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To cite this version:
Maxime Lenormand, Guillaume Deffuant, S. Huet. A commuting generation model requiring only aggregated data. 7th European Social Simulation Association Conference, Sep 2011, Montpellier, France. pp.16. hal-02596121

HAL Id: hal-02596121
https://hal.inrae.fr/hal-02596121
Submitted on 6 Jul 2020

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A commuting generation model requiring only aggregated data

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ESSA 2011
September 20th 2011
Motivation

- Studies on traffic and planning infrastructures 
  *(Ortùzar and Willumsen, 2011)*

- Diffusion of epidemics 
  *(Balcan et al., 2009)*

- Large demographic simulations 
  *(Huet and Deffuant, 2011)*
## Problem description

**INPUT**: Total out and in-commuters (dark grey line and column)

**OUTPUT**: Origin-destination region table (light grey table)

<table>
<thead>
<tr>
<th>Residence</th>
<th>Work</th>
<th>$M_1$</th>
<th>...</th>
<th>$M_j$</th>
<th>...</th>
<th>$M_n$</th>
<th>$M_{n+1}$</th>
<th>...</th>
<th>$M_m$</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>$M_1$</td>
<td>0</td>
<td>...</td>
<td>$R_{1j}$</td>
<td>...</td>
<td>$R_{1n}$</td>
<td>$R_{1n+1}$</td>
<td>...</td>
<td>$R_{1m}$</td>
<td>$O_1$</td>
<td></td>
</tr>
<tr>
<td>...</td>
<td></td>
<td></td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>$M_i$</td>
<td>$R_{j1}$</td>
<td>...</td>
<td>$R_{ij}$</td>
<td>...</td>
<td>$R_{iN}$</td>
<td>$R_{in+1}$</td>
<td>...</td>
<td>$R_{im}$</td>
<td>$O_i$</td>
<td></td>
</tr>
<tr>
<td>...</td>
<td></td>
<td></td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>$M_n$</td>
<td>$R_{n1}$</td>
<td>...</td>
<td>$R_{nj}$</td>
<td>...</td>
<td>0</td>
<td>$R_{nn+1}$</td>
<td>...</td>
<td>$R_{nm}$</td>
<td>$O_n$</td>
<td></td>
</tr>
</tbody>
</table>

Outside

| Total | $I_1$ | ... | $I_j$ | ... | $I_n$ | $I_{n+1}$ | ... | $I_m$ |

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Summary

1. Commuting generation model
2. Exponential law versus power law
3. $\beta$ estimation for universal calibration
Commuting generation model

Input of the model

- \( D = (d_{ij})_{1 \leq i \leq n}^{1 \leq j \leq m} \) the Euclidean distance matrix between the municipalities both in the same region and in the outside.

- \( (l_j)_{1 \leq j \leq m} \) the number of in-commuters of the municipality \( j \) of the region and outside of it.

- \( (O_i)_{1 \leq i \leq n} \) the number of out-commuters of the municipality \( i \) of the region only.
Commuting generation model

Algorithm description

For each remaining commuter who has not already found its place of work (while $O_i > 0 \forall 1 \leq i \leq n$), do:

- Select a living municipality $i$ at random among the municipalities where at least one out-commuter remains (such as $O_i \neq 0$)
- Select the working destination $j$ randomly following the probability distribution given by:
  \[ P_{i \rightarrow j} = \frac{l_j f(d_{ij}, \beta)}{\sum_{k=1}^{m} l_k f(d_{ik}, \beta)}, \quad \beta > 0. \]
- Update the number of in-commuters of $j$: $l_j = l_j - 1$
- Update the number of out-commuters of $i$: $O_i = O_i - 1$

\[ f(d_{ij}, \beta) = d_{ij}^{-\beta} \text{ or } e^{-\beta \frac{d_{ij}}{\bar{d}}} \quad 1 \leq i \leq n \text{ and } 1 \leq j \leq m \]

\(\bar{d}\) is the average distance between the municipalities of the region
Commuting generation model

Calibration

- Real data
- $\beta = 12$
- $\beta = 17$
- $\beta = 22$

Commuting distance (Km)

Kolmogorov-Smirnov Distance

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Summary

1. Commuting generation model
2. Exponential law versus power law
3. $\beta$ estimation for universal calibration
Exponential law versus power law

Comparison indicators

1. The commuting distance distribution

2. $CPC_{n \times m}(S, R) = \frac{2NCC_{n \times m}(S, R)}{NC_{n \times m}(R) + NC_{n \times m}(S)}$

- $NCC_{n \times m}(S, R) = \sum_{i=1}^{n} \sum_{j=1}^{m} \left( S_{ij} \mathbb{1} (R_{ij} - S_{ij}) \geq 0 + R_{ij} \mathbb{1} (R_{ij} - S_{ij}) < 0 \right)$

- $NC_{n \times m}(R) = \sum_{i=1}^{n} \sum_{j=1}^{m} R_{ij}$
Exponential law versus power law

Commuting distance distribution
Exponential law versus power law
Common part of commuters

(a)

(b)

(c)
Summary

1. Commuting generation model
2. Exponential law versus power law
3. $\beta$ estimation for universal calibration
$\beta$ estimation for universal calibration

$\beta = e^{-7.69\bar{d}^{0.92}}$
Cross validation

- We draw at random $\frac{2}{3}$ of the 34 observations to build the model.
- We predict the remaining third with this model.
- We compute the absolute error between prevision and observation.

$\implies$ The process is repeated 1,000 times.
β estimation for universal calibration

Cross validation

![Histogram](image)
\( \beta \) estimation for universal calibration

Cross validation

(a) Frequency

(b) Frequency

(c) Frequency
Conclusion and perspective

Conclusion
- Generation model managing with the lack of data
- Universally calibrated
- Tested on 35 case studies

Perspective
- Tested on more case studies
- Include the zero distance (Commuters and non-commuters)