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Formulating LUTI Calibration as an Optimisation Problem: Example of Tranus Shadow Price Estimation

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Abstract

Much of the planet’s energy consumption, pollutions, waste generation etc. happens in cities, which makes it important to consider urban areas in efforts aiming at sustainable development. Transportation and land use planning has become essential as a decision aid tool. Development of LUTI models (Land Use and Transportation Integrated models) has increased during the last 20 years. Calibration of large-scale LUTI models is a challenging task. It is usually partitioned into a set of smaller, partial parameter estimation problems of individual components of a model, and an integrated calibration of the composite model, taking into account the mutual interactions between these components, is most often lacking. This work presents a reformulation of the calibration of the Tranus model as an optimisation problem. This methodology is applied to the estimation of the endogenous variable called “shadow prices”, this variable acts as an error term of the localisation utility function. We also present a test methodology for validating the calibration against synthetic data that perfectly fit observations. We present this methodology on a small example that permits us to get a visual assessment of the solution.

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1. Introduction

Integrated land use and transport modelling has attracted the attention of researchers since 1960 [1]. Over the years, a large number of models have come into existence. It is well known that integration of land use and transport models creates a complex nonlinear system, which evolves in different scales. Analysing these complex systems is

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typically a hard problem, especially in the presence of uncertainty, whose effects may be difficult to assess. The interaction between all the components of a model makes that small changes in one parameter can cause large changes in the model output. In such cases, calibration plays a central role, as it helps us determine optimal parameters. Calibrating this type of models is a process that requires many steps. Also, the data needed are not always readily available, but even if so, finding the set of parameters that best replicate the data is not simple.

This work is an effort toward an automatic calibration of Tranus, a widely used open-source LUTI model [2]. Formulating the calibration of a LUTi model as an optimisation problem has been done before, for example for the MEPLAN model [3], but the complex nature of each model may force the use of a tailored solution. We propose an optimisation framework for the calibration of Tranus, particularly for obtaining a good estimation of the shadow-price variables.

2. Methodology

2.1. Description of Tranus

Tranus [2] provides a generic framework to model land use and transportation in an integrated manner, both on urban and regional levels. The region of interest is divided into *economic sectors* and *spatial zones*, generalising the classical input-output model proposed by Leontief [4]. Then Tranus combines two modules: the *land use and activity* module which simulates a spatial economic system by assessing the activity locations and economic sector interactions; and a *transportation* module, which estimates the use of the transport network and the associated disutility.

The two modules in the system use discrete choice logit models [5], linked together in a consistent way. This includes activity-location, land-choice, and multi-modal path choice and assignment. The modules are then run iteratively, such that production and consumption demands for each zone are met and equilibrium is achieved. A detailed description of the equations of Tranus land use and transportation modules can be found in [2].

2.2. The activity and land use module

The land use module's objective is to find an equilibrium between the production and demand of all economic sectors and spatial zones of the modelled region. The equilibrium between these depends further on various economic parameters that aim at representing the behaviour of people and businesses, such as demand elasticities and variables representing the general attractiveness of zones (beyond land rent). **Productions** X^n_i express how many "items" of each economic sector n are present in each zone i. **Demands** D^{mn}_i express how many items of a sector n are demanded by i the part of sector m that is located in zone i. Finally, p^n_i defines the **price** of (one item of) sector n located (or produced) in zone i. Here, "price" is dictated by land or floorspace prices, which are true prices, whereas the "price" of a household (roughly speaking, its demand for salary) is derived from the floorspace occupied by the household (see for instance [6]).

All these variables are computed from one another by a system of about a dozen equations, see [2] for details. Since they depend on one another (for instance demand generates production and vice-versa), we are in the presence of a dynamic system. A sketch of the central parts of this system is shown in Figure 1, where we omit many details in order to make this paper as self-contained as possible. It shows the sequence of computations done in Tranus' land use module. At each iteration of the process, current prices are fed into the computation of demands (via intermediate variables not detailed here) which in turn are fed into the computation of productions. Given the new distribution of productions across sectors and zones, production and consumption costs are computed (marked as c in the figure), based on the current prices and transportation costs. These are then used in the next iteration to determine new prices, and the above computations are repeated. The entire process starts from floorspace/land prices, which are given by collected data, as well as productions destined for exportation outside the area of study, which are also given. It is repeated until convergence; concretely, until convergence of productions X and prices p (this implies convergence of all other variables).