frac{\partial q_{34}}{\partial D_A} \]

\[ \frac{\partial q_{34}}{\partial D_B} \]

sensitivities

flows

\[ D_A \]

\[ D_B \]

iteration

iteration

0  20  40  60  80  100

0  20  40  60  80  100
Outline

Introduction

Proportional network loading

Local regression

Global regression

Outlook and summary
Local regression: specification

• essentially, a parametrized proportional network loading

\[ q_i(k) = \alpha_i(k) + \beta_i(k)d_i(k) \]  \hspace{1cm} (5)

• coefficients \( \alpha, \beta \) are updated from simulated (demand/flow) tuples

• switches off proportional network loading during spillback

• still local scope
Local regression: calibration results

\[ \frac{\partial q_{34}}{\partial D_A} \]

\[ \frac{\partial q_{34}}{\partial D_B} \]

sensitivities

flows

iteration

iteration

\[ D_B \]

\[ D_A \]
Outline

Introduction

Proportional network loading

Local regression

Global regression

Outlook and summary
Global regression: specification 1

- naive approach

\[ q_i(k) = \alpha_i(k) + \sum_j \beta_{ij}(k)d_j(k) \]  \hspace{1cm} (6)

is cumbersome

- too many parameters
- identifiability issues

- preprocess demand by principal component (PC) analysis
Global regression: specification 2

- assume fixed plan choice distributions and

\[ \text{VAR}\{d_i\} \propto \text{E}\{d_i\} \]

(e.g., Poission)

- then,

\[ \text{COV}\{d_i, d_j\} \propto \text{E}\{d_{ij}\} \quad (7) \]

where

\[ d_{ij} = \sum_{n=1}^{N} u_{ni} u_{nj} \quad (8) \]

is number of travelers that enter both link \(i\) and \(j\)
Global regression: specification 3

- $M$ largest eigenvectors $b_m, m = 1 \ldots M$, of link demand covariance matrix constitute “demand PCs”
- calculation only requires to iterate over plans
- resulting regression model:

$$q_i(k) = \alpha_i(k) + \sum_{m=1}^{M} \beta_{im}(k) \cdot \langle d(k) - E\{d(k)\}, b_m(k) \rangle \quad (9)$$

- example network: 2 non-zero eigenvectors $\rightarrow$ 3 regression parameters
Global regression: calibration results

\[ \partial q_{34}/\partial D_A \]

\[ \partial q_{34}/\partial D_B \]

sensitivities

flows

\[ D_A \]

\[ D_B \]
Global regression, $\sigma = 5 \text{ veh}$

\[ \frac{\partial q_{34}}{\partial D_A} \]

\[ \frac{\partial q_{34}}{\partial D_B} \]

\[ D_A \]

\[ D_B \]
Global regression, $\sigma = 10$ veh

$$\frac{\partial q_{34}}{\partial D_A}, \quad \frac{\partial q_{34}}{\partial D_B}$$

sensitivities

flows

iteration

$D_A$, $D_B$
Global regression, $\sigma = 20$ veh

- $\partial q_{34}/\partial D_A$
- $\partial q_{34}/\partial D_B$

sensitivities

flows

$D_A$

$D_B$
Outline

Introduction

Proportional network loading

Local regression

Global regression

Outlook and summary
An aggregate demand representation

coverage

principal demand components

0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
0
50
100
150
200
250
300
350
400
450
500
Summary

- proportional network loading fails in congested conditions
- local regression switches off local regression when it fails
- global regression captures spillback-induced effects