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TDLM: An R package for a systematic comparison of trip distribution laws and models

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Summary

Spatial interaction models are widely used to estimate and explain spatial interactions between geographical areas or locations. These models are usually based on the characteristics of the locations and the way they are spatially distributed. Several forms of interaction can occur between locations, one of which is population movements. This particular type of interaction is widely examined in the fields of geography, transportation research, and urban planning. The flows of individuals between locations is usually represented by a trip table better known as an Origin-Destination (OD) matrix (Barbosa et al., 2018; Lenormand et al., 2016). The estimation of OD matrices is part of the four-step travel model in transportation research. It corresponds to the second step, called trip distribution, the aim of which is to match the trip origins with the trip destinations using a spatial interaction model commonly referred to as trip distribution model in the four-step travel framework.

In order to facilitate the use and comparison of trip distribution models, and more generally spatial distribution models, we present **TDML**, an R package providing a set of easy-to-use functions to rigorously and fairly compare trip distribution laws and models as described in Lenormand et al. (2016).

Statement of need

Trip distribution models are generally composed of two mechanisms, one based on a 'law' to estimate the probability that an individual moves from one location to another and a second based on a 'model' used to estimate the number of individuals moving from one location to another. These two mechanisms are rarely disentangled, which could lead to methodological flaws when comparing different laws and/or models (Lenormand et al., 2012; Masucci et al., 2013; Simini et al., 2012; Yang et al., 2014). This is particularly important when we compare the two historical approaches - gravity and intervening opportunities - for the estimation of trip distribution.

We identified several R packages providing an implementation of spatial interaction models that can be used to estimate trip distributions. The **gravity** package (Wölwer et al., 2018), the **spflow** package (Dargel & Laurent, 2021), the **mobility** package (Giles, 2021), and the **simodels** package (Lovelace & Nowosad, 2023). The **gravity**, **spflow**, and **mobility** packages are based on statistical models and have not been designed to compare gravity and intervening opportunities laws and constrained models independently. Although the package structure and functionality of **simodels** are very different from those of **TDLM**, it offers the possibility to compare trip distribution laws and models independently. **simodels** proposes an interesting approach by not defining (nor encouraging the use of) any particular trip distribution laws, but this also makes the systematic comparison of trip distribution laws more complicated for non-expert users. Furthermore, **simodels** does not offer any functionality to systematically compare observed and simulated OD matrices.

To overcome these limitations, the **TDML** R package is based on a two-step approach to generate mobility flows by separating the trip distribution law from the modeling approach used to generate the flows from this law.

Functionality

TDLM is available on CRAN and GitHub. The **TDLM**'s website includes a tutorial describing the functions of this package with an illustrative example based on commuting data from Kansas in the United States in 2000.

TDLM features four main functions for generating OD matrices based on a wide range of trip distribution laws and models and for evaluating the simulated matrices against observed data.

- **run_law_model** is the main function of the package. This function estimates mobility flows using different distribution laws (four gravity laws, three intervening opportunity laws, and a uniform law) and models (unconstrained, production constrained, attraction constrained, and doubly constrained). The function has two sets of arguments, one for the law and another one for the model.
- **run_law** estimates mobility flows using different distribution laws. It is based on the first step of the two-step proposed approach to generate a probability distribution based on the different laws.
- **run_model** estimates mobility flows using different distribution models. It based on the second step of the two-step proposed approach to generate mobility flow based on a matrix of probabilities using different constrained models.
- **gof** computes goodness-of-fit measures between observed and simulated OD matrices. Six goodness-of-fit measures have been considered at this stage.

TDLM includes utility functions to check, format and generate the inputs data and help to calibrate the trip distribution laws.

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